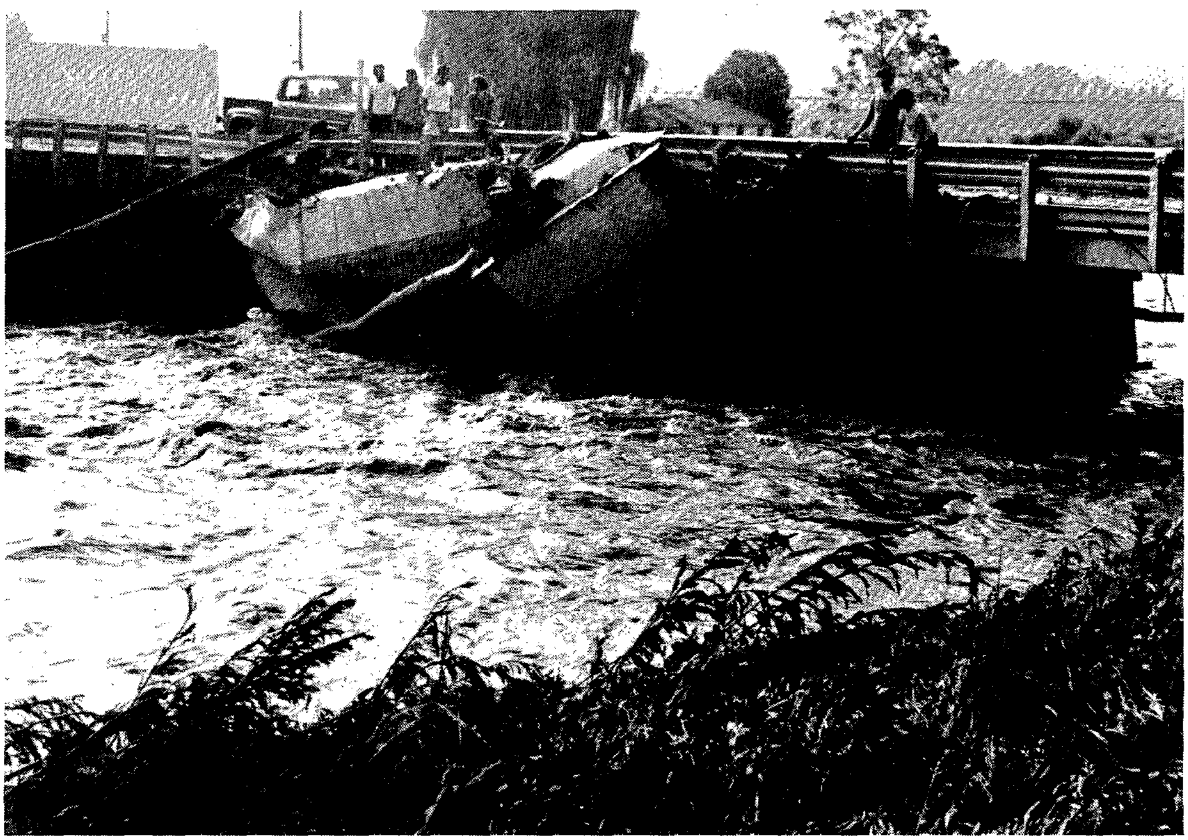
GUIDELINES
ON
COMMUNITY LOCAL FLOOD WARNING
AND RESPONSE SYSTEMS



HYDROLOGY SUBCOMMITTEE

OF THE

FEDERAL INTERAGENCY ADVISORY COMMITTEE

ON WATER DATA

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Additional copies may be obtained via the United States Geological Survey, Office of Water Data Coordination, Reston, Virginia or through the National Technical Information Service, Springfield, Virginia 22161.

Foreward

Floods are the number one natural disaster in the nation. Every state is affected. Thousands of communities are affected by flooding, which disrupts businesses and causes evacuation of more than 300,000 people annually. During the past decade, an average of 200 people died in floods each year in the United States, and annual flood damages now average nearly $5 billion. About 10 percent of the population is affected by flooding. These guidelines are offered to promote better understanding of the types and applications of flood warning systems.

We are indebted to the members of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data whose efforts directed the work of the task group. Special recognition is due the members of the task group who were responsible for preparation of the guidelines:

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Special thanks is also due our secretary, Kathleen O'Leary, for her patience and excellent typing support.

Allen F. Flanders

Chairman, Hydrology Subcommittee

Preface

Local flood warning systems have become an increasingly important means to mitigate losses from floods. In October 1982 the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data decided that there was an urgent need for a document describing the basic principles of local flood warning systems. An interagency work group was established in November 1982 to prepare a report that would describe (1) under what conditions a local flood warning system would be effective; (2) the various types of systems that can be used to identify flood problems and issue warnings; (3) the basic elements of a community response system; and (4) sources of assistance from Federal, State, and local agencies in evaluating and establishing a local flood warning system. The work group was composed of representatives of the Army Corps of Engineers, the Department of Agriculture Soil Conservation Service, the Bureau of Reclamation, the United States Geological Survey, the Department of Commerce, the National Oceanic and Atmospheric Administration, the National Weather Service, the Tennessee Valley Authority, the Federal Emergency Management Agency, and the National Park Service. Invaluable assistance was provided to the work group by flood plain managers from the States of Maryland and Pennsylvania, representing the Association of State Flood Plain Managers.

It is the Hydrology Subcommittee's hope that this report will provide Federal, State, and especially county and local government officials with a basic understanding of local flood warning systems and the kind of help that is available.

Guidelines
on
Local Flood Warning and Response Systems

Table of Contents

FIGURES

TABLES

Chapter I - Introduction

Throughout history, people have settled near rivers, lakes, bays and oceans because of the many economic advantages of living in such areas. Fertile flood plains, developed through erosion and sedimentation, have been used extensively by man for growing food both for himself and his livestock. With the intensification of agriculture, nearby water sources were available for irrigation. As economic activity diversified, water sources became useful for processing raw materials into other products; transporting raw materials, crops and manufactured goods; and the development of water supply and waste disposal projects for growing communities. In more recent times, recreational interests have lead to intense land development along the shorelines of rivers and lakes and in the ocean front and bay front areas of coastal zones.

A price was to be paid for the economic and recreational benefits of occupying land adjacent to water sources. Heavy losses of both property and life have resulted from the recurrent flooding of occupied flood-prone areas. Loss of life due to floods varies greatly from year to year (as shown on Figure 1). The annual average was 102 fatalities in the period 1940-1982; since 1970, the average has increased to 200. The average annual property damage in 1940-1982 was $1.5 billion.

In 1983, there were more than 200 flood-related deaths, primarily from flash floods. Flood damages (in 1983 dollars), as shown on Figure 2, continue an upward trend; in 1983 they were almost $5 billion. Floods are the number one natural disaster in the United States in terms of loss of life and property.

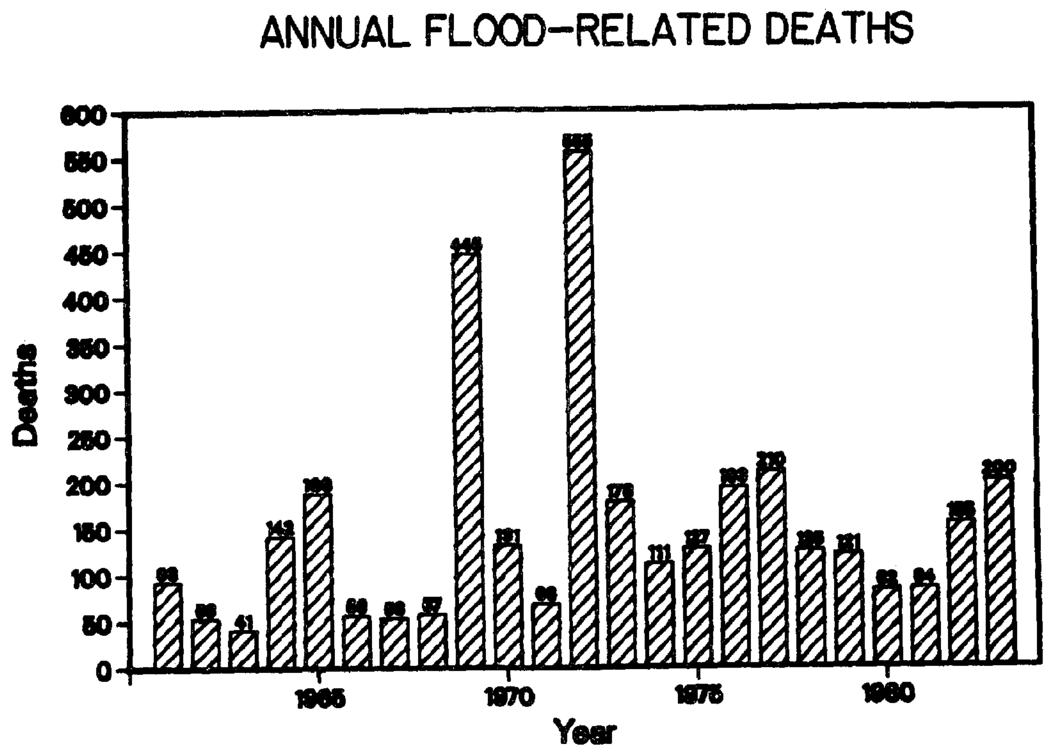


FIGURE 1 ANNUAL FLOOD DEATHS

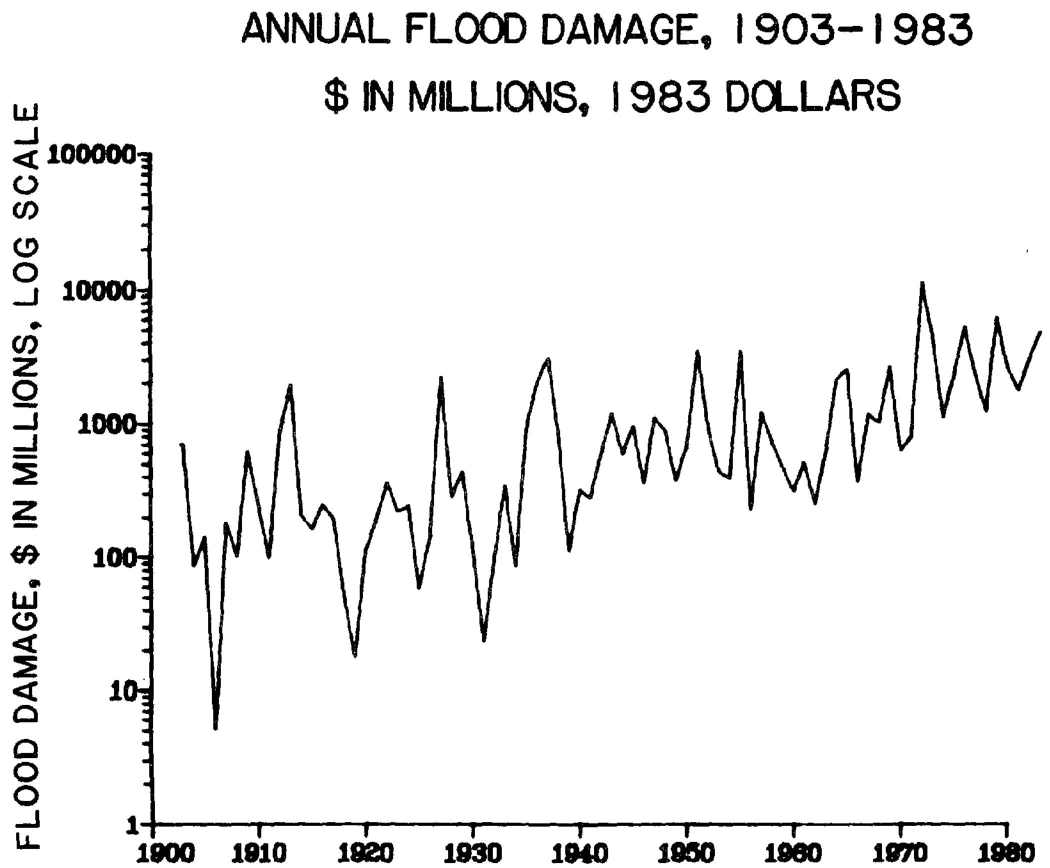


FIGURE 2 ANNUAL FLOOD DAMAGES

Two categories of floods account for most flood losses: those affecting land areas adjacent to streams or rivers (riverine flooding), and those affecting the shorelines of lakes, bays, and oceans. The main concern of this report is riverine flooding and, in particular, locations in which flash floods are likely to occur. In riverine situations, flooding results from rainfall and/or snowmelt runoff that exceeds the capacity of the main channel of the river or stream (bank full capacity). Flooding can also result from such causative events as the breach of a dam or levee, or an ice jam. The source of the threat can vary from a small creek or drainage to a large river such as the Mississippi or the Ohio. A community can be vulnerable to many sources of riverine flooding.

