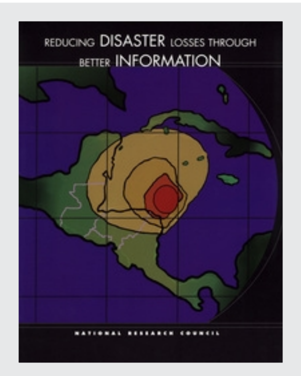

Reducing Disaster Losses Through Better Information

DETAILS

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AUTHORS

Board on Natural Disasters, National Research Council

REDUCING DISASTER LOSSES THROUGH BETTER INFORMATION

Board on Natural Disasters
Commission on Geosciences, Environment, and Resources

National Research Council

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Preface

On February 26, 1997, Vice President Gore requested that federal departments and agencies evaluate the feasibility of a global disaster information network (GDIN) that would integrate and disseminate information to provide better warnings to emergency managers and thereby improve preparedness and response to natural or environmental disasters. This request led to establishment of the Disaster Information Task Force (DITF) to consider the needs and issues associated with such a system. The DITF focused on integration of all sources of information, public or private, and the linkage of those sources with disaster managers, with an initial emphasis on the United States because of the amount and diversity of activity here. Of particular interest was the potential for public-private partnerships in serving users' needs. The results of the DITF study are summarized in *Harnessing Information and Technology for Disaster Management—The Global Disaster Information Network* (DITF, 1997).

Attention to the dissemination of information about natural disasters is motivated by the large losses caused by natural hazards in recent years and by the increasing vulnerability of people who have migrated into hazardous areas and by urbanization. It is generally believed that future losses can be significantly reduced through the application of advances in communications, remote sensing, and computing. Such capabilities make it possible to deliver crucial information to decision makers in a timely manner.

The GDIN Transition Team, which was formed in January 1998 to follow the DITF, sought perspectives on the use of information for natural disaster loss reduction from experts in the public and private sectors, including state and local governments, insurance and other industries, and academia. To this end, it requested that the National Research Council's (NRC) Board on Natural Disasters (BOND) undertake an assessment of how a global or national disaster information network (DIN) could best provide appropriate information on natural disasters to public and private users of such information for purposes of natural disaster management and loss reduction. In response, through this effort the BOND undertook the task to:

- identify which types of data and information the federal agencies could make available with respect to earthquake, volcano, flood, drought, debris flow, wind, wildfire, and severe storm hazards in the United States;
- examine the kinds of tools and products that are available or could be developed to integrate information into forms most useful by property owners, local businesses, and community leaders who must make decisions concerning how to make communities more disaster resilient; and
- recommend ways, within the context of the proposed DIN, to improve the utilization of disaster information for decision makers.

This assessment was carried out by the BOND itself rather than through a committee formed by the board. BOND is a multidisciplinary group of 12 members with expertise in the relevant geological, hydrological, and atmospheric hazards and related disaster management skills. It is responsible for organizing and overseeing the NRC's program on natural disaster issues. To carry out the study, the BOND conducted a three-day workshop in Washington, D.C., which served as the major information-gathering, deliberative, and report-drafting event for the study (see Appendix A). The workshop afforded the opportunity for discussions with federal officials engaged in DIN planning and other experts with experiences beyond those of the BOND members. In addition, it provided for extensive deliberations by BOND members.

This report was drafted by BOND members at the workshop and subsequently refined. It presents an assessment of how natural disaster information can best be provided to public and private users for purposes of natural disaster mitigation, preparedness, response, and recovery. The BOND did not undertake to produce a detailed implementation plan, as that would be the responsibility of the GDIN Transition Team. Rather, this report offers strategic advice and guidance to the transition team. It should also be useful to federal officials engaged in planning and designing the proposed DIN and of interest to decision makers at other levels of government and in the private sector engaged in activities relevant to the communication of data and information in the interest of natural disaster loss reduction and the management of associated natural resources.

The efforts of the BOND members, advisers, staff, and other workshop participants are greatly appreciated. Additionally, the board acknowledges and thanks several individuals chosen for their diverse perspectives and technical expertise to review the report, in accordance with procedures approved by the NRC Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study's charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The reviewers, to whom the board is very grateful, are Peter S. Anderson, Simon Fraser University; James P. Bruce, Ottawa, Canada; George M. Hornberger, University of Virginia; William Scherlis, Carnegie Mellon University; John C. Scott, Center for Public Service Communications; and Giles Whitcombe, Cambridge, Massachusetts. While the reviewers provided many constructive comments and suggestions, responsibility for the final content of the report rests solely with the BOND as the authoring body and the NRC.

Finally, it should not be inferred from this report, with its focus on information dissemination, that existing data (even from the most advanced databases) could not benefit from technological advances in monitoring, more intense monitoring, and further research. For example, assessment of the threat posed by earthquakes is steadily evolving as new knowledge comes to light about the location and nature of active faults and the response of structures to strong ground shaking. Likewise, new understanding of flood risk is being generated by greater understanding of the paleohydrological record. Many other examples could be cited in support of the cautionary argument that any new dissemination effort must supplement and not replace current natural hazard and vulnerability data collection and analysis efforts.

Wilfred D. Iwan, *Chair*
Board on Natural Disasters

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Executive Summary

Losses of life and property from natural disasters in the United States—and throughout the world—have been enormous and the potential for substantially greater future losses looms. It is clearly in the public interest to reduce these impacts and to encourage the development of communities that are resilient to disasters. This goal can be achieved through wise and sustained efforts involving mitigation, preparedness, response, and recovery. Implementing such efforts, particularly in the face of limited resources and competing priorities, requires accurate information that is presented in a timely and appropriate manner to facilitate informed decisions. Substantial information already exists that could be used to this end, but there are numerous obstacles to accessing this information, and methods for integrating information from a variety of sources for decision making are presently inadequate. Implementation of an improved national or international network for making better information available in a more timely manner could substantially improve the situation.

As noted in the Preface, a federal transition team is considering the issues and needs associated with implementing a global or national disaster information network as described in the report by the Disaster Information Task Force (1997). This National Research Council report was commissioned by the transition team to provide advice on how a disaster information network could best make information available to improve decision making, with the ultimate goal of reducing losses from natural disasters. The report is intended to provide the basis for a better appreciation of which types of data and information should be generated in an information program and how this information could best be disseminated to decision makers.

This study, through an intensive information-gathering effort, reached several conclusions regarding how disaster information could better be used to reduce losses in a variety of settings. It is evident that accurate and relevant information could significantly reduce the loss of life and financial costs of a natural disaster. To be most effective, the information must be timely and in a form that is understandable by decision makers. Information about disasters could be used for a variety of purposes and must be adaptable to the decision-making process. For example, disaster information could be used to predict the physical processes as well as the effects of disasters. Also, information could be used in support of decisions to deploy personnel and resources during or after a disaster.

While government agencies have much of the basic data needed for an effective disaster information system, valuable data and information from private sources also are available. A particularly valuable role of private organizations is the dissemination of disaster information, especially the delivery of such information to the general public to minimize losses.

Disaster information user needs vary greatly. For example, some users require highly processed data, while for others raw data are more useful. In any case, the importance of adequate training, and an appreciation of the quality of the data, for any user of disaster information is clear.

As planning proceeds for a disaster information network, these important goals should be pursued:

- improve decision making before, during, and after emergencies through better access to and quality of data and information,
- identify users and their needs,
- provide information products specifically designed to meet users' needs,
- promote efficiency and cost effectiveness, and
- stimulate and facilitate mitigation.

It is clear that despite excellent efforts by many groups the approach to providing information for disaster management is not effectively utilizing a wealth of data that resides with various organizations and that existing technology could deliver to disaster managers important information products that could save lives, reduce damage to property, and lessen the environmental impacts of disasters. The current situation is characterized by numerous shortcomings that inhibit optimal decision making for disaster management. The inability to access information and the lack of standardization, coordination, and communication are all obstacles that need to be overcome.

It is recommended that the Global Disaster Information Network (GDIN) Transition Team move ahead in planning for a disaster information network (DIN), taking into account the following conclusions from this study:

- The need for an improved information network and its potential benefits are clear.
- The foundations of an information network are already in place.
- Recent advances in technology provide the mechanism for establishing a network.
- Successful implementation of the DIN concept will require a commitment of resources from a broad spectrum of stakeholders.
- The products of a DIN should be based from the outset on users' needs.
- A major focus of a DIN should be on integration of various data types.
- Data and information quality and reliability are major issues that need to be addressed.
- An effective dissemination and access plan is critical to the success of any information network.
- The GDIN Transition Team should focus initially on establishing a national DIN (i.e., with a U.S. focus), but the model should be extended to a global process (GDIN) as soon as it can be demonstrated that a DIN is technically and organizationally feasible.

1

Introduction

THE THREAT OF NATURAL DISASTERS

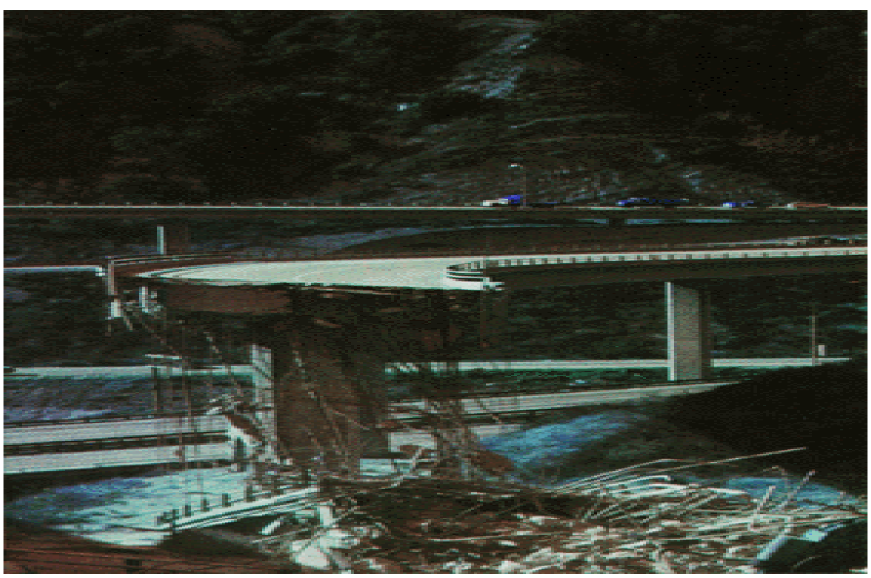
Natural disasters threaten much of the United States. In the past decade, substantial losses were experienced from the Loma Prieta earthquake and Hurricane Hugo in 1989; Hurricane Andrew in Florida in 1992; the Midwest floods in 1993; the Northridge, California, earthquake in 1994; and Hurricane Georges, the Florida fires, and the Texas floods in 1998. In recent years the cost to the nation of natural disasters has been huge, with many hundreds of deaths and tens of billions of dollars in damages (NRC, 1994). The impacts are felt not only by human suffering and property damage but also from loss of livelihood, economic deterioration, and environmental destruction. A large part of the costs of these disasters has fallen on the federal treasury, as well as state and local governments. These and other recent natural disasters also have had a serious impact on the private sector, most notably the insurance industry. Some companies have deemed it necessary to limit the coverage they provide in order to maintain their fiscal strength and to protect policyholders. Indeed, in certain cases they have withdrawn from the market entirely. For example, the states of California and Florida have established special catastrophe funds to assure that property owners continue to have access to insurance coverage.

Unfortunately, several factors may contribute to even greater losses in the future. For example, there has been a steady migration of people to coastal areas, where risks are substantially higher for hurricanes along the Atlantic and Gulf coasts and for earthquakes along the Pacific Coast. Similarly, the continuing movement to urban areas—our communication, transportation, financial, and government hubs—greatly intensifies the potential scale of private and public losses from natural disasters. Furthermore, exposure to hazards in many of the nation's floodplains increases the risks, owing to development and modifications to the landscape.

