NWS also provides general flash flood warning information to all counties in the United States. Two types of forecasts are made. A flash flood watch is issued if conditions indicate flash floods are likely to occur. A flash flood warning is issued when flooding is imminent or reported. These are only general warnings and do not contain detailed information about possible flood conditions. Some flood-prone communities receive more specific forecast information, such as information on flood locations and possible magnitudes, from WSFOs. In addition, communities and other local organizations (e.g., watershed planning districts) have developed localized warning systems based on available technology to provide their own forecasts. About 1000 communities nationwide have or are in the process of developing warning systems.

Local flood warning systems fall into two basic categories—manual and automated (Hydrology Subcommittee 1985). Each type has many variations, and many are unique systems. Flood warning systems follow four steps: collection of data, transmittal of data, analysis of the data and flood forecasting, and alerting of officials. The data that are collected include rainfall and stream data from a set of different locations upstream from the affected community. Data are transmitted to a centralized location, where they are analyzed for flood forecasts. The forecast, which generally includes timing and magnitude of the flood, is given to officials responsible for flood warning.

In manual systems, people are involved at all or almost all stages. They observe rain gages and call a weather office. The person at the weather office records the data and uses a forecast procedure to estimate flood characteristics. That person may then call a local emergency official if a flood is anticipated. An automated system may use a series of automated rain and stream gages to radio-transmit data to a central computer facility. These data are fed into a hydrological model. When a critical parameter is met, a beeper is activated to alert a local official. Some systems combine both manual and automated techniques (e.g., a single stream gage may be automated and linked to a beeper device, while other data are manually collected and analyzed).

Warnings are disseminated from NWS offices to local officials and over NOAA weatherwire (teletype). Local officials and the media further disseminate these warnings using EBS stations, television, cable, and other specialized warning-dissemination techniques.

1.2.8 Avalanches

Avalanche warning efforts result in informing the public of general avalanche conditions; specific warnings are especially directed to people outside controlled avalanche areas. Informal warning programs have operated in some states—for example, Colorado and Washington (Judson 1975; Williams 1980). A cooperative venture between NWS and the U.S. Forest Services (USFS) has sought to enhance avalanche warning efforts to disseminate warnings to back-country and mountain travelers.

A key component of the avalanche warning system is public education regarding avalanche risk in reference to zoning ordinances, ski-run closures, and highway restriction. Reports and warnings are transmitted to the media through NWS facilities. Further coverage is made through mountain NWS radio broadcasts, which are transmitted 24 h a day. This coverage can include intermittent warnings when avalanche risk conditions are especially critical. Intermittent warnings can indicate moderate or high hazard. Moderate-hazard intermittent warnings classify avalanche risk that will most likely result from artificial releases at high elevations. High-hazard intermittent warnings indicate the

possibility of larger avalanches reaching populated areas and roads, and these warnings can also include hazardous lower elevations.

At present, avalanche warning systems are somewhat site-specific and include the participation of NWS and USFS. For example, the Colorado Avalanche Warning Program (CAWP) has operated for about a decade. Programs such as these rely on forecasted weather conditions from NWS and information on the snow pack from USFS. CAWP uses NWS and USFS in quantitative models to forecast local risk.

1.2.9 Nuclear Power Plants

Very precise guidelines have been established by FEMA and the Nuclear Regulatory Commission (NRC) on the design of a warning system for a nuclear power plant. The guidelines cover notification procedures, alerting methods, emergency communications, and testing (FEMA 1985).

FEMA and NRC require nuclear power plants to establish procedures for notifying state and local personnel about an emergency. The content of messages to officials and the public must be established, and there must be a means to provide early notification and clear instructions. Furthermore, these agencies require state and local governments to establish a system for disseminating to the public the initial and following information they receive from the plant via the appropriate broadcast media. The emergency plan must list the broadcast stations or systems with adequate signal strength and 24-h coverage that would be used. The procedures and individuals responsible for notification must be identified. Furthermore, the plan must address the time intervals for broadcasting official information. Federal guidance recommends a maximum interval of 15 min. In addition, broadcasted information must be monitored and inaccurate information corrected.

The regulations require that each organization establish the administrative and physical means to notify the public within the emergency planning zone (EPZ) plume exposure pathway. It is left to the plant operators to demonstrate that the means exist, although state and local governments are responsible for activating a warning. The following procedures must be developed to demonstrate that the means of warning exist: (1) an organizational plan describing responsibilities and backup must be developed, and (2) a plan must be developed to activate the warning system to meet minimum warning times and to guarantee appropriate activation of the warning system.