Both structural and nonstructural methods have been used to try to limit flood damages. The structural methods include channel enlargement and the construction of levees, reservoirs, and bypasses. While such structural measures can greatly reduce the threat of flooding and consequent losses, they may create a false sense of security and encourage development in partially protected areas. Thus, when a rare flood occurs, even greater flood losses may be sustained. This may contribute to the rising trend in flood damages shown in Figure 2. Nonstructural strategies for reducing flood losses include the regulation of flood plain use, floodproofing of buildings, temporary or permanent evacuation of threatened areas, and the development of flood forecasting and flood warning systems. The goal of a local flood warning and response system is to reduce losses by increasing the length of warning time in which a community can react to a potentially damaging event and, given the extra warning time, improve its response. The time between the causative rainfall and actual flooding will vary depending upon a variety of factors but usually increases with the size of the upstream watershed.

About 20,000 communities in the United States are vulnerable to all categories of floods (see Figure 3 and Table 1). River and flood forecast service is provided to 3,100 of these. At the majority of locations with forecast service, the rivers crest in 12 hours or more. Approximately 1,000 other communities either have or are establishing local flood warning systems or are receiving additional warning services from the National Weather Service (NWS). This leaves thousands of communities without site-specific flood warning services.

All counties receive generalized flash flood watches and warnings. A flash flood is defined as one that occurs in a short time interval (minutes to hours) following the causative event. A flash flood watch is issued by the NWS if conditions indicate that flash floods are likely to occur in a designated area. If flash flooding is imminent or reported, a flash flood warning is issued on a county basis. Flash flood watches and warnings are only a limited alerting and do not provide the specific forecast information communities often need.

What can a community do to reduce the threat of floods, thus saving lives and reducing property damage? One cost-effective strategy is to establish a local flood warning and response system.

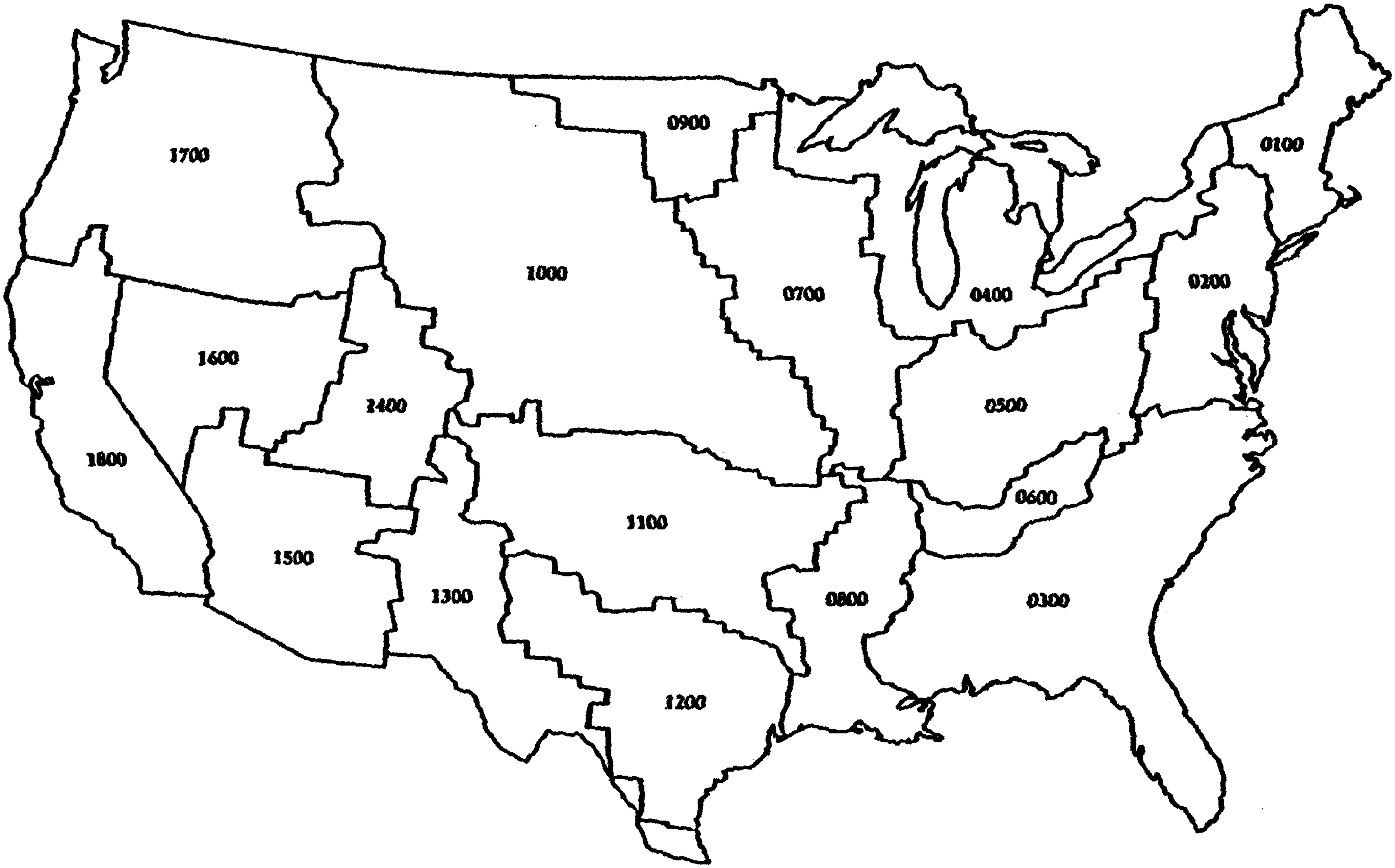


FIGURE 3 – Water Resources Council Regions of the Continental United States

Source: Water Resources Council, Washington, D.C.

Table 1 -- Communities With a Flood Problem

Geographic Area	Water Resources Council Region (see Figure 3)	Communities With a Flood Problem	
		All Places	Places With Population 2,500 or More
		Number	
New England	0100	1,158	498
Middle Atlantic	0200	3,194	870
South Atlantic Gulf	0300	2,156	721
Great Lakes	0400	1,294	747
Ohio	0500	2,593	658
Tennessee	0600	441	117
Upper Mississippi	0700	1,823	536
Lower Mississippi	0800	809	192
Souris-Red-Rainy	0900	188	19
Missouri	1000	1,221	228
Arkansas-White-Red	1100	734	237
Texas-Gulf	1200	1,099	309
Rio Grande	1300	412	60
Upper Colorado	1400	144	19
Lower Colorado	1500	311	52
Great Basin	1600	213	52
Columbia-North Pacific	1700	1,270	212
California	1800	1,027	487
Alaska	1900	325	20
Hawaii	2000	271	34
Caribbean	2100	130	70
United States		20,813	6,148

Source: Water Resources Council, Washington, D.C., 1977.

It is important to note that a local flood warning and response system should be only one part of a comprehensive effort to mitigate the hazards of flooding. A warning and response system is effective primarily in reducing loss of life and providing limited protection to existing flood-prone property, but it does not necessarily promote significant long-term mitigation. The most cost-effective and significant mitigation opportunities occur either before development or before reconstruction after a flood and require a strong local flood plain management program.

This report focuses on the reduction of flood losses through the use of local flood warning and response systems. The topics covered are the need for local flood warning systems; the types of systems; the need for community response; the institutional action required to implement and sustain the systems; and sources of information, assistance, and coordination.

Chapter II lists the factors community officials should consider when evaluating the feasibility of establishing a local flood warning system. These factors are: the hydrologic characteristics of the watershed; the frequency of flooding; the flood loss potential; the warning time in relationship to the benefits; community interest and awareness; and the need for other hydrologic-related capabilities. The need for a response system is also discussed, with information on community interest and awareness, emergency action plans, and selection and maintenance of a response system. Chapter III presents detailed technical information on the methods and equipment available to forecast a flood and issue a warning. To be effective, a local flood warning system must be coupled with a community response system; this is the subject of Chapter IV.

Chapter V deals with total integration of the local flood warning and response systems and presents an example of an existing integrated system. The kinds of assistance that Federal and State agencies can provide are discussed in Chapter VI; these include information on the flood hydrology of specific areas, planning for local flood warning systems, and technical and financial assistance. Additional chapters deal with other activities related to the development of a local flood warning and response system.

Chapter II - Should Your Community Have a Local Flood Warning and Response System?

A. Introduction

Flooding is a natural hazard that can occur at any time. The frequency and magnitude of flooding can vary from minor flooding causing only inconvenience, to major flooding resulting in loss of life and extensive damage to agriculture, industry, transportation, and commercial and residential segments of society. If the threat from flooding is persistent or the potential losses significant, community officials should take steps to reduce flood losses. A local flood warning and response system is one possible step that can be taken to mitigate flood losses.

A local flood warning system is defined as a community or locally based system consisting of volunteers; rainfall, river and other hydrologic gages; hydrologic models or procedures; a communications network; and a community or local flood coordinator responsible for issuing a flood warning. The purpose of a local flood warning system, whether the most sophisticated automated system or a simple manual system, is to provide responsible officials with advance information that can be translated into response actions.

According to recent studies (Carter, 1980) of human behavior during flood disasters, the public does not respond directly to warnings. An appropriate "response" refers to protective actions (i.e., evacuation, seeking shelter, protecting property, etc.). The public typically responds to a warning message by attempting to confirm the existence of a personal threat or risk: tuning in broadcast media, comparing different stations to see if similar warnings are being issued, looking for environmental clues such as heavy rainfall or flooded roads, or seeking additional information from neighbors, friends, relatives, or local authorities. Warning messages are most effective when they confirm other sources of alerts or warnings. A warning should advise people about the actions they should take and what they can expect officials and emergency responders to do. It should also encourage people to pass the word to others, especially those least likely to hear the warning and those who might need help. Obviously, a local warning system that provides timely and accurate flood forecasts is of little value unless individuals take protective actions to reduce losses. The response system defines these critical actions.

B. Evaluation of the Need for a Warning System

While a local flood warning system can provide early recognition that flooding will occur, it may not be effective in reducing flood losses in all communities. Whether or not a local flood warning system is appropriate depends on: (1) the hydrologic characteristics of the watershed; (2) the frequency of flooding; (3) the flood loss potential; (4) the warning time in relation to the benefits; and (5) the need for other hydrologic capabilities. These factors should be evaluated when deciding whether a local flood warning system is a practical means for reducing flood losses in a given community.