REDUCING DISASTER LOSSES

Although losses from past natural disasters have been substantial, they have been far less than they might have been. Various strategies for mitigating losses have been progressively implemented with some very impressive results (NRC, 1994, 1997). For example, improved weather warning systems have resulted in reduced loss of life from hurricanes and floods (NRC, 1998a). Unfortunately, this stands in contrast to the great increase in property damage. Also, better land-use and construction practices have reduced earthquake and flood losses (NRC, 1994).

Disaster decision making takes place before, during, and after a disaster strikes. The phases of decision making are usually described as mitigation, preparedness, response, and recovery. Mitigation involves long-term actions to prevent or reduce a hazardous effect from occurring, such as building structures that can withstand the force of winds or earthquakes. Preparedness anticipates the effects and takes appropriate countermeasures in advance, such as issuing warnings, stockpiling supplies, or establishing evacuation routes. Response includes actions taken during an event and its immediate aftermath, including rescue. And recovery brings a community back to life by restoring essential services and economic vitality. A recent



The Interstate 5/Route 14 interchange, north of Los Angeles, was one of only seven overpasses to collapse in the devastating 1994 Northridge earthquake. Hazard maps helped the California Department of Transportation decide which freeways should have priority for seismic strengthening. (Photo courtesy of USGS.)

report by the Federal Emergency Management Agency (FEMA, 1997) provides a comprehensive overview of natural hazards and approaches to understanding the risks posed and to mitigating their impacts.

IMPORTANCE OF INFORMATION FOR DECISION MAKING

At each phase of the disaster management cycle of mitigation, preparedness, response, and recovery, critical decisions must be made that require getting the right information to the right people at the right time. These decisions are made in both the public and the private sectors and often at local or individual levels. In the public arena, much responsibility rests with the local community that has jurisdiction over public safety and land use, although the community is usually backed up by state and federal assistance.

At present, several federal agencies and other organizations perform a variety of functions relevant to development and communication of information about natural disasters. These functions encompass broad areas of data collection, risk analysis, research, and information dissemination. In a predisaster (or preparedness/mitigation) period the information-producing organizations may collect and manage baseline data; construct predictive models; develop new modeling, data analysis, and instrumentation methods; and help communicate hazard information to user groups through maps, reports, public contacts, and other means. During the response phase (or during the occurrence of an extreme event) the agencies collect and manage real-time data and communicate hazard information, such as in warnings. In the recovery period after an event, the agencies document what happened with the goal of understanding why the event occurred and identifying problems in modeling, data collection, and understanding physical processes. The information and experience gained through these functions is communicated to planners and managers and should enhance and improve understanding of extreme events and make communities better prepared for future events.

As discussed by the Global Disaster Information Network (GDIN) Task Force (DITF, 1997), a fundamental problem in dealing with disasters is that they do not respect boundaries—organizational, political, geographic, professional, topical, or sociological. This complexity requires that disaster information be disseminated to all stakeholders involved in the disaster at hand, and each disaster may have a unique set of stakeholders. Furthermore, in developing the information there is a need to integrate data across many disciplines, organizations, and geographical regions. Representatives from various sectors of disaster management, therefore, must be involved in the design and integration of any new information system.

Parallel with the urbanization and growing complexity of American demography is the rapid advance of technology and information systems. The potential for access to data and the ability to produce derivative information are unprecedented. This trend can be seen in the expanded use and number of space-based sensors, the explosive expansion of communications channels, and the exponential rise in computers connected to the Internet. There has also been tremendous growth in the use of geographic information systems, the Global Positioning System, and modeling and simulation techniques. Each adds significant value in monitoring and simulating events and in characterizing infrastructure, high-hazard areas, and disaster zones, which is essential to rapidly bring scarce resources to bear in the most effective manner in both pre- and postdisaster contexts.

Despite technological advances, disaster risk continues to grow. Emergency managers and others continue to be called on to make decisions during disaster events, as well as in the pre- and postdisaster phases, with incomplete information. In order to make optimal decisions to reduce the loss of life and property, stakeholders uniformly must be able to obtain the needed information in a format that is appropriate for their capabilities.

The availability of information relevant to disasters is greater than ever before. Hundreds of federal, state, local, and international public and private organizations have created databases, largely accessible through the Internet, that are rich in information and knowledge. One can view data within seconds of its collection to, for example, see how a river is rising (see Box 1-1), track a tornado or hurricane, or observe the likely extent of damage caused by an earthquake that has just occurred; also, one can access the latest information on disaster-resistant designs, regions of high and low risk, sources of emergency supplies, preparedness plans, and more. While reliability during periods of great demand is still an obstacle to be overcome, the Internet and World Wide Web make it possible for millions of people to share data and information and to work together in ways not previously possible. Furthermore, it is anticipated that future advances in the Internet will increase reliability, speed, and access to information at lower cost (U.S. Department of Commerce, 1998).

WHY THE PRESENT SITUATION IS INADEQUATE

Disaster managers and other decision makers currently utilize a wide variety of information in all stages of the disaster management cycle of preparedness, mitigation, response, and recovery. However, the information resources that are available are often inadequate. First, the availability of information across the United States is not uniform. Large cities may

BOX 1-1
Increased Access to Streamflow and Stage Information

The role of the U.S. Geological Survey (USGS) in providing information on hydrological hazards has changed dramatically in the past several decades, driven largely by rapidly evolving information technologies, and provides a good example of how information on hazards has become widely available almost instantaneously.

The primary customers for hydrological data and related information in the first two-thirds of the twentieth century were the agencies and organizations responsible for developing the nation's water resources infrastructure. The products that the USGS provided during this period were historical streamflow data and some analyses of data related to water supply risks, reservoir safe yields, and flood frequency determinations. The National Weather Service installed instruments in many USGS stream gaging stations for transmitting river stage data via landline to its forecast offices. The USGS did not transmit real-time data directly to any organization.

Hazards information, such as streamflow data, has become widely available almost instantaneously with new collection, transmission, and dissemination technologies.

The agency's role began to change in the 1950s and 1960s as streamflow monitoring expanded to support reservoir operations and other real-time purposes. Streamflow data during this period were provided primarily in printed form, with provisional real-time data available to specialized users. The typical mode of data transfer to USGS customers in the 1970s is depicted in Figure 1-1.

In the 1980s and 1990s the agency's traditional customer base expanded significantly. Organizations supporting operation of the stream gaging program have included city and county agencies that need information for many different purposes, including flood hazard warning. Today, more than 800 agencies support the stream gaging program and at least two-thirds of them are local government agencies. This change in the USGS customer base coincided with dramatic improvements in the quality and cost effectiveness of satellite and microprocessor technologies available for data management and dissemination. Instead of recording data on paper

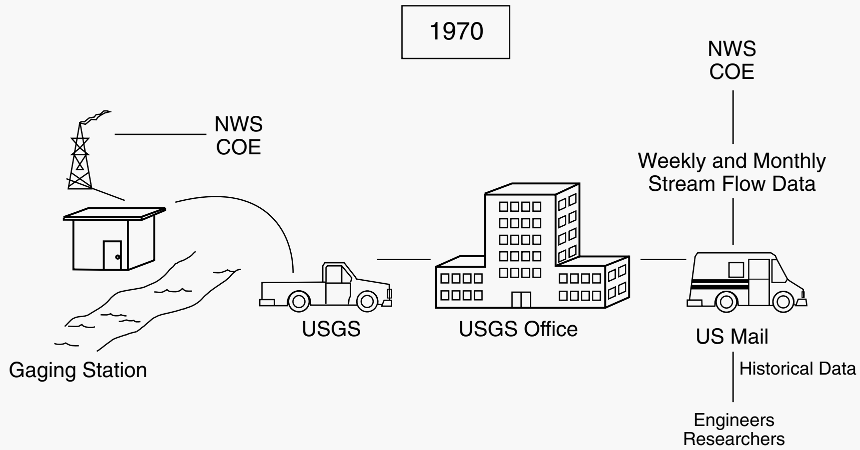


FIGURE 1-1 USGS's mode of hydrological data collection and dissemination in 1970.

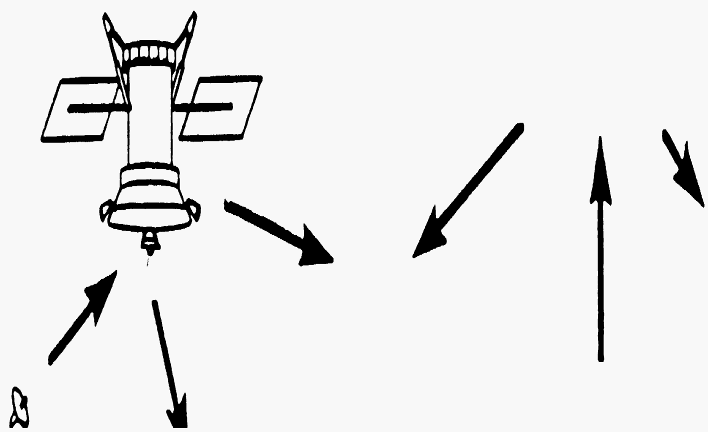


FIGURE 1-2 State-of-the art mode of hydrological data collection and dissemination for USGS in 1998.

charts or punched paper tapes, the USGS began storing data on small storage modules, downloading data to field computers for automatic processing, and transmitting data from field sites via the GOES satellite network, as shown in Figure 1-2. The satellite capability has enabled the USGS to transmit, process, and disseminate both river stage and discharge data every few hours to its customers who need the information for emergency warning and response functions.

have invested millions of dollars in their information systems, while smaller municipalities may be operating with one personal computer, if that.

In addition, the mechanisms to bring data and information to decision makers are uncoordinated. Information is often produced from disparate sources and transmitted in whatever format the provider prefers, requiring significant effort to compile it into a form that provides a coherent picture or even thwarting integration altogether. Data standards are often inconsistent, and, even more dangerous, users are sometimes unaware of the limitations and uncertainties in data or are presented with conflicting interpretations of data without the means to assess the reliability of the sources. All of these issues reduce the efficacy of the decision-making process. The problem is compounded because information delivery systems in many cases become overloaded during crises. For instance, in 1996 a moderate (magnitude 4.7) earthquake in San Jose, California, led to more than a million attempted hits in less than one day on the U.S. Geological Survey's World Wide Web earthquake information server. Most of those attempts were unsuccessful, including those by emergency managers trying to access data and information to aid in the formulation of a response plan.

Along with the technical difficulties for accessing information and data reliability, impediments arise from the lack of interaction between users and providers of information. Many of the data are created through research or monitoring programs that do not have disaster management as part of their mission. The users of such data are passive receivers of information without a role in requesting particular types of data. No entity exists to coordinate or foster communication among these groups. Nevertheless, a wealth of information exists that is potentially invaluable to users in the private sector and local and state governments (see Appendix B, which lists 31 federal disaster information centers).

The need for improved disaster management information is clear. The question at hand is: How could a nationally organized effort best meet this national need?

WHAT IS A DISASTER INFORMATION NETWORK (DIN)?

A DIN would promote understanding, cooperation, coordination, and collaboration among the providers and users of disaster information. It should be noted that a DIN would not be a central database or a network like a telephone or computer network; instead, it would be a comprehensive activity relating all aspects of disaster information, including accessing information resources, producing derivative and integrative information products, and delivering the information to decision makers of all types in a timely and useful manner. The process would draw on many existing resources and capabilities. Some features of a DIN should include:

- improved methods for finding information with specific attributes, for example, for a particular area or type of hazard;
- ways to determine the source, quality, and reliability of information, including standards for data compatibility;
- systems or software for integrating information rapidly to produce and deliver information tailored to the needs of a decision maker for the specific problem at hand; and
- courses to train users and build awareness.

Much of the DIN focus should be on developing integrative products for decision makers. Top priority should be accorded this area because the wealth of information that resides in numerous databases cannot be readily utilized by those who must take action to reduce risks or respond to disaster losses. A few examples, from many that could be cited, of integrative products are:

- international, national, regional, or local maps showing how hazards and risks vary in space and time;
- estimates of probability of occurrence of hazardous events;
- estimates and examples of potential effects, especially for structures;
- real-time display of what is happening during the course of a disaster;
- systems for contingency planning; and
- codes, standards, and construction methods for structures.