The alert system must be capable of providing an alert signal and instructional information to the population within the 10-mile EPZ within 15 min. The initial notification must have essentially 100% coverage of all people within 10 miles. However, in extremely rural, low population areas beyond 5 miles, up to 45 min may be allowed for providing an alert signal and instructional message (FEMA 1985). Others beyond this distance that are difficult to alert within the given time limit are reviewed on a case-by-case basis. Warning plans must account for means of notifying special or institutional populations. The regulations do not require a set communication mode, so long as the above time requirements are met. Physical methods of communication include fixed or mobile sirens with EBS radio communication and tone-alert radios. In special cases, the use of existing institutional alert systems, aircraft, automatic telephone dialers, modulated power, or emergency personnel can be used. Other methods of communication (i.e., informal notification between members of the public) have also been included as part of warning plans.

Plans must also address communication among principal emergency response organizations and to the public. A communication plan must specify contacts and backups in each organization, and what primary and backup equipment is to be used. Plans must include provisions for 24-h notification to state or local officials. Provisions must be made for communication with all state and local governments in EPZ, federal emergency response organizations (including NRC), and all emergency operations facilities. Also, there must be provisions for activating emergency personnel in each organization.

Periodic exercises are required to test warning systems at nuclear power plants and to identify and correct any system deficiencies. In addition, telephone surveys of the population in EPZ are required to further confirm the altering capability of the system.

1.2.10 Hazardous Materials

Many federal agencies are involved in activities to reduce the risks imposed by hazardous materials; for example, major programs are conducted by the U.S. Environmental Protection Agency (EPA), FEMA, the U.S. Coast Guard, the U.S. Department of Transportation (DOT), the Occupational Safety and Health Administration, and NRC. The National Oil and Hazardous Substances Contingency Plan provides guidance on federal response to releases of hazardous material. Other enabling legislation includes the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund), the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act, the Clean Air Act, and the Clean Water Act.

1.2.10.1 Fixed Sites

In some cases fixed-site facilities that could release hazardous chemicals and threaten off-site populations and the communities in which they are located are required by federal legislation to develop emergency or contingency plans. For example, RCRA requires a spill contingency plan with a notification component before facilities can dispose of hazardous materials. More recently communities with facilities that store hazardous materials have been mandated to prepare emergency plans. Overall, the requirements in such legislation regarding warning systems are rather vague. As a result, existing warning systems have been developed primarily by individual companies or communities as a joint cooperative effort or through local requests or mandates.

National policies on emergency planning for chemical accidents evolved in the 1980s and are likely to have changed by the time this report is published. In 1981, FEMA and EPA published a joint planning guide which included the topic of warnings (FEMA/EPA 1981). Following the Superfund Amendments and Reauthorization Act (SARA) Title III legislation, EPA developed interim guidance on the Chemical Emergency Preparedness Program (EPA 1985). In 1987 the National Response Team (NRT) published the *Hazardous Materials Emergency Planning Guide* (NRT 1987), a joint effort of 14 federal agencies; this manual provides interim guidance as well as a framework for communities to work with plants in developing a warning system. FEMA is currently developing a guide for designing warning systems for hazardous material accidents.

These existing guidelines provide little detail about how to build a warning system for a chemical hazard, beyond recommending the development of a method to alert the public. This would include establishing a contact point between the plant and the community who would be responsible for alerting the public and listing the essential data including health hazards, personal protection evacuation routes, shelters, and hospitals.

Sirens, EBS radio, mobile public address systems, and house-to-house contact are recommended for warning the public.

According to the guidance (EPA 1985): "It is important to provide accurate information to the public in order to prevent panic." To this end, a single spokesperson should be used, and all warning activities should be deferred to this individual. Given the potential for urgency, warnings should be given via radio or television, not through newspapers. Any warning plan should evaluate how sirens will be used to notify the public and what geographical areas would be covered. Also, sample messages are recommended for general evacuation, school evacuation, and sheltering.

Industry has also developed a national program on emergency planning for hazardous material accidents called Community Awareness and Emergency Response, or CAER (CMA 1985). One product of this effort is a guide on community warning systems (CMA 1987).

In 1987 a survey was conducted on community warning systems for fixed-site chemical accidents (Sorensen and Rogers 1988) as part of the Section 305b report to Congress (EPA 1988). This survey found that few communities had state-of-the-art warning systems for both technology and management practices. The study concluded that the most effective way to improve warning systems was, first, to develop better plans and implementing procedures and, second, to disseminate improved warning technology.

1.2.10.2 Transportation

Each year there are some 6,000 to 15,000 accidents in the United States involving the transport of hazardous materials. Some of these pose a threat to the health and safety of the surrounding population and require warnings and subsequent protective action by members of the public. DOT regulates land transportation incidents regarding hazardous materials. When an accident occurs that may threaten public safety, the carrier in possession of the hazardous cargo is required to notify the DOT National Response Center hotline to report the incident.