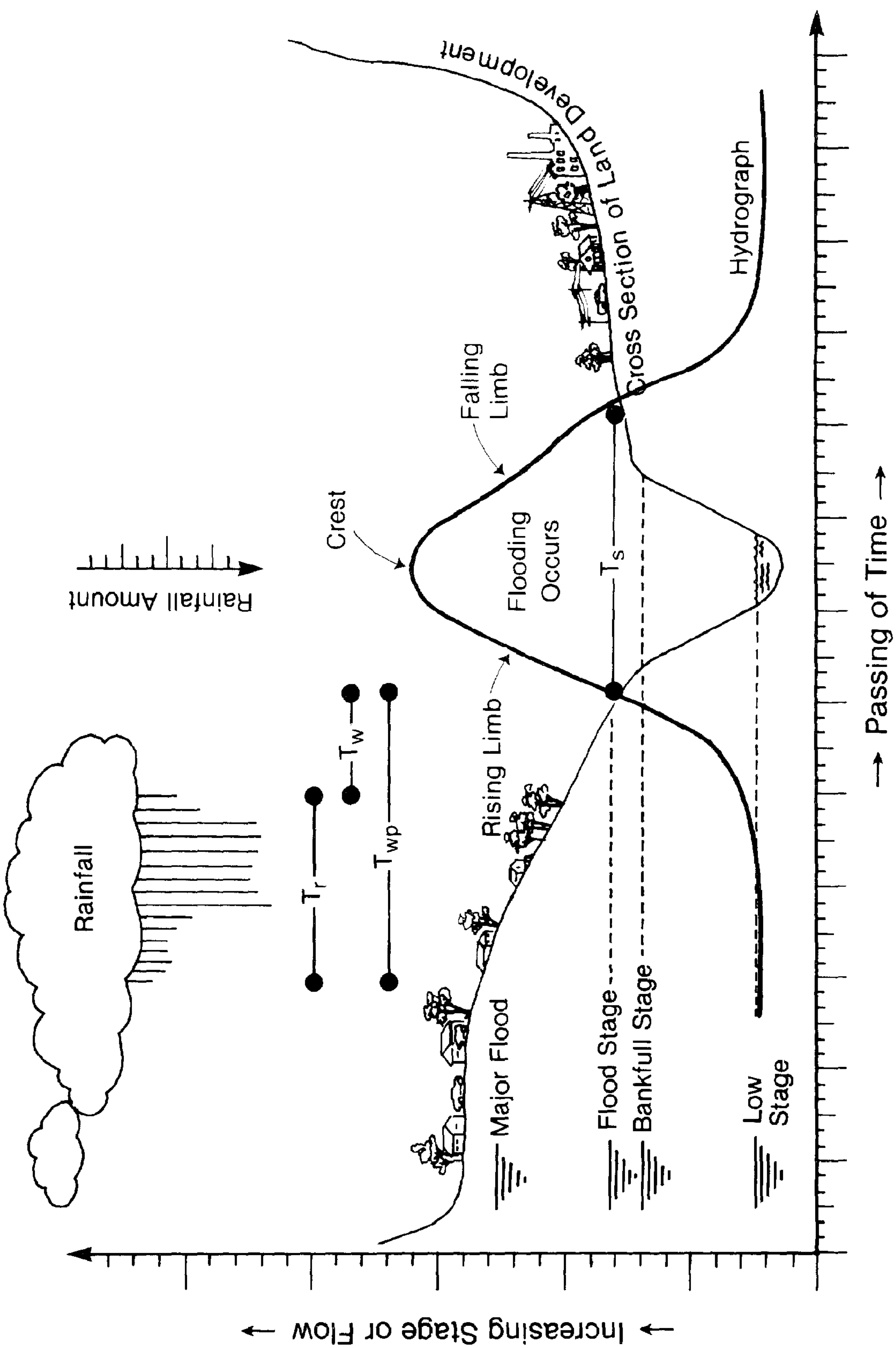
B.1. Hydrologic Characteristics of the Watershed

The first step in evaluating the potential benefits of establishing a local flood warning system is to identify the various sources of flood threat. Sources can vary from large, sluggish rivers that take days or weeks to crest to small creeks that crest in minutes. Each watershed has a unique set of hydrologic characteristics that describe the watershed's response to rainfall. This response is typically represented by a hydrograph, which is a graph of streamflow and/or stage in relation to time at a given location. Figure 4 illustrates a hydrograph.

As rainfall or snowmelt occurs over the watershed, runoff begins and the stream rises. The streamflow continues to increase as the rainfall continues (see rising limb of the hydrograph).

Even after the rainfall or snowmelt ends, the stream will continue to rise in response to runoff. Eventually the runoff will reach a peak and the stream will crest. The stream will then begin falling and eventually recede to a level below flood stage. The potential warning time (Twp) is the maximum lead time available for warning communities of flooding. An effective local flood warning system should identify the specific areas that will flood, the time at which flooding is first expected, when the flood is expected to crest, and the flood crest elevation.

Areas subject to damage and evacuation must be identified in the warning statement. Specific identification will lessen the possibility that the National Weather Service (NWS) flood warning messages -- which give projected flood levels -- may be misunderstood. Both local officials and the general public need to understand how the projected flood levels relate to their particular areas of concern. It is vitally important that the NWS forecast



The relation between a flood hydrograph and land development along a stream is shown. The hydrograph with rainfall amounts is shown in the darker tones with adjacent scales. A distorted cross section of land development is in lighter tones. The vertical scale is the same as the stage for the hydrograph. No horizontal scale is proved for cross section.

Figure 4. Typical Hydrograph

tie in closely with the local flood response plan.

The potential warning time -- the time between the first measurement of rainfall and the first occurrence of flooding -- may vary from minutes to weeks, depending on the watershed. The actual warning time is less than the potential warning time because of the time required to recognize that a flood threat exists and to issue a warning. The potential warning time (Twp) is equal to the sum of the time required for rainfall to accumulate in rain gages before the system will recognize that a flood will occur (Tr) and the actual warning time (Tw). The primary objective of a local flood warning system is to increase the actual warning time until it is as close as possible to the potential warning time.

Other hydrologic characteristics that help define the nature of the flood threat are the rate-of-rise and the length of time the flood waters remain above flood stage (Ts).

B.2. Frequency of Flooding

An important factor in evaluating the potential benefits of a local warning system is the likelihood or frequency of a damaging flood. The key questions are: What are the potential damages, including loss of life, at various flood levels? What is the likelihood that such a flood will occur? The benefits of a flood warning system increase as the likelihood of damaging floods increases. Also, the likelihood that a system's effectiveness will be maintained increases with the frequency of its use. The rarer a flood event with damaging potential, the more difficult it is to maintain community awareness and an operationally ready warning system.

The probability per year of flooding at a particular location varies with flood magnitude. The larger the flood the less likely its occurrence. Since flooding depends upon storm events that occur randomly in nature, there is no way to predict when a flood will occur. It is possible by studying past records to estimate the chances or likelihood that a flood of a given magnitude will occur in a particular year or over a longer period of time.

The likelihood of experiencing a flood of a specified magnitude is expressed by the percent chance of exceeding that magnitude in any one-year period. Thus, a 1-percent-chance flood is a flood of a such magnitude that the probability is one in 100 it will be exceeded in a given year. The recurrence interval is often used to describe flood magnitude. Using the recurrence-interval terminology, the 1-percent-chance flood is called a 100-year flood. This terminology is misleading in that it suggests that one such event can be expected in any given 100-year period. Actually, a 100-year flood can occur at any time, and none or several can occur in a given 100-year period.

The risk of experiencing a flood of a given magnitude increases with the length of the time period. For example, there is a 26-percent chance (the odds are about one in four) that the 1-percent-chance flood will occur during the 30-year period of a normal mortgage. This increases to a 39-percent chance (the odds are about two in five) in a 50-year period. Table 2 shows the relationship between recurrence interval in years, probability per year in percent, and probability per 50-year period in percent.

Table 2 -- Relationship Between Recurrence Interval, Frequency, and Risk (in percent)

Recurrence Interval In Years	Probability Per Year In Percent	Probability in percent that a given flood will occur "N or more times" during a 50-year period				
		N=1	N=2	N=3	N=4	N=5
500	0.2	10	Nil	Nil	Nil	Nil
200	0.5	22	3	Nil	Nil	Nil
100	1.0	39	9	1	Nil	Nil
50	2.0	64	26	8	2	Nil
25	4.0	87	60	32	14	5
10	10.0	99	97	89	75	57
5	20.0	100	100	100	99	98

Note: Nil = less than 1% chance

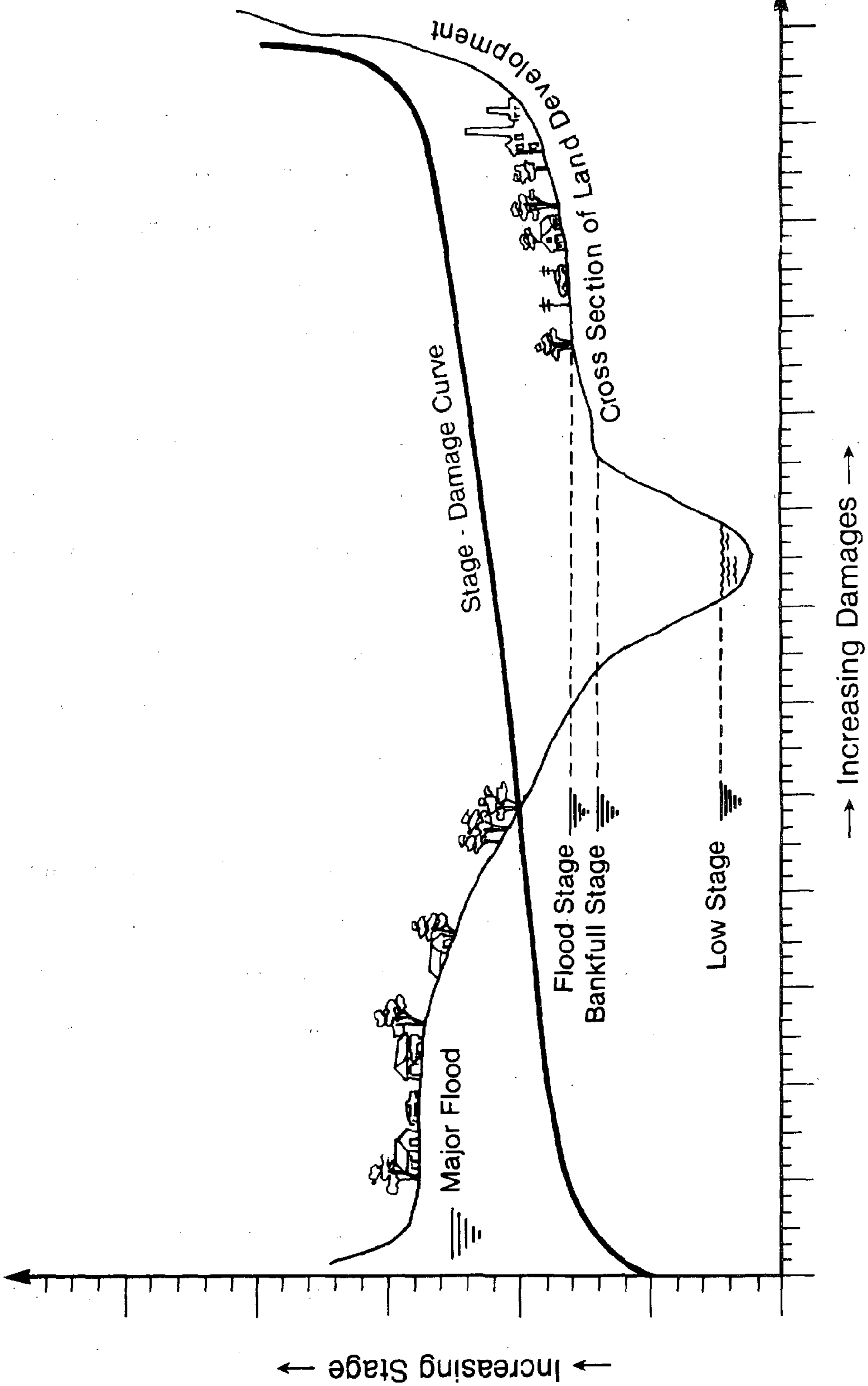
Historical records of floods are an important source of information, but they can be misleading. In most cases, the period of record is relatively short (less than 100 years) and may or may not include a severe flood. This limited period may not accurately reflect the flooding potential for a community. Floods that have occurred within the limited period of record provide a means of communicating the relationship of flood magnitude and probability to the community.