The overall goal of a DIN should be to reduce disaster losses. This can only be achieved by building communities that are resilient to the impacts of disasters. With limited resources, community decision makers need the best information they can get on what the hazards are, how likely they are to occur, what is at risk, how the effects vary throughout a community, and what can be done to mitigate the impacts. Much of the basic data from which this information would be derived is available now; however, the process for making available information products appropriate for decision makers needs to be developed.

2

Information for Decision Making

DATA NEEDS AND RESOURCES

Individuals, corporations, and government officials can be called on at any time to make decisions related to natural disaster mitigation, preparedness, response, and recovery. In making these decisions they utilize whatever information resources are available to them. In the absence of a global or national disaster information network, a wide variety of alternative information resources are utilized. Some organizations have developed their own internal information networks, while others rely on a variety of external information sources. This complexity presents a formidable challenge in analyzing information uses and needs.

Disaster information is needed by decision makers at many different levels and different scales. Officials in municipalities and counties need information that is sufficiently detailed to be useful in all aspects of disaster management—information such as land ownership; detailed hazard and risk maps; and the locations of utility lines, disaster response teams, and emergency supplies. State and federal officials need regional and nationwide data for program design, planning, and response to major disasters. Private corporations, such as utilities, insurance companies, manufacturing companies, and land corporations, as well as such organizations as the American Red Cross, need information on both the local and the national levels for planning, preparedness, response, and recovery. Some of the types of information needed for disaster planning, preparedness, response, and recovery are listed in Table 2-1.

Disaster information is gathered and held by many different organizations at different scales and levels of detail—for example, individuals hold plans, specifications, and as-built drawings of buildings. Companies hold information at different scales on their facilities and systems. Municipalities have maps showing properties, locations of roads, power lines, and sources of emergency supplies. Counties and states have data on infrastructure, hazardous waste sites, and fault lines. The federal government holds back-

TABLE 2-1 Information Resources for Decision Making

Base Data	
	Topography
	Political boundaries
	Public land survey system
	Geographic names
	Demography
	Land ownership/use
	Critical facilities
Scientific Data	
	Hydrography/hydrology (surface and subsurface flows and levels)
	Ocean levels and tides
	Soils
	Geology: rock types/ages/properties/structure
	Meteorology and climatology
	Archeology
	Seismology: active faults, seismicity, seismic wave propagation, ground motion
	Volcanology
	Wildlife: habitat, spawning areas, breeding grounds
Engineering Data	
	Control structures: locks, dams, levees
	Pump stations
	Building inventories/codes
	Offshore facilities
	Transportation, bridges, tunnels
	Utility infrastructure, pipelines, power lines
	Critical facilities
	Communication systems
Economic Data	
	Financial
	Insurance: holdings, losses
	Exposure
Environmental Data	
	Threatened and endangered species
	Hazardous sites
	Water quality
	Critical facilities
Response Data	
	Evacuation routes
	Management plans
	Aircraft routes
	Personnel deployment
	Equipment deployment
	Warning system
	Shelters
	Monitoring system
	Loss estimates

ground data on cartography and demographics and gathers real-time data on precipitation, stream flow, and seismic activity, as listed in Table 2-2. This diversity of interests argues for federal leadership in establishing a national process for better dissemination of disaster information.

CASE STUDIES IN DISASTER DECISION MAKING

The information-gathering process for disaster management is so complex and varied that it almost defies generalization. Instead of attempting a comprehensive analysis of this process, the use of disaster information in decision making is illustrated here through case studies. These case studies show how information resources currently serve decision makers and indicate the strengths and weaknesses of current disaster information systems.

Tornado

At 8:03 p.m. CDT on Saturday, July 13, 1998, a tornado touched down in western Oklahoma City, Oklahoma. For the next 10 minutes it hopscotched its way eastward through the northern suburbs of the city. Fortunately, the tornado was relatively weak, and preliminary damage surveys classified it as an F-2 on a scale of 0 to 5. A trained media storm spotter measured winds at 105 mph at one location.

Numerical weather forecasts produced by the National Weather Service (NWS) three days prior to the Oklahoma City tornado indicated the potential for severe weather in the Southern Great Plains during the evening hours of July 13. Such computer-generated numerical products are available on the World Wide Web and through private distributors of the NWS "Family of Services." Private entities, such as the Weather Channel, newspapers, and the broadcast media distribute this information without charge, in the form of forecasts for specific cities and in graphical formats (maps). Many companies and organizations with sensitivity to severe weather (such as railroads, tourism, and utilities) contract with commercial weather providers for value-added services tailored to their specific needs. A three- to five-day forecast is used to make decisions regarding anticipated staffing levels, possible overtime pay, equipment availability, communications checks, and inventories.

The "severe weather outlook" issued by the NWS Storm Prediction Center at 12:00 p.m. on July 12 placed Oklahoma City in an area of "slight risk" for the following day. Updates on July 13 at 12:00 a.m., 5:00 a.m., and 10:00 a.m. kept Oklahoma City under the "slight risk" threat. The city was included in a "tornado watch" issued by the Storm Prediction Center at

4:01 p.m., fully four hours in advance of touchdown. These "outlooks" and "watches" are available via the World Wide Web and NWS's Family of Services. Also, watches are broadcast on the National Oceanic and Atmospheric Administration's (NOAA) Weather Radio Network. Inclusion in an outlook or tornado watch area triggers many activities throughout local governments and industries. Examples include staffing emergency management centers, dispersing storm spotters, alerting repair crews, tying down light aircraft, and monitoring weather radars owned by television stations.

The NWS's Oklahoma City Forecast Office issued a tornado warning on July 13 at 7:42 p.m. for the county containing Oklahoma City. Tornado warnings are automatically disseminated to local media and local emergency management agencies and broadcast on NOAA Weather Radio. This 21-minute lead time is considerably better than the national average of 12 minutes made possible by the NWS's recent modernization and restructuring. Even 12 minutes allows people to seek shelter in the safest places in their homes, schools, and businesses and to take action to protect some property.

No deaths were reported in the aftermath of the Oklahoma City tornado of July 13, 1998. Preliminary estimates of insured losses were placed at $25 million. There were injuries requiring medical attention, including 17 at an amusement park near Interstate 35 that was still operating its rides and attractions when it took a direct hit by the tornado. The Oklahoma City media broadcast weather information, including the location of the tornado, to the general public. The path of the storm as reported by NWS Doppler radar, the media, and emergency services was crucial to getting aid and medical assistance to the affected areas and to preventing looting.

Tsunami

On October 4, 1994, at 06:23 PDT, a magnitude 8.2 earthquake occurred along the Kuril Islands trench subduction zone, about 150 kilometers off the east coast of Hokkaido, Japan. The Pacific Tsunami Center in Hilo, Hawaii, confirmed that a tsunami had been generated by the earthquake and that destructive tsunami waves had struck northern Japan and the Kuril Islands. Wave heights of 1.3 to 3.5 meters had been reported in northern Japan.

At 09:01 PDT, NOAA issued a tsunami warning for all coastal areas and islands in the Pacific. The warning included estimates of the arrival time of the initial wave at various locations around the Pacific Ocean. NOAA advised that tsunami wave heights could not be predicted and that the tsunami threat could result in a series of waves lasting several hours after the arrival

TABLE 2-2 Examples of Major Types of Information Held and Being Gathered by Federal Agencies

Data Type	Agency/Bureau[a] NOAA	USGS	Other DOI	DOA	Census Bureau
Base cartographic	X	X			X
Land-use/land cover/vegetation type	X	X	X	X	
Ecological		X	X	X	
Seismic		X	X		
Hydrological	X	X	X	X	
Oceanographic	X	X			
Threatened and endangered species		X	X	X	
Geology and soils		X	X	X	
Meteorological	X				
Hazardous sites			X	X	
Nuclear waste sites					
Demographic					X
Fire fuel type			X	X	
Land ownership			X	X	
Aircraft routes	X				
River flow and stage	X	X			
Snow pack				X	
Ground deformation		X			

[a]Abbreviations: NOAA, National Oceanic and Atmospheric Administration; USGS, U.S. Geological Survey; DOI, U.S. Department of the Interior; DOA, U.S. Department of Agriculture; EPA, U.S. Environmental Protection Agency; NRC, U.S. Nuclear Regulatory Commission; FAA, Federal

of the initial one. NOAA further advised that, if no major (or damaging) waves were recorded for two hours after the estimated time of initial arrival, local authorities could assume the tsunami threat had passed. They stated that the "all clear" determination had to be made by local authorities. The warning concluded that bulletins would be issued hourly or sooner if conditions warranted and that the tsunami warning would remain in effect until further notice.

Decision makers at Pacific Gas and Electric's (PG&E) Diablo Canyon Power Plant were concerned about the safety of offshore divers who were conducting maintenance operations on the cooling-water intake structure at the plant. In addition, the sea level often drops significantly as a large tsunami approaches the coastline; if the drop were large enough and long enough, there could be a loss of cooling water. Although the plant has emergency cooling water in reservoirs onshore, those responsible for emergency response at the plant were apprehensive.

EPA	NRC	FAA	FEMA	NASA	DOD	DOE
					X	
X				X	X	
	X		X			
X			X			
					X	
X						
		X	X			
X			X		X	
	X				X	X
		X			X	
				X		

Aviation Administration; FEMA, Federal Emergency Management Agency; NASA, National Aeronautics and Space Administration; DOD, U.S. Department of Defense; DOE, U.S. Department of Energy.

At 10:00 PDT, with the tsunami about six hours away, PG&E decision makers called on their geosciences department for advice. It was determined that there was no immediate concern for the safety of the divers but that it would be prudent to keep a close watch on the situation as it developed. An important indicator of the potential danger of the approaching tsunami would be the wave's characteristics as it arrived at Hilo, Hawaii. Knowing the wave characteristics of the tsunami at Hilo, a confident judgment could be made about the likelihood of the tsunami wave being destructive when it struck the California coastline about two hours later.

When the tsunami arrived at Hilo about 8 hours after the earthquake occurred, the waves were 0.5 meters high. Given other nondestructive wave heights elsewhere as the tsunami traveled across the Pacific, NOAA canceled the tsunami warning at 14:50 PDT. The cancellation notice remarked that no destructive Pacific-wide tsunami wave threat existed; however, it continued to caution against local conditions, which could cause variations in tsunami wave action.

With somewhat less than two hours until the time the wave was predicted to reach the California coast, NOAA faxed to PG&E the data from tide-gauge recordings. Officials there had already made a conservative decision to remove their divers from the water in case the approaching tsunami posed a threat to them.

The response of local authorities varied. Some ignored the warning, while others passed it on to the public to let people decide what, if anything, they wanted to do. Some believed evacuation of coastal areas should be ordered immediately. This resulted in some corporate decision makers wondering if they should take precautionary actions or simply ignore the warning.

Although the tsunami warning alerted individuals and organizations of the potential for a destructive tsunami along the Pacific Coast of California, it resulted in considerable confusion. Because of the lack of more timely and user-focused information, valuable response time was lost. NOAA's responsibility was only to issue the warning and to provide periodic updates as the tide-gauge data were received. It was the responsibility of local authorities to decide what actions needed to be taken to protect the well-being of potentially exposed populations along low-lying coastal areas. The warning revealed a general lack of understanding with regard to what should be done to prepare for the arrival of tsunami waves, but even knowledgeable people such as PG&E geoscientists were unable to use the available information effectively.

Volcanic Eruption

On Tuesday afternoon, August 25, 1992, Mt. Spurr in Alaska erupted and sent an ash plume 16 kilometers (10 miles) into the air. A few hours later the skies over Anchorage, located 130 kilometers (80 miles) east of Mt. Spurr, became blackened and gray "snow" fell over the city. The airborne particles and fallen ash forced the temporary closure of the Anchorage Airport, which served as the principal airport for transporting ARCO and British Petroleum workers to the North Slope of Alaska.