Several other federal agencies can be involved in responses to a transportation accident involving hazardous materials. EPA maintains national and regional response centers with teams that are sent to sites of serious spills on land. The U.S. Coast Guard responds to incidents in ports and on water. The prime responsibilities of these teams are to provide technical assistance in containing and cleaning up spilled materials. The U.S. Department of Agriculture and the Public Health Service also respond to major incidents that exceed the capacity of state agencies. FEMA and other federal agencies also respond to incidents.

The prime responsibility for issuing a warning falls on local emergency response organizations, usually the state police, local sheriff or police, or fire department, that are the first to arrive at the scene of a spill. The primary warning problems that these organizations face are identifying the hazardous materials involved in an incident, determining the threat that they present, and then deciding who to warn and what to tell them. Some communities have developed plans to guide this activity, but most incidents require ad hoc responses.

To support warning efforts, DOT publishes a guidebook on emergency response for use in hazardous material incidents (DOT 1984). While this book gives no information on warnings, it does describe appropriate emergency actions for a variety of hazardous materials. The guide recommends that the on-the-scene commander contact CHEMTREC, a private emergency consulting service operated by the Chemical

Manufacturers Association (1985), which maintains a 24-h 800 telephone number. CHEMTREC provides advice on the materials involved and on how to handle the situation and immediately contacts the shipper of the materials for more detailed information and appropriate follow-up, including on-scene assistance. Often, CHEMTREC has to contact the manufacturer's representative before advice on substances can be provided.

Warnings regarding land spills are usually conducted on a door-to-door basis by law enforcement personnel or by the use of bullhorns on vehicles. Radio and telephone may be used as notification mechanisms in more protracted situations where the threats are less immediate. Thus, warning systems for this class of hazard are rather unsystematic and depend on ad hoc responses. Despite the lack of planning, numerous evacuations are successfully undertaken each year in connection with hazardous materials accidents.

1.2.11 Dam Failure

Dams can fail, causing downstream flooding, for a variety of reasons, including excess precipitation and runoff, structural failure, overtopping, or seismic activity. There are no major warning systems operated by the government for dam and reservoir systems. Warning systems for the nation's 10,000 dams, where they exist, are largely site-specific. For example, in Colorado warning and evacuation planning for dam failure is the domain of local governments. Recent efforts have attempted to increase the awareness of need for such warning systems (Division of Disaster Services 1985). It is believed that only a few communities in the nation have plans and warning capability; those that do probably exhibit a wide range in warning system structure and quality.

Several federal agencies with extensive reservoir systems—including the Corps of Engineers, the Bureau of Reclamation, and the Tennessee Valley Authority—are now developing warning systems guidance. The Corps of Engineers has developed prototype plans and planning guidance for its reservoirs. The Federal Interagency Committee on Dam Safety has developed emergency action planning guidelines for dams.

Dam warning systems are first tied to detection or prediction of possible failures. The means of detection are either from visual inspection or from such instruments as acoustic detectors, slope failure detectors, reservoir water level gages, or downstream flood detectors. Most dams rely on visual detection rather than instruments. Warning systems for dam failures may also be linked to events that lead to dam failure, such as floods or earthquakes. Particularly in the case of floods, the elements of a warning system may be very similar. Dam failure warnings can be issued through a variety of channels depending on the availability of communication and alert devices; little standardization exists.

1.2.12 Nuclear Attack

Nuclear attack poses difficult warning problems owing to the potential scope of the warning effort. The Civil Defense Warning System (CDWS) was developed to provide the means of warning federal, military, state and local officials, and the civilian population of an impending or actual enemy attack, accidental missile launch, or radioactive fallout. The CDWS combines national, state, and local resources. The heart of the system is the National Warning System (NAWAS) (FEMA 1981). Operated by FEMA, NAWAS is a series of nationwide dedicated telephone lines operated on a 24-h basis. NAWAS consists of two national warning centers, ten regional warning centers, primary warning points, state warning points, extension warning points, and duplicate warning points.

A warning of nuclear attack would most likely originate from the North American Air Defense Command (NORAD), on the basis of tactical and strategic intelligence data (GAO 1986). This warning would be passed on to NORAD headquarters in Colorado Springs. An alternative National Warning Center is located in Maryland. The National Warning Center then simultaneously disseminates the warning to all NAWAS warning points.