B.3. Flood Loss Potential

Evaluating flood loss potential is an important step in determining the need for a local flood warning system. Flood loss potential, as used here, is the potential for loss of life and property damage from the occurrence of various magnitudes of floods. Evaluating flood loss potential consists of assessing the resident population and damageable property located on the flood plain that would be directly affected by flooding. Many communities have established stage-damage charts that show the relationship between river stage and flood damages (see Figure 5). These charts must be kept up to date to reflect changes in urban development. The relationship of river stage to inundation area is important in determining flood loss potential. Community flood studies, such as those developed for flood insurance, provide profiles and maps that reveal the magnitude of flooding expected and permit the identification of critical public services that are vulnerable to flooding.

A number of questions must be answered when evaluating flood loss potential. Is there a potential for loss of life associated with floods? What structures are located within the flood plain? What are the annual flood damages? What is the potential flood damage for a particularly severe flood such as the 1-percent-chance flood? Where are the evacuation routes in relation to the area of inundation?

In many instances, data are not available to answer all of these questions, but the more questions that can be answered, the more certainty there will be determining both the need for a local warning system and the cost effectiveness of a particular warning system. Cost effectiveness is calculated by



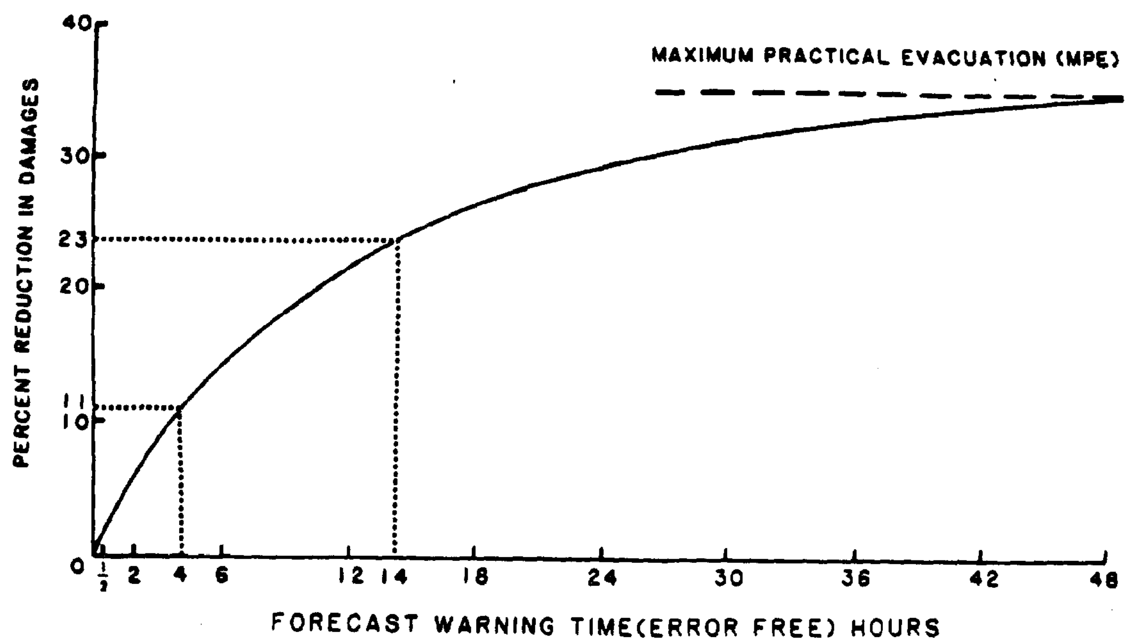
These graphs show the relation of flood damages and land develop along a stream. The darker tone is stage damage with vertical and horizontal scales provided. The lighter tone is a compressed cross section of land development with the same vertical scale.

Figure 5. Stage Damage Relation

comparing the benefits (reduction of damages and loss of life) to the costs associated with purchasing and maintaining a system. Such analysis is also helpful in selecting the type of local flood warning system appropriate for a given community. Appendix A contains a detailed description of the benefit-to-cost analysis that can be conducted by a community. It is important for community officials to review all possible sources of funding before making decisions on a local system.

B.4. Warning Time as Related to Benefits

Warning time is a critical factor in mitigating flood losses. The more lead time available for appropriate action, the greater the reduction in flood damages that can be achieved. Figure 6 depicts the relationship between warning time and the percent reduction of damages, often expressed as warning time vs. benefits.



DAMAGE REDUCTION VS WARNING TIME

FIGURE 6

The curve represents a hypothetical suburban community with an active emergency flood response system; it is presented here to illustrate the potential benefits of an improved warning system. The hypothetical analysis shows that even a few hours lead time can result in some reduction in flood losses. In order to compute the economic benefits of implementing a local flood warning system, a unique curve must be derived for each community. (In many cases, data may not be available to conduct such an analysis.) To use the curve, the present lead time must be computed. If the present lead time is four hours and the installation of an automated flood warning system would increase the lead time to 14 hours, the percent reduction in flood damages would increase from 11 percent to 23 percent. The net reduction in flood damages would be 12 percent by increasing lead time by 10 hours.

This reduction in annual flood damages can be significant to the economic health of a community. In Ventura County, California, for example, flood control district officials and Fillmore City officials credit an automated flood warning system and response system purchased for 50,000 with preventing $5 million in flood damages from the February 1980 flood (Bartfield & Taylor, 1982).

B.5. Expansion of Hydrologic Capabilities

Some communities use automated local flood warning systems for other purposes, such as managing reservoirs and allocating water for municipal and irrigation use. In the future, these systems may be capable of providing information for agriculture and forecasts for water management and water quality.

C. Selection of a Local Flood Warning System (LFWS)

Selection of the type of local flood warning system most appropriate for a particular community should be based on an evaluation of the hydrologic characteristics of the watershed, the frequency of damaging floods, the warning time vs. benefits, the need for other hydrologic capabilities, and the cost of the system. Automated flood warning systems cost more but can provide greater benefits, including the ability to meet other hydrologic forecast needs. Manual systems are inexpensive but limited in their capabilities.

In the selection process, the accuracy, warning lead time, and reliability requirements should be determined. Accuracy and reliability affect the credibility of warnings and the extent of actions that can be taken in response to them. The costs of flood response actions must be balanced against the accuracy of the warnings and confidence in the local flood warning performance.

Accuracy varies according to the type of warning system selected, the quantity and quality of the data input to the warning system, the hydrologic procedure or hydrologic model used and the hydrologic characteristics of the watershed.

The reliability of the local flood warning system is another important factor. Electrical and telephone service is disrupted during moderate or severe floods. Power disruption or the failure of gages or other elements may limit the usefulness of a system, So care must be exercised in selecting the components. The planning must also include consideration of a backup operation.

To maximize benefits from a local flood warning system, warnings must be given as far in advance of actual flooding as possible. This inevitably leads to some percentage of false warnings, a percentage that will increase as an individual property's frequency of exposure to flooding increases. Since false warnings are inevitable, the costs they will generate should be considered as a warning system cost when evaluating benefits and costs.

D. Need for a Response System

A flood warning system by itself is useless. If it is to be effective, the community must have procedures to ensure that people leave the flooding areas and that actions are taken to reduce property damages. These procedures, which consist of a planned set of responses to the threat, are known as a community response system. This system is the mechanism community emergency response officials can use to respond to any type of warning, whether generated from a local warning system or another source.

A community response system consists of: (1) an emergency action plan (EAP); (2) trained individuals to carry out the planned actions; (3) maintenance of the system; and (4) means to foster community interest and awareness. The roles of the various community infrastructure services must be clearly defined, and key personnel such as the police chief, fire chief, the director of emergency services, and staff must be trained and knowledgeable about how to react to various flood events. The following questions must be answered: Who will monitor flood events? Who will make decisions on the flood-fighting actions to be taken? What support resources are available? Who will supervise volunteer labor if it is needed for such labor-intensive tasks as sandbagging? Who will provide overall coordination? Defining the organizational structure and the key individuals and their respective roles is extremely important in establishing an effective response system. Chapter IV outlines the steps necessary to implement a community response system.

D.1. Emergency Action Plans

Each community should have an emergency action plan (EAP) that directs the community to act in rapid response to a flood warning. The EAP includes instructions for emergency services personnel to reduce flood losses.

D.2. Training of Personnel

A continual training program is essential so that the technical staff is aware of what to do in specific circumstances. Competent professional support is necessary to ensure that established procedures and training are current so that, in an emergency, people will react efficiently and effectively.

D.3. Maintenance of the Response System

Maintenance of the response system is critical to operational readiness. Maintenance includes the training of individuals, updating the EAP, conducting practice drills, maintaining inventories of equipment and trained personnel available for flood emergencies, and periodic testing of equipment, including computer hardware and software.

D.4. Community Interest and Awareness

A vital factor in assessing the usefulness of a local flood warning system is the interest and awareness of the local population. If a local system is to function properly, community interest must be active and sustained. All types of local flood warning systems require a network of knowledgeable and trained individuals dedicated to the well-being of the community. Operation of these systems requires extensive coordination and preparation of key personnel at the community, county, State, Federal, and private-sector levels. Failure to maintain a high level of community awareness and interest in flood problems not only limits the effectiveness of a local flood warning system but usually leads to its failure.

An information program should be started and maintained to acquaint flood plain residents with actions to take when a warning is given. The information should be site-specific for each resident. Some flood plain residents would have to evacuate immediately, while others may have time to take steps to protect their personal property. All residents must be continually reminded of evacuation routes and centers where they can seek aid.

E. Selection of a Response System

The type of response system and the level of involvement will vary greatly from community to community, depending on local conditions. A community response system designed for other hazards may require major adjustment to accomodate flood warnings. These adjustments may consist of redefining the organizational structure, redefining the roles of response officials, adding personnel, and increasing the awareness and interest of the entire community. There are many examples of successful response systems. Interested community individuals may obtain information about model response systems from various Federal agencies such as Federal Emergency Management Agency, Soil Conservation Service, Tennessee Valley Authority, the Army Corps of Engineers, and the National Weather Service. In communities with an integrated emergency management system, a flood warning and response system may be one element of that system.

Chapter III - Local Flood Warning System

A. Introduction

a local flood warning system consists of four steps leading up to the determination that an imminent flood threat exists, and the dissemination of this information to local officials. The local flood warning system can be classified into the following four steps:

1. Collect Data
2. Transmit Data
3. Forecast the Flood
4. Inform Local Officials

Each step is critical in the process of recognizing that a flood threat exists and in determining the magnitude of flooding. This chapter discusses these steps in relation to the basic types of local flood warning systems now in use.

B. Types of Local Flood Warning Systems

There are two basic classifications of local flood warning systems available for community use: manual systems, which are relatively simple and inexpensive, and automated systems, which use state-of-the-art automated data collection and warning transmission systems and computers to provide flood forecasts. There are many variations within these two basic types.

The basic concept of a local flood warning system is simple. River and rainfall data are collected upstream from a community. Data are then transmitted to a central collection point. This information is used to predict the magnitude of expected flooding, where flooding will occur, when flooding will begin, when the crest will arrive, and when the stream will recede below flood stage. This provides potential threat information and the warning time that is critical for Federal, State, county, and local organizations to take action to preserve life and property.

Within both manual and automated systems there are many approaches, techniques, and variations that can be applied to meet a particular community's needs. The generic classifications of manual and automated are presented here for ease of description. Many installations contain a mix of automated and manual components. Since each watershed is unique and community needs vary, a simple classification of automated or manual systems is not strictly possible.