Prompt response by ARCO to an eruption warning issued by the Alaska Volcanic Observatory resulted in the following actions: relocation from Anchorage to Fairbanks of two Boeing 727 airplanes used to transport workers and supplies from Anchorage to the North Slope, establishment of interim North Slope ARCO transport operations out of Fairbanks, provision of bus transportation for flight crews and passengers between Anchorage and Fairbanks, and curtailment of ARCO night flights in the region. These actions remained in effect for several weeks until it was safe to resume normal ARCO flight operations from the Anchorage airport. The actions taken enabled vital oil field operations to continue without interruption and greatly reduced the danger to personnel and support equipment. Not all operations were so fortunate. Some commercial aircraft had engine damage and were stranded in Anchorage until the airport became functional again and the airborne particles had dissipated.

Flood

The July 31, 1976, Big Thompson Canyon flash flood occurred with little warning and claimed 145 lives. In response to this disaster, officials of the city of Boulder, Colorado, became concerned about what might happen if a similar storm should occur over Boulder Creek just 50 kilometers farther south. Researchers studied the Big Thompson flood and determined the feasibility of implementing an early flood detection and warning system for the city of Boulder. By January 1978 an agreement was reached to design and install an automated flood detection network of approximately 20 real time self-reporting rain and stream gages. This system became one of the earliest ALERT (Automated Local Evaluation in Real-Time) systems implemented in the United States. A comprehensive flood warning plan also was developed for Boulder Creek that incorporated the early detection and notification components into a warning decision process. Local officials are committed to updating and exercising this plan annually.

The Boulder Creek system was initially operated and maintained by the Boulder County Sheriff's Department. Through its first decade of operation, Sheriff's Department officials were the principal users of the data and remote access capabilities were very limited. This situation changed dramatically after the development of the personal computer. Today with Internet use commonplace, the demands for accurate real-time data are rapidly increasing. The gaging network has been expanded to include more than 130 stations monitoring many other drainage basins and streams in the six-county Denver metropolitan area, and data collection, analysis, and display functions have been integrated into an areawide system. Greatly improved graphical displays and telecommunications capabilities have made remote access to this system very popular.

Wildland Fire

More lightning strikes occur in Florida than in any other state in the nation. With the very wet winter and very dry spring of 1998, it was not surprising that Florida had one of the worst fire seasons in recent history. The unusually dry conditions and lack of fuel treatment for the past several years (prescribed fires to reduce overgrowth of brush and grasses) allowed a buildup of fuel ready for high-intensity fires.

As multiple fires broke out in northeastern Florida, local fire-fighting organizations were stretched beyond their capabilities and requested assistance from sister agencies throughout the state and from federal agencies in the surrounding states. The National Interagency Coordination Center located at the National Interagency Fire Center in Boise, Idaho, provides national wildland fire coordination of limited resources and support for fires anywhere in and outside the country. Resources such as infrared scanning aircraft were moved to Florida to meet the needs of local fire-fighting organizations. This was possible because of the great amount of information that is shared among the agencies. Standards presently exist for training, experience, management, and technical information interpretation that assure coordinated and consistent emergency response independent of geographical region.

Communities of 1,000 or more people were established in two to three days to take care of the needs of the fire fighters. This included food, showers, transportation, and many other resources. Locations of the camps and staging areas were based on the latest knowledge of which direction the fire was expected to travel. This information is derived from intelligence reports from all available sources, especially weather forecasts. The safety of fire fighters is paramount when they are trying to protect private citizens and also maintain a safe environment for themselves when off duty.

As the fires burned throughout May and June, a massive work force formed behind the scenes to provide intelligence and support for the fire operations. Fire behavior specialists, meteorologists, and fire managers used the available information to identify the areas most severely impacted by drought and the highest fuel loading buildups to project fire spread in threatened areas. Meteorologists downlinked weather data and modeled local weather conditions right at the fire site. Field observers were scouting the line and constantly reporting about fire and fuel information. Data from infrared scanning aircraft, satellites, and ground-based sensors helped decision makers predict the fire spread (movement) and smoke impacts and allowed them to evacuate homeowners from areas of immediate danger. Data were also used to predict indices such as flame height and resistance to control, which in turn were used to determine the amount of crews, equipment, supplies, and aircraft needed to be deployed in the region. Tactical

The greatest risk from wildfires can be in the wildland-urban interface areas, where rural lands meet the outskirts of urban lands. As the number of people in these areas grows, so will the frequency and severity of fires. (Photo courtesy of the U.S. Forest Service.)

decisions were made based on the latest information being received by aerial or ground-based data collections.

Earthquake

Millions of people viewing television coverage of the third game of the World Series in 1989 were instantly aware that a major earthquake had struck San Francisco. Graphic images of shaking at Candlestick Park, plumes of smoke from fires in the Marina District, and collapse of both the San Francisco-Oakland Bay Bridge and the Cypress Freeway viaduct bore witness to the widespread effects of the Loma Prieta earthquake on San Francisco and Oakland. Dramatic television images created an impression that the most significant damage was in the bay area. What was unknown at the time was that the smaller communities of Santa Cruz and Watsonville, about 70 miles south of San Francisco and much closer to the epicenter of the earthquake, experienced devastating damage to their core downtown areas. Even emergency response officials in those communities assumed they were better off than the bay area. By then needed emergency resources bypassed these communities in route to the bay area. It was not until the next day that information was available that indicated the extent of damage to such communities as Santa Cruz and Watsonville. The response of emergency personnel and equipment and relief resources to such regions was much slower than needed.

To prevent situations like this in the future, a new state-of-the-art satellite communications system was installed, a new emergency management structure was created, and now an earthquake monitoring and information system is being installed in Southern California. This new system, called TriNet, is intended to provide accurate information on the intensity and geographic distribution of shaking within minutes of the occurrence of a major earthquake. It uses sensors placed in a spatial array on the ground and a sophisticated communications system to relay ground-shaking information to a central processing site for integration and dissemination. This information will guide the gathering of disaster intelligence and the deployment of emergency response resources to the regions where damage is most likely to have occurred. The result will be reduced response time and more accurate deployment of critical resources. This will reduce both the number of casualties and the level of property damage caused by fires and aftershocks. The first phase of the system will be deployed in the southern portion of the state and will be completed in 2002. Planning has begun to expand the system to all of California and to facilitate the distribution of information to a wider range of stakeholders.

Hurricane

In September 1988 Hurricane Gilbert moved into the Gulf of Mexico after leaving behind considerable destruction across Jamaica and Cancun, Mexico. By Thursday, September 15, it was a very dangerous storm with sustained winds of 120 mph. The official National Hurricane Center forecast called for the storm to make landfall somewhere near the Texas-Mexico border, but because of the uncertainties inherent in the forecast, residents of the Texas coast south of Corpus Christi were advised to remain alert for a change in track.

Throughout the day the Galveston city manager, who was also the city's emergency management coordinator, relied on the NWS forecasts which indicated that the area with the highest probability of landfall was well south of Galveston. Consequently, there would be no need to issue an evacuation notice for Galveston. However, early in the afternoon, the port of Galveston received a forecast from a private meteorological company stating that it thought Hurricane Gilbert would make landfall between Galveston and Corpus Christi during early afternoon on Friday. This forecast was passed to the mayor and the emergency management coordinator. During the afternoon a Galveston radio station carried the same private weather service forecast predicting landfall much farther north than predicted by the National Hurricane Center.

At 4 p.m. the city of La Marque (10 miles north of Galveston on the mainland) recommended evacuation of its citizens. At 6 p.m. the emergency coordinator received a message over the Texas Law Enforcement Telecommunications System that described a scenario of a landfall 40 miles south of Galveston. Although in retrospect this was a worst-case scenario and not a forecast, the confusion factor from the various forecasts was now high enough that at 8 p.m. the emergency coordinator issued a recommendation for total evacuation of Galveston Island. While it is, of course, always better to be safe than sorry, this evacuation proved to be unnecessary and costly as on Friday, September 16, Gilbert came ashore in Mexico, south of Brownsville, Texas.

OBSERVATIONS

The above case studies, although not illustrative of all situations that might be encountered, indicate how information can and is used to mitigate the effects of natural disasters in a variety of settings. The following observations may be made from the case studies presented and from others:

- Timely and accurate information can significantly reduce loss of life and financial impacts from a natural disaster.
- For most natural disasters, time is of the essence in the delivery of information for the purpose of decision making.
- Disaster information must be in a form that is readily understandable by the potential user.
- When conflicting sources of information exist in an emergency situation, the potential for incorrect decisions is increased, with costly or even life-threatening consequences.
- Acting on incorrect information can be as costly as not acting on correct information.
- Decision makers use disaster information in a variety of different ways, and for optimum benefit this information must be readily adaptable to the decision-making process.
- Information systems can be used to predict the physical processes of disasters as well as their effects.
- Location and intensity information can be used to deploy vital personnel and resources to counter the effects of natural disasters.

Aerial view of flooding in Grand Forks, North Dakota, during spring of 1997. (Photo courtesy of U.S. Geological Survey.)

- Private organizations can provide a useful function in the dissemination of disaster information, especially in delivering such information to the general public.
- Private for-profit organizations assist in delivering disaster information, and it is likely that this will continue to be the case in the future.
- Government agencies possess much of the basic data that are needed for an effective disaster information system, but data are also valuable from private sources.
- Disaster information user needs vary greatly. For some, highly processed data are most useful, while for others raw data are more useful.
- It is important that users of disaster information be adequately trained.
- As atmospheric and oceanographic conditions know no national boundaries, global disaster information is needed for natural disasters.
- In some cases, early and progressive information can be used to optimize the deployment of personnel and resources in a potential high-hazard area prior to the actual occurrence of the effects of a natural disaster there.
- Information products could benefit greatly from user input in defining process requirements for hazard-specific situations at the national (or global) scale.

3

Benefits and Challenges of an Integrated Disaster Information Network

CHALLENGES AND OPPORTUNITIES

The case studies described in Chapter 2 illustrate that disaster managers face a wide variety of situations, each with virtually unique requirements for information. Different types of disasters present varying demands on the timeliness of information delivery, specific requirements for base data, and needs for integration of real-time information. But the cases show the importance of being able to access data rapidly, integrate the data into appropriate information products, and deliver the products to decision makers in a timely manner.

Modern technology provides unprecedented new opportunities for fulfilling the needs of decision makers. Some information systems that are already in operation demonstrate the potential for integrating real-time data with archival information in dynamic models to arm decision makers with powerful tools. The following systems described in boxes 3-1 to 3-4, which were presented at the June 1998 Board on Natural Disasters workshop as working examples, demonstrate the power of such systems in specific applications and indicate the potential benefits that could be realized with a national or global disaster information system.

These and many other systems demonstrate the utility and power of modern capabilities for accessing and integrating disaster information. Integrated information products delivered in a timely manner have the potential to serve the needs of local, state, and federal officials; the public and private sectors; volunteers; and citizens who are responsible for disaster management or who are subject to disasters.

Emergency management is basically about managing and coordinating a complex system of information resources. The system includes addressing not only the necessary technical components for disaster response and decision making (which is an enormous task in and of itself) but also the economic and sociological components of all phases of disaster planning.

BOX 3-1
Atmospheric Release Advisory Capability

Improved warning systems have done much to reduce natural disaster losses by giving people more time to prepare. For a tornado a community may have an advance warning of several minutes. For a hurricane it might be several days. And although earthquakes cannot be predicted, vulnerable areas expect and prepare for them. But what about those events, disasters in and of themselves, that cannot be forseen and that can affect large numbers of people within minutes or hours? An earthquake can cause the release of hazardous substances. A sudden wind change can steer toxic gasses from a volcano toward a city. The Atmospheric Release Advisory Capability (ARAC) is a national emergency response service of the Lawrence Livermore National Laboratory that is designed to improve decision making in just such an event.