Each state has a designated warning point operated on a 24-h basis and responsible for controlling warnings within the state. In addition, the NAWAS primary warning points and extension warning points include 400 federal points and 1600 city and county warning points. Primary warning points, staffed on a 24-h basis, are responsible for public dissemination of warnings. Duplicate warning points are staffed in emergencies and used when primary warning points cannot be in operation.

NAWAS is supplemented by state and local civil defense warning systems which transmit the warning to officials and the public. State civil defense offices are usually linked to other state agencies, county sheriffs, and civil defense agencies. Local civil defense officials transmit warning information to institutions and to the general public.

CDWS relies on outdoor siren systems and various forms of electronic communications, including commercial radio and television, EBS, cable television, group-alerting bell and light terminals operated by telephone companies, tone-alert radios, and public address systems. The outdoor siren system has two levels of warning. A 3- to 5-min wavering tone is an attack warning and means an attack is in progress. A 3- to 5-min steady tone is an attention/alert warning and means that people should seek added information. The CDWS supports EBS, which is designed to get a single source message out to the public in the event of a warning. It can be activated by the president and could be used to disseminate a message from the president; however, the EBS system can be used by persons other than the president.

1.2.13 Terrorist Attack

The Federal Bureau of Investigation (FBI) defines terrorism as the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof in furtherance of political or social objectives. Such incidents traditionally have taken the form of armed attack on institutions, hostage seizure, planting explosives, or other forms of incursion designed to force cooperation from authorities in terms of publicity, release of prisoners, or monetary remuneration. Some four dozen terrorist incidents are reported within the United States annually, and this number might change in the future.

To our knowledge, no systematic, integrated warning plan has been developed to deal with a terrorist incident. It is likely that a large amount of strategic intelligence is collected about potential terrorist activities by, for example, the FBI, but how this information is processed and how a warning would be disseminated to appropriate officials or agencies is not public knowledge.

International police organizations such as INTERPOL maintain computerized files on terrorist groups and individuals. These may be used for pre-incident reference, incident management, and postincident assessment. Information technology serves a number of functions in this area, including crisis management, crisis simulation, analysis of essential terrorist elements, profile maintenance, and data storage and transmission.

Specific events and circumstances are often provided with unique warning system arrangements. In preparation for the 1984 Olympic Games, the Los Angeles Police

Department established active intelligence networks and liaisons with other agencies in the U.S. antiterrorist community, and reportedly conferred with British, West German (Chartrand 1985), and Israeli intelligence services. During, the 1984 U.S. presidential elections, the FBI and the Secret Service collaborated to protect presidential candidates. Persons who were considered potential threats to the candidates were registered in the National Crime Information Center files, which are automated and readily accessible.

1.3 REPORT ORGANIZATION

This report is divided into four general parts. In the first part (Sects. 1 and 2), we describe and define a warning system. The first section described existing warning systems in the United States. Section 2 is a conceptualization of the generic components of all warning systems. In this section, we note that all warning systems are divided into a detection or technical component (monitoring and detection, data assessment and analysis, prediction, and informing); an emergency management component (interpretation, decision to warn, method and content of warning, and monitoring of response); and a public response component (interpretation and response). We also address the method and content of informal warnings and the divergent viewpoints regarding what a warning system is.

Section 3 constitutes the second general part of the report. In this section, we offer a set of practical recommendations for planners to consider when building, maintaining, or evaluating a public emergency warning system. We believe that these recommendations are based on solid empirical evidence. While we caution readers that we are researchers and are not well-versed in the political realities of regulatory agencies or governmental jurisdictions, nevertheless, political realities and the ideal-type of warning system we propose in Sect. 3 can be integrated to take full advantage of the knowledge accumulated in this area of research.

The third part of this report—covering Sects. 4, 5, and 6—addresses the reasons why an ideal-type emergency warning system might look like the system proposed in Sect. 3. In Sect. 4, we present research findings on why a warning system can be less than totally effective from an organizational viewpoint. It is clear, for example, that uncertainties regarding the impending event, the parties with whom to communicate, and impacts perceived to be associated with a false alarm are the major organizational obstacles to warning system effectiveness. We also offer planning strategies to reduce these problems. Section 5 reviews research on public response to warnings. This section proposes that warnings determine what members of the public perceive their risk to be in a warning event and that these situational risk perceptions are the key determinants of actual response to warnings. We then catalogue research findings that have been found to explain variation in risk perception and warning response. The topic of Sect. 6 is how differences and similarities across hazard types—in terms of relevant warning system and response concepts—suggests overlap and differences in warning system plans. Our conclusion is that overlap across warning systems is warranted, but that complete overlap across all warning system types is probably not possible.

In Sect. 7, we summarize current research needs based on the state of knowledge regarding the public response, organizational, and practical aspects of public emergency warning systems.

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