Manual local flood forecast systems consist of: (1) a data collection system; (2) a community flash flood coordinator; (3) a simple-to-use flood forecast procedure; and (4) a communication network to distribute warnings to appropriate emergency response officials, including the mass media and the National Weather Service (NWS). The forecast system should be linked to a community response system. Figure 7 illustrates the concept of a manual self-help local flood forecasting system. Although these systems are simple to operate, their continuous operation over long periods of time may be difficult, especially in areas where flooding is infrequent. They can be surprisingly accurate when adequate data are available.

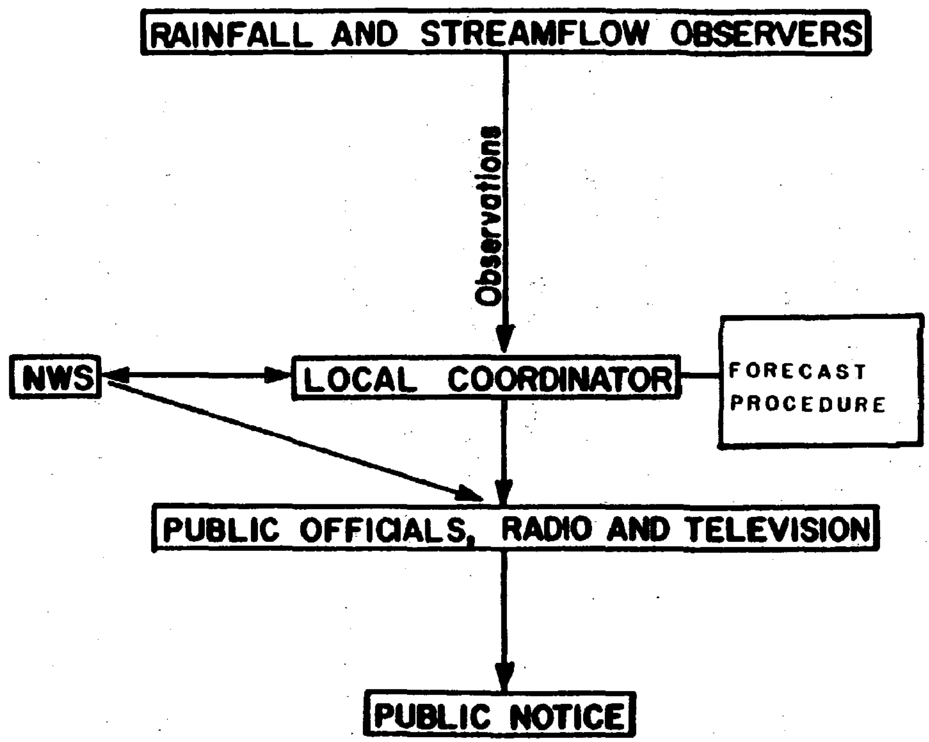


FIGURE 7

SCHEMATIC ILLUSTRATION OF TYPICAL FLOOD WARNING SYSTEM

Automated local flood warning systems consist of the following components: (1) automated precipitation and river gages; (2) a communications system; (3) automated data collection and processing equipment; (4) data collection and system forecasting software; and (5) a warning distribution system.

Automated stream forecasting has developed in the past decade as a result of rapid growth in the application of hydrologic models to computer technology, coupled with decreases in the cost of computers. The evolutionary development of automated systems continues to improve the accuracy, timeliness, and reliability of flood warning capability. Automated flood warning systems are gaining in popularity around the nation; about 150 communities in 20 states are now operating or planning to install automated systems.

Automated local flood warning systems vary in design, capability, and operation. An assessment of needs must be conducted by the community to determine the level of sophistication required. System operation may vary from a simple flash flood alarm that audibly announces imminent flooding, to the continuous computerized analysis of precipitation and streamflow and a hydrologic model to forecast flood levels. Since community needs and resources vary greatly, the factors discussed in Chapter 2 must be fully evaluated before the type of automated system required can be determined.

C. Step 1 - Collect Data

For most local flood warning systems, hydrologic data consists of river and rainfall data collected at manual or automated gages. Rainfall or precipitation gages measure the amount and rate of precipitation falling at a given location. Precipitation may be rain, snow, sleet, drizzle, freezing rain, or all of them. River gages measure the height of the water surface elevation in rivers or streams. Many types of river and rainfall gages are available, depending on the degree of accuracy and sophistication required. Although satellite and radar data are expensive, they can often be integrated into a local flood warning system by using information available at the local NWS office. In most instances, it is desirable to use some automated gages with manual systems and some manual gages with automated systems.

C.1. Manual Systems

The simplest and least expensive approach to data collection is to use volunteer observers and inexpensive equipment to collect rainfall and river level data. Inexpensive plastic rain gages can be used by volunteer observers who report rainfall amounts by telephone to a community coordinator. Rainfall reporting criteria can vary from reporting three times a day once a .5 inch rainfall has been measured, to hourly if flood conditions are severe. River stages are usually obtained by an observer who reads a simple staff gage or wire weight gage and telephones the observations to a coordinator.

C.2. Automated Systems

A tipping bucket precipitation gage is used in most automated systems. The tipping bucket, or event, gage is simple. Every time one millimeter of rainfall fills the bucket, the bucket tips and causes a signal to be transmitted to a radio transmitter unit. One tip of the bucket is frequently called an event. The radio transmitter then instantaneously transmits a unique station identifier and an accumulated precipitation value to a receiver station located nearby. The receiver station keeps track of the accumulated precipitation for each gage. (For areas in which precipitation can occur as snow, a special type of displacement gage may be required; further information on procedures for cold regions is contained in Rechard and Wei). Figure 8 shows a schematic diagram of a typical (non-snow area) automated or event-reporting precipitation gage.

An automated stream gage is a simple event-reporting unit that transmits preselected incremental changes in stream elevation. Every time the stream rises or falls to a predefined elevation (for example 0.5 ft.), a signal is sent to a radio transmitter, which instantly sends a signal to a receiver station identifying the station and describing the change in elevation. As in the automated precipitation gage unit, the receiver station keeps track of the stream height for each gage. Rante (1982) provides further information on standard stream gaging techniques.

In remote locations for which a stream gage is not available, a bubbler gage can be used. Bubbler gages, which measure water pressure, can be located a considerable distance from the stream and still provide accurate information on stream elevation.

Automated precipitation and stream gages are reliable in operation. Since they can be operated by battery without AC power, they can transmit critical data in the harshest environmental conditions.

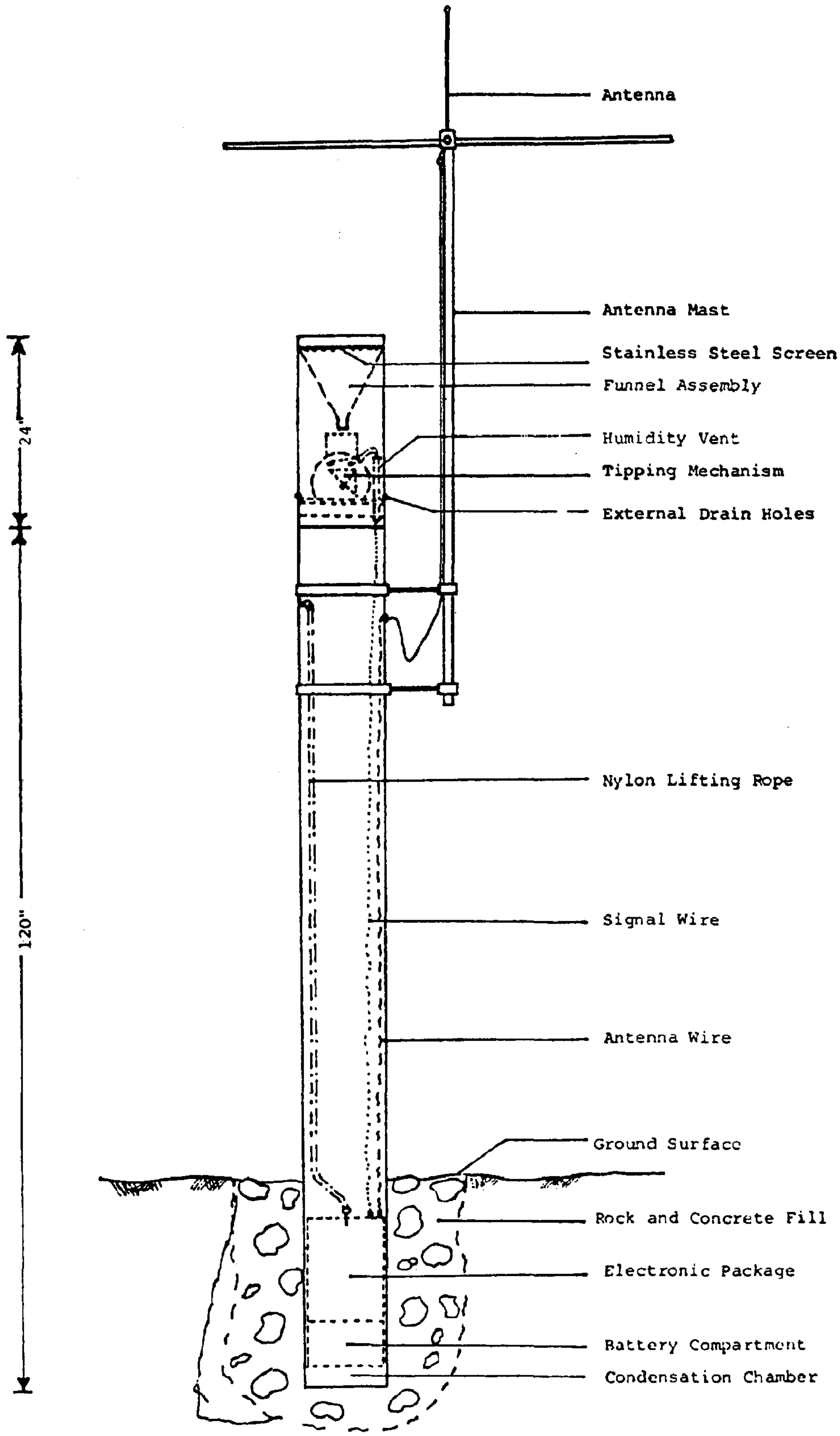


FIGURE 8 – A DIAGRAM OF AUTOMATED PRECIPITATION GAGE

D. Step 2 – Transmit Data

Various types of communications systems are used to transmit data. In manual local flood warning systems, information is generally transmitted by telephone land lines, CB radio, or ham operators. Automated systems use UHF, VHF, or microwave radio transmission, meteor burst telemetry, or satellites.

Data from automated precipitation and streamflow gages are transmitted via line-of-sight radio transmission. The brief transmission time required by self-reporting gages (less than 250 milliseconds) allows for large data bases to be acquired in substantial detail while eliminating radio interference from other gages in the network. Where direct radio transmission to a base station is not feasible, radio relays are used.

E. Step 3 – Forecast the Flood

E.1. Manual Data Collection

A flood forecast procedure provides a means to translate rainfall that occurs over the watershed to a stream elevation at a stream gage. Manual procedures normally use tables, graphs, or charts that use average rainfall and a flood index (input) to provide a flood prediction (output). Flood predictions vary from a categorical forecast (i.e., minor, moderate, or severe flooding) to a crest value. Figure 9 shows a typical flood forecasting procedure used in the operation of a local flood warning system.

In a typical forecast procedure, the NWS gives the flash flood coordinator a weekly flood index. This flood index is a measure of soil moisture. In Figure 9, the flood index is the amount of rainfall in six hours required to produce flood stage. The local coordinator uses the flood index to set the

Yellow Creek at U.S. 25E Bridge

Flood Advisory Table

Forecast is for the USGS gage near 25E bridge over Yellow Creek below Middlesboro
Flood of Record was 23.4 ft. on April 4, 1977
Warning Stage is 16 ft. drainage area 61 sq. mi. Gage Datum 1097.99 ft. MSL

Flood Stage is 12.0 feet

Crest occurs about 6 hours after heavy rain ends.