Integrating real-time data with archival information provides a powerful tool for disaster managers.

After receiving just a minimum amount of information (time, location, and type of hazardous release), an ARAC response is set in motion. In less than two hours, and sometimes in minutes, ARAC will access the relevant data sources and synthesize the information to give emergency managers the probable path of the release, the extent to which it will spread, and the affected population and areas. Emergency managers can use ARAC plots and expertise to develop an appropriate response strategy to minimize hazards to life and health as well as property. The program provides support until all airborne releases are terminated, hazardous threats are mapped, and the impacts are assessed. In addition, ARAC can be used as a training tool by using actual real-time weather information to create a realistic release scenario so that authorities are ready for the real thing. Currently in use at many U.S. Department of Energy facilities, this capability could be developed for use at the state and local levels and could serve as a powerful tool for those at the front lines.

BOX 3-2
Information Technology for Disaster Management

EIS/GEM InfoBook Software, designed by Essential Technologies, Inc. (Rockville, Md.), is intended to provide disaster managers with an effective crisis management tool by bringing together important software. The software blends four core elements for disaster management: (1) a data administration component to put sound, comprehensive information at users' fingertips; (2) maps to help answer the questions of who, what, and where will be affected by a disaster event and identify resources for assistance; (3) models to help managers project impacts; and (4) a flexible communications component to facilitate the sharing of real-time information at a number of levels. These four components merge to provide decision makers with an accurate and complete representation of an emergency situation. Disaster managers thus have access to coordinated information from multiple sources with relative ease.

The software's capabilities allow those responding to an event to make the best decisions possible. On January 17, 1994, EIS maps, data, and aerial photographs were exchanged electronically on personal computers between officials in Washington, D.C., and federal disaster offices in California following the Northridge earthquake. The real-time visual images and reports were viewed by decision makers on the local, state, and federal levels simultaneously, which helped them determine the extent of damage and speed relief efforts to the earthquake's victims.

Commercially available software packages can put disaster information at users' fingertips.

This level of coordination is difficult for individual organizations and stakeholders with limited resources, staffing, and time. An integrated national disaster information network could harness all of these components into a standardized, accessible, and user-friendly format.

Much of the information needed to create a disaster information network is already in place (see Appendix B). Federal investment in research and other programs is creating vast amounts of physical, scientific, histori-

BOX 3-3
New Networks in Southern California

The 1994 Northridge earthquake killed 57 people and caused damages that have been estimated to be as high as $40 billion. More earthquakes of similar or greater impact can be expected in the greater Los Angeles area. To meet the threat to life and potentially devastating property losses, two new monitoring networks have been established: TriNet and SCIGN. TriNet, which is operated by the U.S. Geological Survey (USGS), the California Institute of Technology, and the California Division of Mines and Geology, with major funding from the Federal Emergency Management Agency, is an expanded and upgraded network of seismometers and strong-motion detectors. The Southern California Integrated Global Positioning System Network (SCIGN) monitors deformation of the earth's surface. Partners in SCIGN include the Jet Propulsion Laboratory, the University of California at San Diego, and the USGS, with funding from the USGS, National Aeronautics and Space Administration, National Science Foundation, and the W. M. Keck Foundation. TriNet allows rapid determination of an earthquake's location and magnitude and the distribution of strong ground motion for all felt earthquakes. This real-time and near-real-time information, broadcast to the California Office of Emergency Services and others, such as local power companies, will allow faster and better response to earthquakes. SCIGN's tracking of ground deformation is of interest to all those responsible for the integrity of major engineered structures, such as dams, water reservoirs, aqueducts and pipelines, gas pipelines, bridges, and tall buildings.

Major multiorganizational networks provide real-time earthquake information for disaster managers in Southern California.

cal, and cultural information. This information can help decision makers in the private sector and local and state governments understand hazards and the resulting risks and improve their decisions during all phases of the disaster management cycle. Potential users, other than the agency and program stakeholders for whom the information was developed, are often hampered

BOX 3-4
U.S. Army Corps of Engineers Data Integration Program for Emergency Management

The U.S. Army Corps of Engineers has developed a data integration program designed to not only pull together high-quality data sources for emergency management but also make them available to the public. ENGLink Interactive is an integrated system for communications, command, and control. Its database and mapping components allow for quick access to critical baseline and event-specific data. The data are displayed as interactive maps.

A data integration program provides hazards information in map form for emergency managers and the public.

One of the system's components, the Digital Project Notebook, allows users to identify a location of interest, submit a query to the database, and receive a map based on chosen criteria via a web browser. An event viewer gives users access to information on all emergency events in which the Corps is involved on global and U.S. scales, including floods, hurricanes, and other hydrometeorological events. Locator and mapping tools provide detailed information on an event location and are accessible and designed to work with popular software packages.

ENGLink's capabilities have been put to use in a number of recent disasters. After Hurricanes Marilyn (1995) and Bertha (1996), maps of the U.S. Virgin Islands were created that helped identify critical features and speed response and recovery.

by not knowing what exists or by finding it to be in an unusable form. Users often lack the capability, knowledge, or motivation to integrate this information into their decision-making processes.

Another problem is that information collected by agencies and organizations for operationally specific uses is often inconsistent with the techniques, formats, and terminology used by other agencies and organizations. The resulting mixture of inconsistent information makes use a daunting task and requires integration efforts often beyond the capability of most users. Disaster information network consensus standards would allow more efficient and accurate integration and use of information. Protocols would define communications, database structure, data formatting, hardware/software requirements, networking, quality control, and other issues needed to assure the linking of users, information providers, and entrepreneurs.

GOALS OF A DISASTER INFORMATION SYSTEM

These case studies and other similar experiences suggest that the design of a disaster information system should be guided by several primary goals:

- **To improve decision making before, during, and after emergencies through improved access to and quality of information.** Losses caused by natural disasters can be reduced by taking appropriate action based on wise decision making. Therefore, the foremost consideration in designing an information system is how well it serves decision makers. To this end, a system should provide enhanced access to reliable information. Access is steadily improving through advances in computing and telecommunications technologies, and timely access is becoming less and less problematic. Technological advances are also improving reliability and speed—at decreasing costs. In addition, a system should provide robust accessibility to data and information for critical decision makers by assuring priority access in times of emergencies. This is essential for effective response and continuity of government.

Improving access to information should be linked closely with providing evaluations of its reliability. Many decision makers are not in a position to appraise the quality of information and to understand the implications of its uncertainties. An information system should address this issue and provide some measure of quality evaluation for information users. One of the problems associated with the huge increase of information available via the Internet is the need to authenticate the accuracy and currency of data as well as verify the sources providing the information. Many of the traditional mechanisms for validating information and evaluating data quality do not exist in the networked environment. This poses particular problems for the disaster management community, which requires not only rapid access information but also a high level of confidence in the integrity of the data and information received. Addressing this issue will require a combination of organizational mechanisms that can develop criteria for quality standards and technical approaches, such as digital certificates that can verify sources of information and validate content.

The increased availability of information and its standardization, agreements on protocols, and increased linkage to users nationwide should stimulate a market for entrepreneurs to develop tools for user-specific purposes. Tools may include on-line search engines, data integration routines, loss estimation software, and event description models that integrate appropriate information for decisions. These tools might also include quality assurance routines analogous to filtering software to ensure information reliability. While a private nonprofit organization in cooperation with government agencies may sponsor the development of selected tools for specific users, the information system should empower entrepreneurs to create innovative user-serving products and tools with commercial value.

• **To provide information products that are specifically designed to meet the needs of users.** Most existing information resources on disasters were designed for specific purposes, in many cases related to research and development studies. Over time the broader utility of these resources has been recognized, and efforts have been made to draw on them for a wide variety of needs. The disaster management community, one of the critical users, has had mixed success in this endeavor because the data and information were not necessarily developed with this group of users in mind. In developing a disaster information network it is essential to focus on users' needs and give foremost priority to structuring and formatting the system to deliver products specifically designed to facilitate decision making.

It is important to recognize the diversity of users' needs and to tailor products accordingly. The needs of public or private emergency managers, land-use planners, insurers, and facility operators, for example, are specialized and different. Users' needs should probably be identified on a sector-by-sector basis, with a coordination mechanism to link each sector with the relevant information providers. Many of the information providers who are funded to create the data for research purposes will need incentives to modify their data and provide distribution facilities for emergency managers.

Systems should be designed to allow multiple products to be generated from common datasets and to provide on-demand capabilities for customized information. Search technologies that enable both novice and sophisticated users to query the same database also can contribute to serving diverse user communities.

• **To promote efficiency and cost effectiveness.** The various data and information resources that can be utilized for disaster management have come into existence for a wide variety of purposes and with many different funding arrangements. The continued viability of these resources requires that they remain tied to the organizations that nurture and sustain them. The fact that these resources are distributed no longer presents an obstacle to incorporating them into a system for disaster management, owing to the capabilities of the Internet. Integrating the various data and information resources would not only provide new decision-making products but also do so in a far more efficient manner than if the various resources were to proceed separately. Through common formats and standards, information could be shared and duplication avoided. Organizations would no longer have to collect certain types of data since they could access the data remotely from another source. Interactions among the various user sectors would be enhanced, leading to the sharing of applications.

Of critical importance, the creation of an integrated disaster information system would establish a framework that would encourage organizations and individuals to develop integrative products because a larger market would exist for them.

- **To stimulate and facilitate mitigation.** As computing and communications technologies are integrated into all functions of government at the local as well as state and federal levels, emergency management will be radically transformed. Wireless technologies will provide mobile communications that facilitate government's ability to track functions on a continuous basis, wherever they are located. Combined with enhanced wire communications and the integration of disparate databases, municipal management information systems will be capable of monitoring and synchronizing various activities across government agencies and departments.

An integrated information system would provide a process by which all levels of government could link information resources. The larger, more technologically developed jurisdictions could use the system to integrate local resources in a more cohesive way. Smaller underfunded jurisdictions will have available at a more reasonable cost information and tools to assist in decision making. Similarly, the network could allow nongovernmental entities to have access to an integrated information base to better support emergency management decisions.

CHALLENGES IN PROVIDING INFORMATION FOR DECISION MAKING

In developing a disaster information network, a number of considerations are important with respect to providing information on the nature of a hazard, the potential losses that may result from impending and future disasters, and the development of strategies for reducing this damage. It is critical that those who provide information be aware of the concerns and limitations of those who receive it. Furthermore, interaction of the various interested parties depends on the type of information available, how it is presented to them, how individuals process the information, and the con-

Some beachfront property became uninhabitable due to damage from Hurricane Fran in 1996. (Photo courtesy of FEMA.)

text in which they make their decisions. It is also important to understand how choices are made when dealing with problems that involve risk and uncertainty. Discussed below are some issues related to these considerations that need to be addressed in developing a disaster information network.

Types of Data Made Available to Users

Advances in information technologies have made it possible to perform disaster modeling that simulates a wide variety of different scenarios reflecting the uncertainties of different estimates of risk. For example, it is now feasible for insurers to evaluate the impact of different exposure levels on both expected losses and maximum possible losses by simulating a wide range of different estimates of seismic events using data generated by scientific experts. Similar studies can be undertaken to evaluate the costs and benefits of mitigation measures. However, the growing number of disaster models presents many challenges to users who rely on these models to estimate risk or potential damage. Each model uses different assumptions, different methodologies, different data, and different parameters in generating estimates of risk and damage. There is a critical need for a better understanding of how and why these models differ and for reconciling the differences in a more rigorous manner than has been done to date.

The interaction of different information users depends on the type of information available and how it is presented, how the information is processed, and the programs and policies that are in place. There is a growing empirical literature which shows that individuals utilize information in ways that are often different from what is considered to be rational by theories of choice. Unless one understands what types of data are collected in addressing a particular problem and how the data are utilized by the concerned individuals or groups, a proposed set of strategies is not likely to perform in the way that would be predicted by these theories. For example, if individuals in floodplain areas believe that their properties will not be damaged during their lifetimes, they will not voluntarily purchase flood insurance even if the rates are highly subsidized.