	Stage Ft.	Disch. 1000 CFS	Average Basin Rainfall (inches) For Time Duration of Guidance used												
	4.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	1.0	1.2	1.4	1.7	2.0	2.3
	5.0	0.3	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.4	1.6	1.9	2.4	2.9	3.3
	6.0	0.6	0.2	0.3	0.4	0.5	0.8	1.1	1.4	1.8	2.1	2.5	3.0	3.6	4.1
	7.0	0.9	0.4	0.5	0.6	0.7	1.1	1.3	1.7	2.2	2.6	3.1	3.6	4.1	4.6
	8.0	1.2	0.5	0.6	0.8	1.0	1.4	1.6	2.1	2.5	3.0	3.5	4.0	4.5	5.1
	9.0	1.6	0.7	0.9	1.0	1.2	1.7	2.0	2.5	3.0	3.5	3.9	4.4	4.9	5.5
	10.0	2.1	0.9	1.2	1.3	1.5	2.0	2.5	2.9	3.4	3.9	4.4	4.9	5.3	5.9
	11.0	2.6	1.1	1.3	1.5	1.7	2.2	2.7	3.2	3.7	4.2	4.7	5.2	5.7	6.2
Flood Index	12.0	3.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
	13.0	3.8	1.7	1.9	2.1	2.3	2.8	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.8
	14.0	4.5	1.9	2.2	2.4	2.6	3.1	3.7	4.2	4.7	5.2	5.7	6.2	6.7	7.2
	15.0	5.2	2.3	2.5	2.7	2.9	3.5	4.0	4.5	5.1	5.6	6.1	6.6	7.0	7.5
	16.0	6.0	2.6	2.8	3.1	3.3	3.9	4.4	4.9	5.5	5.9	6.4	6.9	7.4	7.7
	17.0	6.8	2.9	3.2	3.4	3.7	4.3	4.8	5.4	5.9	6.3	6.8	7.3	7.7	8.0
	18.0	7.7	3.3	3.6	3.8	4.1	4.7	5.2	5.8	6.3	6.8	7.2	7.7	8.1	8.4
	19.0	8.4	3.6	3.9	4.1	4.4	5.0	5.6	6.1	6.6	7.1	7.5	8.0	8.4	8.7
	20.0	9.1	3.9	4.2	4.5	4.7	5.3	5.9	6.5	7.0	7.4	7.9	8.4	8.8	9.0
	21.0	9.9	4.3	4.5	4.8	5.0	5.6	6.2	6.8	7.3	7.8	8.2	8.7	9.1	9.3
	22.0	10.6	4.6	4.9	5.1	5.4	6.0	6.6	7.1	7.6	8.1	8.5	9.0	9.4	9.6
	23.0	11.4	4.9	5.2	5.5	5.7	6.3	6.9	7.4	8.0	8.4	8.9	9.4	9.8	10.0
	24.0	12.2	5.3	5.6	5.8	6.1	6.7	7.3	7.8	8.3	8.8	9.2	9.7	10.1	10.3

6 Hr. Unitgraph Peak Ordinate = 2320 CFS   Flood Stage R.O. = 1.38 in.

FIGURE 9 – SAMPLE FORECAST PROCEDURE FOR MANUAL LOCAL FLOOD WARNING SYSTEMS

column to be used to provide a forecast. He then calculates the average rainfall over the watershed for a one-hour period by collecting the individual rainfall observations of the volunteer observers. Using the flood index and an average watershed rainfall, the coordinator can produce a forecast. For illustration purposes (Figure 9), assume that the current flood index is 3.5 inches, and that average of 6.1 inches of rain has occurred in six hours over Yellow Creek. Enter the row marked FI (flood index) to 3.5 inches. Follow down the column of rainfall values under 3.5 and find 6.1. Now proceed left along the row and find a stage of 19 ft. The forecast is that 19 ft. will occur at the gage (7 ft. above flood stage) six hours after the heavy rain ends.

E.2. Automated Data Collection and Processing Equipment

In an automated system, data are gathered at strategically located remote sites and transmitted to a centralized location for automated processing and analysis. The processing hardware is under the control of the local agency that has responsibility for the flood warning program. Similar equipment may be located at the state emergency operations center (EOC) and/or at the nearest NWS office responsible for flood forecast and warning. The components of the system are a radio receiver for receipt of event-reported radio signals and a dedicated microcomputer system. The data collection system operates continuously in a fully automatic mode, constantly receiving data and processing information for display to the user.

Because automated systems collect a great quantity of incoming data, the computer located at the base or receiver station must have a data processing system. Incoming data must be screened for errors and posted properly in a data base for later retrieval. Since automated systems vary greatly in their ability to screen incoming data and diagnose problems, sophisticated data processing software is needed to provide an accurate representation of the current hydrologic conditions of a watershed. Poor data will obviously result in poor forecasts.

E.3. Flood Forecast Software

The flood forecast software consists of various techniques and procedures that can be used to post, process, and display data, warn community officials of critical increases in rainfall and river gages, provide flood forecasts and warnings, and provide advisory forecasts based on rainfall forecasts or other predictions. Various levels of sophistication are available in computer software. A community's choice of software will depend on its needs and its computer resources. The following flood forecast software capabilities can be obtained from private vendors:

- Precipitation and river gage data collection
- Quality control of input data
- Store and forward data
- Display of input precipitation data in tabular or map form
- Display of river gage data
- Visual or audible alarm based on excessive precipitation rate or predetermined rise in river (rate of rise)
- Hydrologic models
- Advisory forecast information in which forecast rainfall can be input to determine resulting river forecast
- Linkup to the closest NWS forecast office

F. Step 4 - Inform Local Officials

Normally, a local flood warning system should specify precise, predefined conditions that will determine the seriousness of the flood threat. When these predefined conditions exist, the technical people responsible for predicting the flood threat disseminate this information to appropriate local officials. In the case of dam failure at a hydropower project or reservoir licensed by the Federal Energy Regulatory Commission, the person responsible for predicting the flood threat is often a consultant hired by the licensee. [The consultant must collect all available data or make certain assumptions about missing data, such as the time the dam failed, volume of water behind the dam, etc. This data is required as input to a mathematical dam break model, which will forecast the area of inundation caused by the dambreak.] It is important to note that the consultant is not responsible for disseminating this information to appropriate local officials; the licensee has that responsibility.

Although disseminating a flood warning to the community is the responsibility of the local warning coordinator, it is essential that dissemination activities be coordinated with the closest NWS office and other need-to-know agencies to assure that the warning messages are consistent. If the public receives conflicting flood forecasts, it is unlikely to take action on any forecast.

G. Current Usage

Approximately 1000 local flood warning systems are currently in operation

(Figure 10). Only 100 or so of these systems are now automated, but recent developments in automated systems have led to their increasing popularity. It is estimated that 500 automated systems will be in operation within this decade.

G.1. Manual Systems

The most common flood warning systems are manual or self-help systems that typically use volunteer observers and inexpensive equipment to collect data. Data transmission is normally by phone. The flood forecast uses a manual system such as the one shown in Figure 9. The following table lists the advantages and disadvantages of a manual system.

Manual System

Advantages	Disadvantages
o Simple to operate	o Costly delays in data collection/ warning dissemination for short-fused flood events with short lead times
o Inexpensive	
o Encourages high level of community involvement	o High turnover rate of community volunteers, leading to reduced effectiveness
	o Not as timely or accurate as automated systems
	o Volunteers - requires training and retraining

G.2. Automated Systems

Communities are increasingly turning to automated systems as their costs decline and their reliability increases. Systems vary as to which and how

LOCAL FLOOD WARNING SYSTEMS

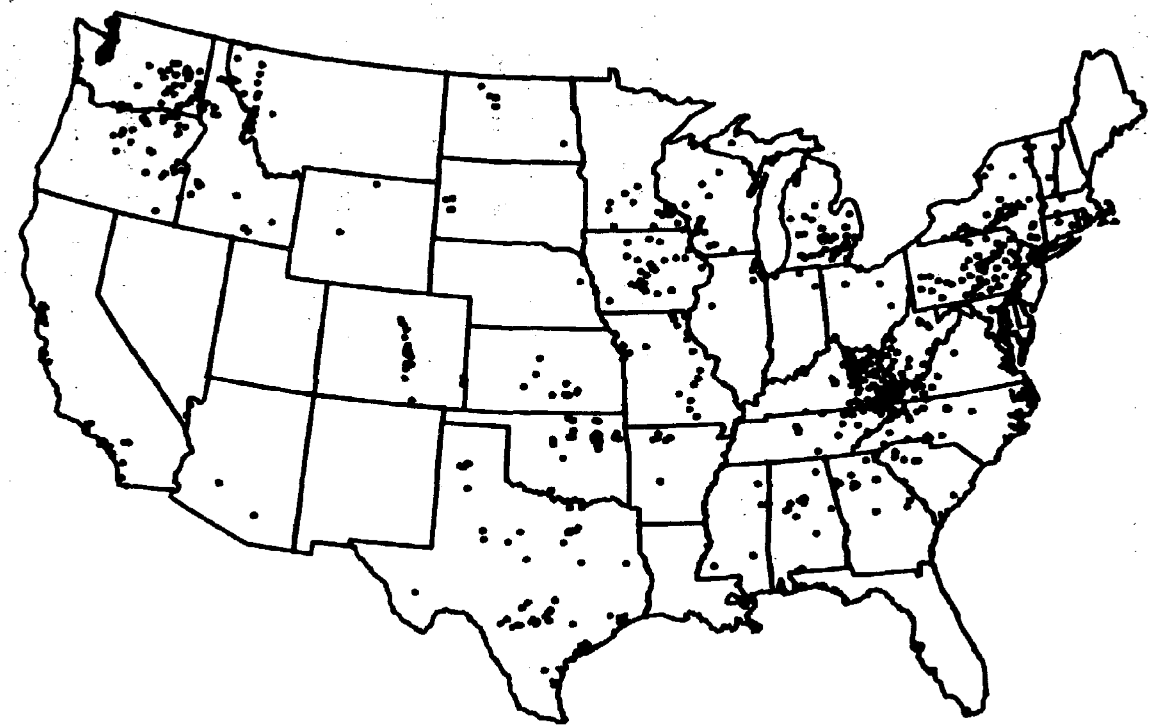


FIGURE 10

811 MANUAL AND AUTOMATED SYSTEMS

many components are automated. A fully automated system consists of automated precipitation and river gages, a radio data transmission system, and a computer to process the data and provide a flood forecast. Two examples of modern automated flood warning system (ALERT and IFLOWS) are described below. The following table lists the advantages and disadvantages of an automated system.

Automated System

Advantages	Disadvantages
o Provides timely, accurate reliable data and warnings	o High initial cost
	o Requires high level of expertise to install and in some cases to use
o Provides stable data network	o Maintenance costs of hardware and software may be substantial
o Provides comprehensive historical data base	o Software support may be limited
o Continuously updates information to provide current (real-time) data as it occurs	o May require costly periodic replacement

G.3. ALERT

The Automated Local Evaluation in Real Time (ALERT) system, a typical automated local flood warning system, was developed by the NWS California-Nevada River Forecast Center in Sacramento, California. Available from private vendors, the ALERT system is being adopted at a growing number of sites for flood warnings, reservoir management control, flood fighting and data acquisition. The system consists of automatic self-reporting river and rainfall gages, a communications system based on line-of-sight radio transmission of data, and a base station. The base station consists of radio-receiving electronic equipment and a microprocessor. Data Analysis software is available to collect quality control and display data. A hydrologic model to provide simulation of streamflow is also available as part of the ALERT system. Many of the general capabilities of automated systems discussed above are available in the ALERT system.