It is important to determine the types of information that should be presented to potential users on what scientists know about the risks associated with specific natural hazards (e.g., the probability of a particular disaster occurring, the nature of the losses with and without specific mitigation measures). In this regard it will be necessary to decide how best to present information to users that reflects disagreement among scientific experts on the risks of the hazard and the costs associated with specific strategies for reducing losses. Information and strategies that are robust over a wide range will be most useful to decision makers.

Tools and Products for Integrating Information

There are often very high costs associated with collecting data on any specific hazard. For this reason there is a tendency to maintain the status quo, which sometimes can be positive, such as if one chooses not to develop a piece of land in a hazard-prone area. Other times change may be needed. In this case it is important for those providing information to understand what information a user will need for a particular decision and how reducing the cost of obtaining the data may aid this process. With new information technologies it is easier to collect information, but there is considerably more data from which a particular user can choose. The scarce resources for decision makers today are attention and time rather than data. The data must be converted into relevant and timely information. It is important to understand how individuals are likely to make choices when dealing with decisions that involve risk and uncertainty. By understanding the decision-making processes of individuals and groups (i.e., their probability biases and simplified decision rules), it is possible to design better decision strategies that are likely to achieve the desired objectives.

Methods should be developed to utilize systematic approaches, such as cost-benefit analyses, to enable decision makers to evaluate alternative strategies for reducing losses. New information technologies, such as the World Wide Web, should be used to determine what information decision makers think is important to consider in specifying and evaluating different strategies. This will enable the capture of sets of costs and benefits that might not otherwise be considered in dealing with a specific problem. Tools and products need to be developed and evaluated for updating data on costs, benefits, and strategies as new information becomes available.

Improving Utilization of Disaster Information for Decision Makers

It is vital to determine what information specific decision makers would like to have available for evaluating and implementing specific strategies for loss reduction. Methods need to be found for incorporating the decision-making processes of the key interested parties in developing relevant strategies for reducing losses. Ways need to be found to use new technologies to get feedback on how useful specific information is likely to be to decision makers and how useful it actually has been. How can one use a disaster information network to determine what additional information might be useful over time? It is also important to communicate the "success stories" of communities or regions to others so that they can learn and build on those experiences.

Recognizing Nested Decision-Making Structures

In setting up a disaster information network, it is important to recognize that a change in any given policy must be carefully structured to reflect the formal and informal institutional arrangements and the nested decision-making structure between stakeholders. Each interested party has its own set of values and agendas that influence the way it processes information and interacts with other groups. To illustrate the nested decision structure, consider the challenges associated with reducing disaster losses through mitigation measures. Relatively few property owners adopt loss reduction measures even if they are relatively inexpensive and promise to yield sufficient benefits to justify the cost. One solution to this problem is to provide individuals with information concerning the dangers of living in specific areas. Other stakeholders have good financial reasons not to implement this

BOX 3-5
Taking Predisaster Measures

Providing better information alone may not reduce disaster losses. It may be necessary to combine the dissemination of information with other strategies such as economic incentives, regulations, and standards. For example, insurance premium reductions for adopting loss reduction measures should encourage property owners to seek information on cost-effective mitigation measures. Clearly specified building codes should encourage property owners to get information through inspections on whether the standards have been met. This information could then be made available to other interested parties such as the property sellers, insurers, mortgage holders, and public-sector agencies at the local, state, and federal levels.

Information is a powerful resource to be used in conjunction with mitigation measures to reduce risk from disasters.

The failure of information alone to solve the problem of reducing disaster losses is evidenced by the lack of interest of many individuals in voluntarily purchasing property insurance and adopting mitigation measures. Many residents in hazard-prone areas think that a disaster will not

measure. For example, property sellers have no reason to provide prospective buyers with information on the hazards associated with living in a particular structure that fails to meet the building code. They are supported implicitly by current owners who want to sell the property at as high a price happen to them even though scientific analysis suggests some likelihood that structures will be damaged, some severely, in the next 5 to 10 years. If people perceive the probability to be below a given threshold level of risk, they are not likely to worry about it and hence will think that it is not necessary to protect themselves against the event. Following disasters there is an increase in the demand for insurance protection because the event is salient in many people's minds, so that its perceived probability exceeds the threshold level of concern.

The factors that determine the demand for insurance protection are still not well understood, although recent controlled experimental studies provide some insight into consumers, decision-making processes. There is evidence that presenting information in different forms may affect how consumers determine whether to purchase insurance coverage and how much to pay. Some of these effects are the vividness of a projected event as portrayed by the news media and the use of rebates so that a policyholder thinks that he or she has experienced a gain if he or she does not collect on the policy. Data from insurance markets suggest that these same effects occur when similar real-life decisions are made. Findings from the laboratory and the field suggest that the theory of consumer choice regarding insurance needs to be rethought and factors influencing the decision-making process should be considered when determining what information to present to those at risk.

as possible. Furthermore, a potential buyer may have little interest in understanding a structure's design if he or she is not convinced of the risks associated with future disasters. These interacting self-interests and nested decision-making structures must be taken into account in effective dissemination of disaster information.

4

Conclusions and Recommendations

The current "nonsystem" for providing information for disaster management is not effectively utilizing a wealth of information that resides with various organizations. Existing technologies could deliver to disaster managers important new information products that could save lives, reduce damage to property, and lessen the environmental impacts of natural disasters. Continued improvements in technology should help make information more widely, quickly, and reliably available—and at less cost. The current situation is characterized by numerous shortcomings that inhibit optimal decision making for disaster management. The inability to access information and the lack of standardization, coordination, and communication are all obstacles that a disaster information network (DIN) could overcome. It is recommended that the Global Disaster Information Network (GDIN) Transition Team move ahead in planning for a disaster information network, taking into account the following conclusions from the present study:

- **The need for an improved information network and its potential benefits are clear.** Chapter 3 establishes the need for an improved disaster information system. There can be no justification for continuing in the current mode of nonstandard disparate resources when available modern technologies would make their linkage into one system a relatively straightforward matter, with obvious potential payoffs in saving lives and reducing losses if the system is utilized effectively.
- **The foundations for an information network are already in place.** While a significant undertaking, establishing a DIN would build on a substantial foundation that already exists. The most costly element of building the basic databases is well under way, and the community of users already exists. A network could be established initially by coordinating existing information resources and developing standards and protocols to ensure their reliability and usability and effectively linking with the user

community. The cost of establishing the information system would be trivial compared with the cost already spent in developing the resources.

The existing federal data-gathering and information programs (see Table 2-2) reflect an enormous investment of funds, mostly public, and the dedicated and sustained efforts of many investigators. These databases were derived from a variety of endeavors, including instrumental monitoring, field surveys, data compilations, and laboratory studies. Many of the efforts are of a continuing nature, as data are updated and phenomena are continuously monitored. Altogether, there has been, and continues to be, a very substantial investment of resources in developing and maintaining the databases used for disaster management.

Despite the importance of these databases, their utility is impaired by a host of problems deriving from incompatible formats, inconsistent geographic reference systems, conflicting standards, and other human-caused factors. Many of these problems could be resolved and the value and utility of the databases for disaster decision making greatly enhanced through improved organizational and technological coordination with only an incremental increase in cost. It is clearly in the public interest to do this.

• **Recent advances in technology provide the mechanism for establishing a network.** The Internet and high-speed telecommunications provide the necessary technologies for establishing an information network. Through the Internet, a DIN could be assembled by tapping data and information resources wherever they happen to reside worldwide. Thus, problems associated with assembling resources into a central repository are avoided, and the various organizations that developed the resources can each maintain their identity and roles in the larger system. Among the issues that require attention are determining which organizations need to be included; what datasets should be provided; who is responsible for establishing and updating links, maintaining the accuracy and currency of data, and preserving the data for long-term access; and what technical infrastructure is required at each site to accommodate increased traffic on the different systems.

• **Successful implementation of the DIN concept will require a commitment of resources from a broad spectrum of stakeholders.** Although the costs of establishing a DIN would not be large compared with its likely benefits or the investments already made in developing data and information resources, maintaining a DIN would require additional expenditures and commitments from the organizations involved. Converting data into a standardized format and providing data to the DIN, although a much easier task today because of the Internet than in the past, still require the commitment of resources, especially human resources. Many of the data are created through research or monitoring programs that do not have disaster management as their principal purpose. These organizations should be offered federal incentives to participate in the system because without the raw data the DIN would have nothing to communicate.

Successful implementation of a DIN will require a commitment of resources from a broad spectrum of stakeholders and sustained organizational and individual commitment of material, financial, and human resources by DIN users and providers. While resource capability varies and not all DIN participants may be able to commit material or financial resources, each has a professional obligation to actively commit human resources.

• **The products of a DIN should be based from the outset on users' needs.** The success or failure of an information system is determined by the level of effort and support given to it by its constituency. Thus, it is paramount that broad representation of elements making up the community of users and providers be intimately involved in all aspects of the start-up phase of a DIN. This includes such tasks as further defining the initial concept and evolving program plans for the overall system and an operating strategy. The importance of early ownership of a DIN by a wide variety of users and providers cannot be overstated. In this regard, the GDIN Transition Team is encouraged to consider other programs such as the National Aeronautics and Space Administration's Earth Science Enterprise Federation, an activity designed to disseminate information about the earth at a variety of scales (NRC, 1998b).

In order for the DIN to provide value-added services and products, it must be responsive to the immediate and future information needs of users. The critical prerequisite is systematic and continuous involvement of an information users' representative from the disaster management community in the design, development, operation, and maintenance of the DIN throughout its evolution. Involvement means establishment of a user/provider forum wherein information users and data providers openly discuss their capabilities and needs and together address each of the major natural hazards in the context of each of the four emergency management system phases (mitigation, preparedness, response, and recovery). Through the forum the needs of existing and new users could be defined through a taxonomy of user profiles that define the type, format, specificity, timeliness, and accuracy of disaster information desired for specific natural hazards.

Thus, through user/provider activities, opportunities for avoiding redundancy and reducing disaster management costs could be realized by improved and better use of existing data collection and data management technologies in activities such as outreach programs and data-sharing cooperatives. An inclusive and ongoing user-provider interface is a prerequisite to the development of an effective DIN.

- **A major focus of a DIN should be on integration of various data types.** One challenging aspect of a DIN would be to determine how data collected from a large and diverse group of providers can be linked so as to be presented in a meaningful and timely way to an even larger user community. Development of common interfaces can facilitate this process by integrating distributed information sources. Prospective information providers must also have incentives that attract them to this process. Interpretive products such as images, graphs, tables, and maps must be developed with the end users in mind. In designing these "first look" products, emphasis should be on simplicity while maintaining user capability to investigate and question the data more deeply. To accomplish this, standards and protocols should be agreed on by a representative group of potential users and information providers. Existing information integration models should be assessed to facilitate discussion and identify the pros and cons of various approaches. The selected protocols must address communications, database structure, data formatting (by both data providers and DIN servers), hardware/software requirements, networking, and quality control. Consideration should be given to future system growth and the early and continuing evolution of interpretive products. User creativity should be fostered and encouraged by the DIN.

To maximize participation and cooperation by the many potential information providers, the data collection methods must be flexible and relatively easy to implement. Prescribing fixed formats would likely be met with resistance, thereby limiting the number of providers willing to participate in the project. Metadata files (files describing the data) are one means of achieving data acquisition format flexibility. The DIN should provide examples of metadata files and standards and explain how they would be used by the system. This should help encourage participation. Procedures will also be needed to manage and maintain the information that is collected. Routine follow-ups concerning metadata records will be important to ensure system and data integrity. A management structure and staffing requirements should be specified for handling these ongoing tasks.

Integrating and sharing information from a wide variety of sources is an exciting concept that many will embrace. However, using this resource for emergency decision support will require considerable training, confidence on the part of users, and a clear understanding of the network's inherent uncertainties and limitations. It will take time before the DIN can establish itself as a credible tool for use during critical events. Developers of the DIN should consult with emergency managers, behavioral scientists, and other professionals on how best to address this issue.

Some of the most useful information products for disaster management could be derived by merging real-time with archival information. Some examples are as follows:

- Preparing for an approaching hurricane requires incorporating meteorological data into models that predict storm track and storm surge and then overlaying the results on maps showing population distribution, evacuation routes, deployment of emergency personnel and supplies, and other relevant response information.
- Responding to an earthquake involves rapid determination of magnitude and location followed by modeling to predict ground shaking and damage, which requires soil maps and building inventories, culminating in an assessment of losses and response requirements.
- Assessing the threat of rising floodwaters requires analysis of real-time stream gage data, modeling river basin and channel hydraulics, predicting the ability of levees and other defense structures to contain the flow, and anticipating problems.

Capabilities for integrating information would be especially helpful to disaster managers during the occurrence of compound disasters. For example, an earthquake in Southern California that occurs when Santa Ana winds are blowing off the Mojave Desert could result in widespread and difficult-to-contain wildfires. The capability to integrate earthquake and wildfire modeling could be crucial in responding. Similarly, the combination of a volcanic eruption and ash fall with heavy rain, such as occurred in the Philippines when Mt. Pinatubo erupted and Typhoon Yunya hit in 1991, would require integration of information to predict the weight of ash deposits on roofs, among numerous effects, as well as the ability to move equipment in such conditions. Add to this the occurrence of an earthquake, which did happen later in the Philippines, and the need for integration of information becomes of paramount importance.

Rapid information integration would also be of critical value in predicting or responding to technological or environmental problems caused by a natural hazard. Earthquakes can cause dams to breach or rupture fuel storage tanks, landslides can break pipelines, and fires can destroy wildlife habitats. Timely information delivered to the right decision makers clearly would significantly reduce losses. Special attention should be paid to automatic data integration, for example, to trigger alarms, so as to assure accuracy of data and avoidance of false alarms.

• **Data and information quality and reliability are major issues that need to be addressed.** Although the Internet provides the means for accessing information resources, it does nothing to assure their quality and reliability. It would be easy to fall into the trap of thinking that more information is always better; however, bad information likely will lead to bad decisions. Thus, one of the challenges of a DIN would be how to evaluate the reliability of the information in the system.

Emergency managers face a particular challenge in using disaster information because of the critical time-constrained nature of their situation. Therefore, a DIN would need to provide mechanisms for emergency managers to evaluate the reliability of data and information they receive. Data provided by government agencies, for example, should come with specific quality assurances, including dating. It is obvious that emergency managers who try to use a DIN for the first time during a crisis would be the most likely to have problems, which points to the importance of training.

• **An effective dissemination and access plan is critical to the success of any information system.** Time and attention are scarce resources and limit the amount of data that individuals and groups will want to collect. Awareness of the decision-making processes and biases of individuals is needed in order to design a useful disaster information system. Connectivity between users and sources of data and information should be assured in the design of a DIN. This linkage would be provided through the Internet, but in time of emergencies access to the Internet is likely to be disrupted. Because emergency management staffs must have access to communications, robustness and redundancy are critical elements of the system.

Although the Internet may provide the common network for dissemination of information, the principles of robustness and redundancy lead to examination of other means and methods to achieve assured connectivity. Potential means and methods include private nets such as Intranet or Extranet, which allow controlled access to special communities, thus avoiding some connectivity problems in time of emergencies. At the source nodes, allowances for emergency managers to have priority access to information in time for decision making should be implemented. Such procedures are not easily achieved on a national basis and will require additional administrative overhead and support.

- **The GDIN Transition Team should focus initially on establishing a national DIN (i.e., with a U.S. focus), but the model should be extended to a global process (GDIN) as soon as it can be demonstrated that a DIN is technically and organizationally feasible.** The team members represent agencies with generally limited international missions and experiences. It would be advisable to concentrate on development of a national process where agencies are most familiar and information technologies are well advanced. The process could be extended as soon as the U.S. model works reasonably well both technically and organizationally. Disasters are worldwide issues, and many of the relevant phenomena are global in nature. The International Decade for Natural Disaster Reduction[1] has heightened global awareness of the value of disaster information and opened lines of communication relevant to disaster issues, factors that should help facilitate extension of a DIN from U.S. to global proportions.

[1]For information on the International Decade for Natural Disaster Reduction see http://hoschi.cic.sfu.ca/~idndr/.

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APPENDIXES

APPENDIX A

Workshop Agenda

"The Role of an Information Network in Reducing
Losses from Natural Disasters"

Board on Natural Disasters
Green Building, Room 126
2001 Wisconsin Ave., NW
Washington, D.C.
June 22-24, 1998

Monday, June 22

Open Session:

9:00 a.m. Discussion of study goals and expectations

10:00 Break

10:10 Global Disaster Information Network—Overview and Discussion
Peter Ward

11:00 Current Examples of Disaster Information Integration

- Remote Sensing, GIS, and the Intranet
  Andrew Bruzewicz

- Atmospheric Release Advisory Capability
  Thomas Sullivan, U.S. Department of Energy

12:00 p.m. Lunch

1:00	Presentations *continued*

- Crisis Management and Oil Spill Training
  Mike Collins, Ship Analytics International
- Emergency Information System (EIS)/InfoBook
  Jim Morentz, Essential Technologies, Inc.

2:00 Issues for Consideration (to stimulate later discussion)

Discussion leaders (10 minutes each)

- Kevin Stewart—*Information availability and the needs of entities engaged in flood prediction and response*
- John Hwang—*Information needs of local government for emergency management*
- Dave Jones—*Disaster information with respect to public perception and response*
- Joanne Nigg—*Warning and disaster information systems: User perspectives*
- Lloyd Cluff—*General needs of the industrial sector, public utilities in particular, for various types of information*

3:10 Break

3:20 Open Discussion

4:10 Report Outline and Writing Assignments

5:30 Recess for the day

Tuesday, June 23

8:30 a.m. Working Group Writing Sessions

12:30 p.m. Lunch

1:30 Working Group Sessions *continued*

3:00 Discussion and Feedback on Chapter Outlines

5:00 Recess for the day

Wednesday, June 24

8:30 a.m. Writing Session

12:00 p.m. Working Lunch and Wrap-up

- Working group progress reports
- Assignments and due dates for draft
- Discussion of follow-up to project completion

1:30 Meeting adjourns

APPENDIX B

Federal Disaster Information Centers*

Advanced System Center (ASC), USGS: A facility in Reston, Virginia, that provides special facilities for member agencies of the Civil Applications Committee (CAC) to integrated classified data into unclassified programs.

Alaska Volcano Observatory (AVO), DOI/USGS, UAF/GI, ADGGS: Fairbanks and Anchorage, Alaska. Monitors and studies Alaska's hazardous volcanoes to predict and record volcanic activity and to implement public safety measures. *URL:* http://www.avo.alaska.edu

Aviation Weather Center (AWC): Kansas City, Missouri. Enhances aviation safety by issuing warnings, forecasts, and analyses of hazardous weather to aircraft in flight and to the aviation community. The center also forecasts weather conditions affecting domestic and international aviation interests out to two days. The AWC is one of nine centers within the National Centers for Environmental Prediction (NCEP). *URL:* http://www.awc-kc.noaa.gov

Cascades Volcano Observatory (CVO), DOI/USGS: Vancouver, Washington. Provides accurate and timely information pertinent to the assessment, warning, and mitigation of natural hazards (volcanoes, earthquakes, landslides, and debris flows) and performs research into the effects of geologic or hydrologic processes on the landscape (e.g., volcanic gases on the atmosphere, increased sediment transport on streams). *URL:* http://vulcan.wr.usgs.gov

Center for Integration of Natural Disaster Information (CINDI): A research facility operated by the USGS to develop better ways to integrate and disseminate disaster data and information. Many other agencies with

*From http://disasterinfo.net/GDIN/Feasible.html.

natural disaster responsibilities contribute data and expertise to this effort. *URL:* http://cindi.usgs.gov/events/index/html

Climate Prediction Center (CPC): Washington, D.C. Maintains a continuous watch on short-term climate fluctuations to diagnose and predict them. Assists agencies both inside and outside the federal government in coping with climate-related problems such as food supply, energy allocation, and water resources. The CPC is one of nine centers within the NCEP. *URL:* http://nic.fb4.noaa.gov

Cold Region Research and Engineering Laboratory (CRREL), DOD/USACE: Hanover, New Hampshire. Provides research on solving technical problems that develop in cold regions, especially those related to construction, transport, and military operations. CRREL provides this information to defense services, civilian agencies of the federal government, and to state agencies, municipalities, and private industry. *URL:* http://www.crrel.usace.army.mil

Earth Resources Observation Systems (EROS) Data Center (EDC), DOI/USGS: Sioux Falls, South Dakota. Handles data collection and distribution of images from satellites and aircraft. The EDC holds the three decades of land-surface phenomena information within the National Satellite Land Remote Sensing Data Archive. The EDC also acts as the Distributed Active Archive Center, or DAAC, for land processes on behalf of NASA's Mission to Planet Earth. *URL:* http://edcwww.cr.usgs.gov/eros-home.html

Emergency Operations Center (EOC), DOD/U.S. Army Corps of Engineers: EOCs provide command and control for emergency operations, which include advance measures, flood response, and post-flood recovery as well as activities to save lives and protect improved property. Additionally, FEMA is supported during disaster response under Public Law 93-288, including the Federal Response Plan. EOCs support the Commanding General U.S. Forces Command and commanders outside CONUS for mobilization, deployment, and sustainment of U.S. forces during contingencies.

Environmental Modeling Center (EMC): Camp Springs, Maryland. Improves numerical weather, marine, and climate predictions at the NCEP through research in data assimilation and modeling. The EMC develops, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and coupled system using advanced methods developed internally as well as cooperatively with scientists from universities, NOAA laboratories and other government agencies, and the international scientific community. The EMC is one of nine centers within the NCEP. *URL:* http://nic.fb4.noaa.gov:8000

FEMA National Mapping and Analysis Center and Regional Offices, FEMA: Washington, D.C. Maintains baseline disaster management data and develops integrated products distributed to regional offices, which further assimilate local information for emergency management purposes. *URL:* http://www.fema.gov/msc

Hawaiian Volcano Observatory (HVO), DOI/USGS: Hawaii National Park, Hawaii. Monitors and studies Hawaii's hazardous volcanoes to predict and record eruptive activity and to implement public safety measures. *URL:* http://hvo.wr.usgs.gov

Hydrometeorological Prediction Center (HPC): Camp Springs, Maryland. Provides basic hydrometeorological analysis and forecasts for National Weather Service field offices and the entire meteorological community. HPC meteorologists are experts in quantitative precipitation forecasting and numerical model interpretation. Products provided by the HPC include surface analyses, outlooks for heavy rain and snow, and weather forecasts through 5 days. The HPC is one of nine centers within the NCEP. *URL:* http://www.ncep.noaa.gov/HPC

Mapping Applications Center (MAC), DOI/USGS: Reston, Virginia. Serves as the U.S. government's leading civilian organization devoted to developing maps and geospatial data based on high altitude photographs, earth orbiting satellite images, and other technologically advanced and unconventional sources. *URL:* http://www-nMDusgs.gov/mac

Marine Prediction Center (MPC): Issues marine warnings and guidance in text and graphical format for maritime users. Quality controls marine observations globally from ship, buoy, and automated marine observations for gross errors prior to being assimilated into computer model guidance. The MPC is one of nine centers within the NCEP. *URL:* http://www.ncep.noaa.gov/MPC

Mid-Continent Mapping Center (MCMC), DOI/USGS: Rolla, Missouri. Operates as a major field production facility in the National Mapping Division of the U.S. Geological Survey. Produces paper and digital maps.