G.4. IFLOWS

The Integrated Flood Observing and Warning System (IFLOWS) is an example of a network of automated local flood warning systems. Each of the 100 counties in IFLOWS has or is developing an automated local flood warning system. The county systems consist of automatic radio reporting rain gages, radio relays or repeaters (if required), a radio receiver, and system software. Each county is usually capable of collecting and displaying real-time precipitation data. All of the counties are linked to a designated State Emergency Operation Center and NWS offices, so data can be retrieved by any county, State or NWS office in the IFLOWS system. Some states also have a subsystem that allows for voice communication between the States, counties, and NWS offices.

G.5. Flash Flood Alarm Gages

Flash flood alarm gages consist of water level sensor(s) connected to an alarm or light located at a community agency that operates 24 hours a day. Stages exceeding a preset level trigger the alarm. The distance between the upstream alarm gage and the community determines the amount of warning time. Sixty five flash flood alarm systems are now in operation. Specifications for the construction of a cost-effective flash flood alarm gage system are available from the NWS. Most of the required elements can be purchased "off the shelf." The NWS has installed a few flash flood alarm gage systems in connection with IFLOWS to test their performance and effectiveness. Figure 11 is a schematic illustration of a typical flash flood alarm system.

A more sophisticated gage, consisting of a radio/electronics signaling package and antenna in a self-contained enclosure, has been developed by a private firm. A water-level sensor pipe uses a pressure sensor to provide a single-level alerting. When an alarm is triggered at the remote station, an identifier signal is sent to the control station.

The following table lists the advantages and disadvantages of flash flood alarm gages.

Flash Flood Alarm Gages

Advantages	Disadvantages
o Relatively inexpensive	o Warn of flood condition only, no indication of magnitude
o Simple operation	o Lead time usually short
o Provide instant audio/visual alarm	o Usually require community expertise in electronics
o Beeper-activated warning reaches key people	

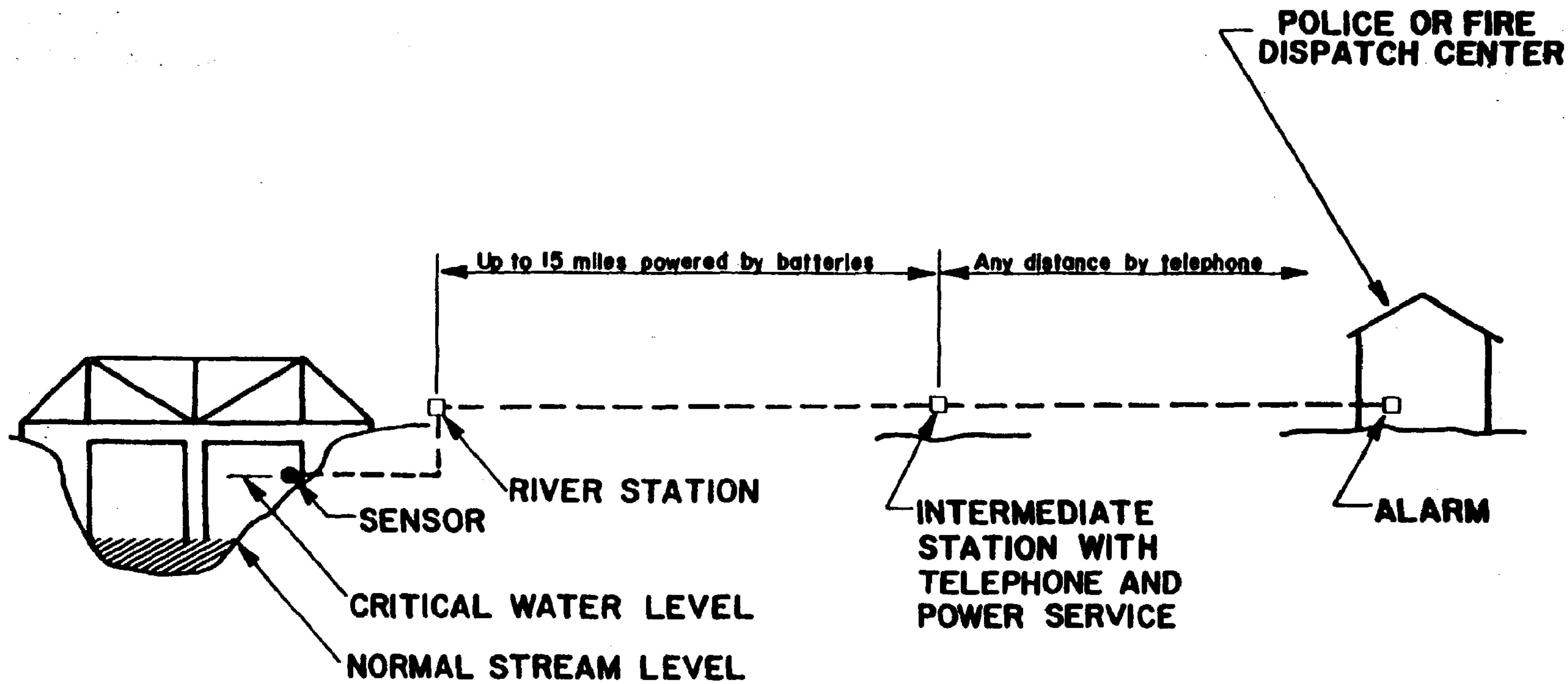


FIGURE 11

SCHEMATIC ILLUSTRATION OF TYPICAL FLASH FLOOD ALARM INSTALLATION

Chapter IV Community Response System

A. Introduction

The community response system consists of the steps taken by a local community in response to information that a flood is imminent. The community response system can be generally defined as three steps that follow the four steps in a local flood warning system (Chapter III):

5. Warn local residents
6. Evacuate
7. Re-enter

B. Responsibility

The best flood warning system is useless without effective dissemination of the information to residents of the flood plain. Effective notification of an impending flood is necessary to reduce loss of life and property damage. Timely warning of citizens is especially important in communities where flooding has not occurred recently. Local community responsibilities and actions required to warn residents effectively of immediate or possible flood hazards include:

- Establishment of an emergency action plan (EAP) that describes actions necessary to mitigate flood damages and provides for the dissemination of information on immediate and potential flood hazards.

- Maintenance of the warning system and the EAP;

- o Maintenance of public awareness of and interest in the system and the plan;

- o Anticipation of problems associated with establishing and maintaining public awareness and interest.

C. Step 5 - Warn Local Residents

A community response system presumes the existence of a flood recognition system such as the local flood warning system described in Chapter III. Using related information such as flood watches, flood warnings, and other information received from Federal, State, or local agencies, local emergency services personnel must make decisions on the actions necessary to save life and property.

A physical location should be established to receive all flood-related information, prepare local forecasts, and issue warnings. This control center should be located outside the flood plain and supplied with an emergency power source. The center may be an emergency operations center (EOC), police station, fire station, or other facility.

Operating procedures at the central control center should be thoroughy planned and spelled out within the emergency action plan. The flood operations section of the EAP should cover the elements of warning, evacuation and rescue, damage mitigation, recovery, other emergency operations, public information, plan implementation, and plan maintenance.

Once local emergency services personnel have made a judgment as to the severity of flooding expected, the impact the event will have on the community, and the actions necessary to save life and property, a public warning should be disseminated.

A community should have established procedures for issuing a warning to the public. These procedures will provide warnings to residents directly threatened by the flood (those residing within the flood plain) and to the general public. Warnings can be disseminated by telephone, state police emergency microwave networks, radio and TV, in person, by helicopter, sirens, or truck-mounted loudspeakers.

Warnings should be coordinated with the NWS and other agencies responsible for warning and response actions. This action is important since misinformation and false rumors develop quickly during severe flood events.

D. Step 6 - Evacuate

D.1. Saving Lives

To prevent loss of life from flooding, a community must plan evacuation and rescue operations. As part of the EAP, the community needs to identify: (1) areas subject to coastal and riverine flooding at various elevations; (2) areas that will be inundated because of poor drainage; and (3) areas that may require evacuation for reasons other than inundation, such as loss of access or escape routes, loss of emergency services, or other site-specific problems.

Local officials need to determine evacuation procedures and should select an appropriate destination for each area to be evacuated. The evacuation procedures should identify the best available evacuation routes and establish evacuation priority areas on the basis of the warning time available. Facilities such as hospitals and elderly housing located in the flood plain may need special evacuation assistance.

D.2. Mitigation Measures

To reduce public and private damages from flooding or flood-related causes, planned flood fighting, property relocation, and floodproofing tasks should be discussed in the EAP. Communities may wish to include, as appendices to the EAP, plans and guidance documents on long-range, permanent mitigation measures or programs. The appendices could include discussions of programs for public acquisition and open-space use of the most severely affected areas; capital improvement programs to correct infrastructure deficiencies; and the placement of warning signs and flood crest elevation signs in strategic public locations to enhance public awareness. Inclusion of such guidance in the EAP may encourage local officials to investigate and recognize the need for a comprehensive flood plain management program.

D.3. Other Emergency Operations

Other emergency operations such as utility management (established procedures for curtailing services to flooded areas), traffic control, and maintenance of vital services (establishing operational procedures for police, fire, and medical services, utility repair, rescue services, etc.) should be included in the EAP. Special attention should be given to water, power, and sewer problems due to flooding. Lack of potable water is often a serious problem after a flood. Also, since flooding may divide a community and limit the service available to each section, emergency operations should be planned to allocate emergency services to all parts of the community.

E. Step 7 - Re-Enter

The objective of the re-enter step is to initiate and carry out post-flood actions that will maintain public health, return community services to normal at the earliest possible time, and provide aid and assistance in the re-entry process.

In the re-entry step, public health must be maintained by following established procedures for handling the dead and injured. To assure smooth return to normal services, the EAP should specify procedures for resuming utility services and returning traffic to normal patterns.

Procedures for mobilizing volunteer organizations such as the Red Cross, the Salvation Army, etc., using State and Federal assistance, and activating mutual aid programs should also be identified in the EAP.

Chapter V - The Integrated Local Flood Warning and Response System

A. Introduction

The integrated local flood warning and response system combines the local flood warning system (Chapter III) with the community response system (Chapter IV). Figure 12 illustrates the seven-step process of the integrated system. These seven steps are applicable to the simplest manual system or the most sophisticated automated system.

The integrated system is the entire process of collecting data, transmitting it to a centralized collection center, analyzing and processing the data, preparing a flood forecast, informing local officials, issuing a warning, taking actions to save life and property, and re-entry. The critical links between a local flood warning system and a community response system are community awareness and interest, a high degree of system maintenance, trained individuals to carry out planned actions, and a master emergency action plan (EAP) to follow. An integrated system in Lycoming, Pennsylvania, is described in Appendix B.

Systems that involve numerous local communities along small streams and rivers should be coordinated on a multi-county or multi-community basis. Downstream communities may benefit from warnings given to upstream communities.

B. Community Interest and Awareness

Consistent with every community's responsibility to protect its citizens from harm and to promote public safety, each community with flood plain areas must

LOCAL FLOOD WARNING SYSTEM

STEP 1. COLLECT DATA

STEP 2. TRANSMIT DATA

STEP 3. FORECAST THE FLOOD

STEP 4. INFORM LOCAL OFFICIALS

RESPONSE SYSTEM

STEP 5. WARN LOCAL RESIDENTS

STEP 6. EVACUATE

STEP 7. RE-ENTER

FIGURE 12 - THE INTEGRATED SYSTEM

keep its residents informed of the potential for flooding, promote the mitigation of hazards and losses in the flood plain, and sustain citizen interest in the operation and maintenance of the integrated system. The chief executive officer of the community needs to designate a government official such as the director of emergency operations, the director of public works, the fire chief, or the police chief to be the official responsible for establishing and maintaining the local flood warning system and the community response system. This official should be responsible for ensuring that all residents of structures located in the flood plain are aware of the flood hazard, the existence of the local flood warning system and the community response system, and the actions that should be taken in response to flood watch and warning notifications. Both the chief executive officer and the person with principal responsibility for the flooding warning and response systems should promote the mitigation of existing and potential flood hazards. Various Federal and State agencies are available to assist community officials in establishing and maintaining the integrated system and hazard mitigation programs.