An Earth Science Information Center (ESIC), where walk-in and phone orders for USGS products are processed, is also part of the mapping center. *URL:* http://pluto.er.usgs.gov/xindex.html

National Centers for Environmental Prediction (NCEP), DOC/NOAA/NWS: Washington, D.C. Provides worldwide weather forecast guidance products. This agency is the starting point for all weather forecasts. It is the parent center for Tropical Prediction Center (TPC) and National Hurricane Center (NHC). *URL:* http://www.ncep.noaa.gov

National Climatic Data Center (NCDC), DOC/NOAA: Asheville, North Carolina. Supports programs involving remotely sensed and in situ information on meteorology and climate. NCDC operates World Data Center-A (WDC-A) for Meteorology under the auspices of the National Academy of Sciences, with the responsibility of gathering data on global climate and weather. *URL:* http://demo1.eis.noaa.govnesdis/nesdis_ncdc.html

National Earthquake Information Center (NEIC), DOI/USGS: Golden, Colorado. Determines earthquake locations following occurrence, alerts appropriate entities, archives earthquake information, and performs active research to improve earthquake detection. *URL:* http://wwwneic.cr.usgs.gov

National Hurricane Center (NHC), Tropical Prediction Center (TPC), DOC/NOAA/NWS: Miami, Florida. NHC and its parent center, TPC, maintain a continuous watch on tropical cyclones over the Atlantic, Caribbean, Gulf of Mexico, and the Eastern Pacific (from May 15 through November 30); they prepare and distribute hurricane watches and warnings, as well as marine and military advisories; conduct research to evaluate and improve hurricane forecasting techniques; and are involved in public awareness programs. The TPC is one of nine centers within the NCEP. *URL:* http://www.nhc.noaa.gov

National Imagery and Mapping Agency (NIMA) Disaster Support Center: Washington, D.C. Provides products derived from classified assets to U.S. government agencies. *URL:* http://www.nima.mil

National Interagency Fire Center (NIFC), DOI (BLM, FWS, NPS, BIA, OAS), USDA (USFS), DOC (NOAA/NWS): Boise, Idaho. Serves as primary U.S. logistical support center for wildfire suppression; also serves as a focal point for wildfire information and technology. *URL:* http://www.nifc.gov

National Response Center (NRC), DOT/USCG: Washington, D.C. Serves as the sole national point of contact for reporting all oil, chemical, radiological, biological, and etiological discharges into the environment anywhere in the United States and its territories; sends alerts to appropriate entities; and serves as the communications and operations center for the National Response Team (NRT). *URL:* http://www.dot.gov/dotinfo/uscg/hq/nrc

National Severe Storms Laboratory (NSSL), DOC/NOAA/NWS: Norman, Oklahoma. Enhances national capabilities to provide accurate and timely forecasts and warnings of hazardous weather events (e.g., blizzards, ice storms, flash floods, tornadoes, lightning) through research into weather processes, research in forecasting and warning techniques, and development of operational applications and transfer of technology. *URL:* http://www.nssl.noaa.gov

National Storm Prediction Center (SPC): Norman, Oklahoma. SPC monitors hourly and forecasts severe and non-severe thunder-storms, tornadoes, winter storms, extreme winds, heavy rain, and other hazardous weather phenomena across the continental United States. Its parent agency is the National Centers for Environmental Prediction (DOC/NOAA/NWS). *URL:* http://www.nssl.noaa.gov/~spc

National Weather Service (NWS), DOC/NOAA: Silver Spring, Maryland. Serves to protect the life and property of U.S. citizens from natural disasters by issuing warnings and forecasts for hurricanes, tornadoes, floods, winter and summer storms, and all manner of severe or extreme weather. *URL:* http://www.noaa.gov/nws/nws.html

Pacific Disaster Center (PDC), DOD: Kihei, Maui, Hawaii. The PDC is a federal center designed to provide world-class information support to federal, state, and local disaster managers in mitigation, preparedness, response, and recovery for disasters within the Pacific region. The PDC is being developed under the auspices of the DoD with the goal of transitioning the operation to an appropriate federal civil agency at the full operational capability milestone. *URL:* http://www.pdc.org

Pacific Tsunami Warning Center (PTWC), DOC/NOAA/NWS: Ewa Beach, Oahu, Hawaii. Serves as operational center of the Pacific Tsunami Warning System (PTWS), providing Pacific basin tsunami watches, warnings, and information/education services to the disaster preparedness community and the general public.

Rocky Mountain Mapping Center, DOI/USGS: Denver, Colorado. Produces and develops map products and conducts research, concentrating activities in western United States. Facility is responsible for distributing more than 100,000 map-related products of the United States Geological Survey (USGS) and other federal agencies. *URL:* http://avsrvr-1.cr.usgs.gov

Volcano Systems Center (VSC), University of Washington and USGS: Seattle, Washington. Formed to integrate research across disciplines to understand the role of volcanic systems in geological evolution. *URL:* http://www.vsc.washington.edu

West Coast/Alaska Tsunami Warning Center (WC/ATWC), DOC/NOAA/NWS: Palmer, Alaska. Serves as the Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California; provides timely tsunami warnings, watches, advisories, and information/education services to the disaster preparedness community and the general public. *URL:* http://www.alaska.net/~at+wc

APPENDIX C

Biographies of BOND Members

Wilfred D. Iwan, Chair, is director of the Earthquake Engineering Laboratory at the California Institute of Technology. A noted earthquake engineer, he chaired the Board on Natural Disaster's Committee on Hazards Mitigation Engineering, and has served on or chaired various National Research Council committees, including the Committee on Natural Disasters. He was chairman of the California Seismic Safety Commission from July 1992 to June 1994 and is a member of the International Association for Earthquake Engineering, among other associations. He received his Ph.D. from the California Institute of Technology.

Lloyd S. Cluff is manager of the Geosciences Department at the Pacific Gas & Electric Company and is an expert on the identification of active seismic faults and their potential motions. He manages PG&E's Earthquake Risk Management Program. Prior to joining PG&E, Mr. Cluff was director of geosciences at Woodward-Clyde Consultants, in San Francisco, where he directed siting and design evaluations for critical facilities worldwide. He is a commissioner on the California Seismic Safety Commission and has served as its chairman. Mr. Cluff has served the National Research Council in a number of capacities: as chair of the Committee on Practical Lessons from the Loma Prieta Earthquake, as a member of the U.S. National Committee for the Decade for Natural Disaster Reduction, and as a member of the Board on Earth Sciences and Resources. He has also served as a member of numerous NRC committees, including the Subcommittee on Earthquake Research and the Committee on Earthquake Engineering Research. He holds a B.S. in geology from the University of Utah, Salt Lake City. He is a member of the National Academy of Engineering.

Lucile M. Jones is a seismologist with the U.S. Geological Survey and a visiting research associate at the Seismological Laboratory, California Institute of Technology. She also participates in the management of the Southern California Seismic Network and in the monitoring of earthquakes in Southern California. Her primary research interests are the physics of earthquakes, foreshocks and earthquake prediction, and the seismotectonics (earthquake-producing geological structures) of Southern California. As a graduate student at Massachusetts Institute of Technology, Dr. Jones was awarded a Fulbright Fellowship in 1979 to work for 12 months at the State Seismology Bureau in Beijing. She was the first American scientist to work in China after normalization of relations. Dr. Jones is actively involved in seismological research and has authored over 40 papers on seismology.

James F. Kimpel is professor of meteorology at the University of Oklahoma, Norman. He develops programs in hydrometeorology and remote sensing, working with the National Severe Storms Laboratory and Next-Generation Radar Operational Systems. He is a past chairman of the University Center for Atmospheric Research, and past chair of the Advisory Committee for the Atmospheric Sciences of the National Science Foundation as well as a member of numerous professional societies and associations.

Howard C. Kunreuther is the Cecilia Yen Koo Professor of Decision Sciences and Public Policy at the Wharton School, University of Pennsylvania. He is also codirector of the Wharton Risk Management and Decision Processes Center. An economist, he has served on numerous National Research Council boards and committees, including the Water Science and Technology Board and the Committee on Earthquake Engineering. He has written extensively on decision making with respect to low-probability/high-consequence events. His current research focuses on the role of insurance coupled with regulations and standards in reducing losses from natural and technological hazards.

Stephanie H. Masaki-Schatz is a consultant in disaster recovery, emergency management, and life safety planning. She has extensive experience in contingency planning, most recently with ARCO (Atlantic Richfield Company) where she directed the strategic planning, operation, and financial controls for corporate emergency preparedness and support for business resumption. Her professional work in the public sector was in physical land-use planning and community economic development. Ms. Masaki-Schatz serves on the Board of Directors of the Business and Industry Council for Emergency Planning and Preparedness and on the Caltech/U.S. Geological Survey TriNet Advisory Committee and is cofounder of the Downtown Earthquake Preparedness Action Council in Los Angeles. She received a master of arts degree in architecture and urban planning from the University of California at Los Angeles.

Joanne M. Nigg is a professor of sociology and codirector of the Disaster Research Center at the University of Delaware. Dr. Nigg is an expert on societal response to natural hazards and disasters. Specifically, her research has focused on the public's understanding of disaster forecasts; public, organizational, and governmental responses to natural disasters; the factors that facilitate or inhibit the development of disaster preparedness and mitigation programs by local governments; and the evaluation of disaster education programs. From 1983 to 1991 she served on the National Research Council's Committee on Earthquake Engineering. Dr. Nigg is president-elect of the Earthquake Engineering Research Institute. She received her Ph.D. in sociology from the University of California at Los Angeles.

Dallas L. Peck served as director of the U.S. Geological Survey from 1981 to 1993, culminating a long career as a geologist with the agency. Among his many positions at the USGS, Dr. Peck worked as a volcanologist at the Hawaiian Volcano Observatory, where he studied the activity of the Kilauea volcano. He also served for four years as chief geologist of the USGS. As director, Dr. Peck was a strong supporter of the United Nations International Decade for Natural Disaster Reduction. He received his Ph.D. in geology from Harvard University.

Richard J. Roth, Sr., is a retired insurance executive, having worked as a property/casualty officer for over 50 years. A fellow of the Casualty Actuarial Society, he is a trained meteorologist with experience in many aspects of disaster insurance. He received a presidential commendation from President Reagan and an Outstanding Public Service Award from the Federal Emergency Management Agency for his work as the first chairman of the Write-Your-Own Standards Committee of the Federal Insurance Administration. He holds a B.S. with honors from Northwestern University and received his meteorology training from the Massachusetts Institute of Technology.

Harvey G. Ryland is the president and chief executive officer of the Institute for Business and Home Safety in Boston. Trained as a systems engineer, Mr. Ryland has a strong background in the analysis and design of emergency management and public safety systems. From 1992 to 1996 he served as deputy director of the Federal Emergency Management Agency. Mr. Ryland is an expert on natural disaster preparedness and mitigation policy at the federal level. He received his M.S. in engineering science from Florida State University.

Ellis M. Stanley, Sr., is the assistant city administrative officer for the city of Los Angeles. Prior to this position, he was director of the Atlanta-Fulton County Emergency Management Agency and was an emergency manager there since 1975. He is an adjunct instructor at the Emergency Management Institute. He has served on the Board of Visitors of the National Emergency Training Centers, Emergency Management Institute. He is also a past president of the National Coordinating Council on Emergency Management and currently chairs its International Development Committee and its Certification Commission. He is also president-elect of the American Society of Professional Emergency Planners. He serves on the advisory board of the National Institute for Urban Search and Rescue, the National Weather Service's Modernization Committee, and other organizations.

Frank H. Thomas is a natural hazards consultant who formerly served as associate director of the Federal Emergency Management Agency's National Flood Insurance Program. Dr. Thomas is an expert on the mitigation of natural hazards and is particularly interested in the integration of multihazard loss reduction in the emergency management community. He has served as a liaison to the National Research Council's Water Science and Technology Board. Dr. Thomas received his Ph.D. in geography from Northwestern University.