In areas where flooding is frequent and visible to community residents, some level of community interest and awareness is sustained. In areas where flooding is infrequent or rare, the maintenance of community interest and awareness is difficult.

C. Integrated System Maintenance

Every community must establish procedures to update, improve and ensure the efficient operation of the integrated system. The tasks involved in maintenance of the system range from maintaining and upgrading equipment and software (if an automated system is involved) to updating and improving the emergency action plan. To maintain an integrated system properly, the community must:

- Yearly, or shortly after a flooding event, update and improve the emergency action plan.

- Maintain and replace equipment, including hydrologic gages, electronic equipment, computer, hardware, radio transmitter and receiver equipment, flood fighting equipment, and communications equipment.

- Test equipment periodically to assure that it is functioning properly.

- Establish procedures for evaluating the performance of the system during actual or simulated flood conditions.

- Establish procedures and schedules by conducting drills (at least annually) that simulate floods.

- Include funding for personnel and equipment operation, maintenance, purchase and replacement in the annual community budget.

- Provide special personnel training to ensure capabilities when floods occur.

- Develop backup systems and substitution procedures for equipment, people, and processes to assure a rapid response to any breakdown in the system.

D. Trained Community Officials

Maintaining a high degree of operational readiness for the integrated system requires on-going training of key personnel. All assigned personnel must be knowledgeable enough to execute the established procedures. On-going training is especially critical in communities that have a high turnover rate of people involved in emergency services.

Maintaining a training program for volunteer observers, the local flood warning system coordinator, emergency services personnel, maintenance personnel and central control center personnel is vital to the successful operation of the entire system.

Chapter VI - The Role of Government Agencies

A. Introduction

A number of State and Federal agencies have instituted programs for helping communities identify and solve local flood problems. The programs and responsibilities vary, but the objectives are the same -- wise use of the flood plain and a reduction in the loss of life attributable to flooding. A local flood warning and response system is often an integral part of a community's flood damage abatement and public safety strategy.

The National Weather Service is responsible for forecasting the weather and for warning the public about life-threatening weather conditions, including floods. Other Federal agencies have flood damage abatement programs as well as response and recovery roles. The roles of the various Federal and State agencies in developing flood warning and response systems are broadly described in the following pages to provide a guide to local communities seeking assistance in evaluating the need for local flood warning and response systems and developing appropriate local programs.

B. Army Corps of Engineers

The Army Corps of Engineers provides a broad range of water resource development projects to the Nation. The Corps has constructed and operates major dams, hydroelectric power plants, levees, harbors, waterways, locks, and recreation areas throughout the United States.

The Corps may undertake investigations of water and related land resources plans under specific authorizations by the Congress or, for smaller studies, under general continuing authorities. Special authorizations are either legislative actions by the Congress or resolutions by either the House Public Works and Transportation Committee or the Senate Environment and Public Works Committee. Continuing authorities permit the Corps to undertake investigations and construction of small projects for flood control, navigation, beach erosion control, clearing, and emergency bank protection. Other legislation empowers the Corps to undertake investigations for modifying completed projects or their operation; for modifying or adding to structures and the operation of structures; or for cooperative assistance to States in the preparation of comprehensive plans for water resources development, utilization, and conservation.

These authorities require the Corps to consider all alternatives in controlling flood waters, reducing the susceptibility of property to flood damage, and mitigating human and financial losses. The Corps considers both structural and nonstructural measures in planning for flood damage prevention or reduction. The Corps also considers all practicable and relevant alternatives applicable to sound flood plain management, including modifying the ways in which people would otherwise occupy and use flood plain lands and waters.

Nonstructural solutions include local flood warning and response systems; temporary or permanent evacuation and relocation; emergency flood fighting and financial relief; land-use regulations and building codes; floodproofing with or without land-use regulations; and area renewal and conversion to open spaces. Structural solutions include dams and reservoirs, levees, dikes, walls, diversion channels, bridge modifications, channel alterations, pumping, and land treatment. Structural and nonstructural solutions are considered individually or in combination.

Under another authority, the Corps can provide information, technical planning assistance, and guidance on request to both Federal and non-Federal entities in identifying the magnitude and extent of the flood hazard and in planning wise use of flood plains. Direct response and assistance of this kind are provided through the Flood Plain Management Services Program. The Corps also administers studies that provide basic hydrologic and hydraulic information to the Federal Emergency Management Agency.

For help, guidance, or technical assistance, contact the local Corps of Engineers office listed below.

Office, Chief of Engineers
Department of the Army
Washington, D.C. 20314

DIVISIONS AND DISTRICTS

U.S. Army Engineer Division,
Lower Mississippi Valley
P.O. Box 80
Vicksburg, Mississippi 39180

U.S. Army Engineer District, **Memphis**
668 Federal Office Building
Memphis, Tennessee 38103

U.S. Army Engineer District, **New Orleans**
P.O. Box 60267
New Orleans, Louisiana 70160

U.S. Army Engineer District, **St. Louis**
210 North 12th Street
St. Louis, Missouri 63101

U.S. Army Engineer District, **Vicksburg**
P.O. Box 60
Vicksburg, Mississippi 39180

U.S. Army Engineer Division,
Missouri River
P.O. Box 103
Downtown Station
Omaha, Nebraska 68101

U.S. Army Engineer District, **Kansas City**
500 Federal Building
East 12th Street
Kansas City, Missouri 64106

U.S. Army Engineer District, **Omaha**
6014 U.S. Post Office and Court House
215 North 17th Street
Omaha, Nebraska 68102

U.S. Army Engineer Division,
New England
424 Trapelo Road
Waltham, Massachusetts 02154

U.S. Army Engineer Division,
North Atlantic
90 Church Street
New York, New York 10007

U.S. Army Engineer District, **Baltimore**
P.O. Box 1715
Baltimore, Maryland 21203

U.S. Army Engineer District, **New York**
26 Federal Plaza
New York, New York 10007

U.S. Army Engineer District, **Norfolk**
803 Front Street
Norfolk, Virginia 23510

U.S. Army Engineer District, **Philadelphia**
U.S. Custom House
2nd and Chestnut Streets
Philadelphia Pennsylvania 19106

U.S. Army Engineer Division,
North Central
536 South Clark Street Illinois 60605
Chicago, Illinois 60605

U.S. Army Engineer District, **Buffalo**
1776 Niagara Street
Buffalo, New York 14207

U.S. Army Engineer District, **Chicago**
219 South Dearborn Street
Chicago, Illinois 60604

U.S. Army Engineer District, **Detroit**
P.O. Box 1027
Detroit, Michigan 48231

U.S. Army Engineer District, **Rock Island**
Clock Tower Building
Rock Island, Illinois 61201

U.S. Army Engineer District, **St. Paul**
1125 U.S. Post Office & Customhouse
St. Paul, Minnesota 55101

U.S. Army Engineer Division, North Pacific
P.O. Box 2870
Portland, Oregon 97208

U.S. Army Engineer District, **Alaska**
P.O. Box 7002
Anchorage, Alaska 99510

U.S. Army Engineer District, **Portland**
P.O. Box 2946
Portland, Oregon 97208

U.S. Army Engineer District, **Seattle**
P.O. Box C-3755
4735 East Marginal Way, South
Seattle, Washington 98124

U.S. Army Engineer District, **Walla Walla**
Building 602
City-County Airport
Walla Walla, Washington 99362

U.S. Army Engineer Division, Ohio River
P.O. Box 1159
Cincinnati, Ohio 45201

U.S. Army Engineer District, **Huntington**
P.O. Box 2127
Huntington, West Virginia 25721

U.S. Army Engineer District, **Louisville**
P.O. Box 59
Louisville, Kentucky 40201

U.S. Army Engineer District, **Nashville**
P.O. Box 1070
Nashville, Tennessee 37202

U.S. Army Engineer District, **Pittsburgh**
Federal Building
1000 Liberty Avenue
Pittsburgh, Pennsylvania 15222

U.S. Army Engineer Division, Pacific Ocean
Building 230 Fort Shafter
Honolulu, Hawaii 96813
(Write APO San Francisco 96558)

U.S. Army Engineer Division, South Atlantic
510 Title Building
30 Pryor Street, S.W.
Atlanta, Georgia 30303

U.S. Army Engineer District, **Charleston**
P.O. Box 919
Charleston, South Carolina 29402

U.S. Army Engineer District, **Jacksonville**
P.O. Box 4970
Jacksonville, Florida 32201

U.S. Army Engineer District, **Mobile**
P.O. Box 2288
Mobile, Alabama 36628

U.S. Army Engineer District, **Savannah**
P.O. Box 889
Savannah, Georgia 31402

U.S. Army Engineer District, **Wilmington**
P.O. Box 1890
Wilmington, North Carolina 28401

U.S. Army Engineer Division, South Pacific
630 Sansome Street
Room 1216
San Francisco, California 94111

U.S. Army Engineer District, **Los Angeles**
P.O. Box 2711
Los Angeles, California 90053

U.S. Army Engineer District, **Sacramento**
650 Capitol Mall
Sacramento, California 95814

U.S. Army Engineer District, **San Francisco**
211 Main Street
San Francisco, California 94105

U.S. Army Engineer Division, Southwestern
1114 Commerce Street
Dallas, Texas 75242

U.S. Army Engineer District, **Albuquerque**
P.O. Box 1580
Albuquerque, New Mexico 87103

U.S. Army Engineer District, **Fort Worth**
P.O. Box 17300
Fort Worth, Texas 76102

U.S. Army Engineer District, **Galveston**
P.O. Box 1229
Galveston, Texas 77553

U.S. Army Engineer District, **Little Rock**
P.O. Box 867
Little Rock, Arkansas 72203

U.S. Army Engineer District, **Tulsa**
P.O. Box 61
Tulsa, Oklahoma 74102

C. Bureau of Reclamation

The Bureau of Reclamation, an agency of the U.S. Department of the Interior, plans, builds, and operates water development projects in the Nation's 17 western states. Dams, reservoirs, and canals have been built to provide water for agricultural, municipal, industrial, and other purposes. The Bureau can furnish information on the potential for flooding at locations affected by water development projects. Technical assistance can be obtained from a flood hydrologist at each of the Bureau's seven regional offices. For more information, contact the nearest office at the address shown below.

Regional Offices of the Bureau of Reclamation:

Upper Missouri Region
P.O. Box 2553
Billings, MT 59103

Lower Missouri Region
Building 20
Denver Federal Center
Denver, CO 80225

Upper Colorado Region
P.O. Box 11568
Salt Lake City, UT 84147

Lower Colorado Region
P.O. Box 427
Boulder City, CO 89005

Pacific Northwest Region
P.O. Box 043
550 West Fort Street
Boise, ID 83742

Mid-Pacific Region
Federal Office Building
2800 Cottage Way
Sacramento, CA 95825

Southwest Region
Commerce Building
714 S. Tyler, Suite 201
Amarillo, TX 79101

D. Soil Conservation Service (SCS)

The Soil Conservation Service (SCS) recognizes the use of flood warning systems along with other nonstructural and structural measures as means of reducing flood damages. SCS can provide both financial and technical assistance to develop and install local flood warning systems.

In watersheds that are less than 250,000 acres in size (Public Law 566 watersheds), SCS can pay up to 80 percent of the installation costs for flood warning system. Similar funding authorities are available under the Resource Conservation and Development Program. Because the principles and guidelines of this program (U.S. Water Resources Council, 1973) are applicable to the watershed program, flood warning systems must be economically justified to be eligible for cost-share assistance. Normally, SCS cooperates with NOAA-NWS to develop and install the systems. Cost-sharing may be provided for the installation of rain and/or stream gages, radio relay equipment, a computer or analysis system, and a warning system. After the system is operational, the local sponsors must operate and maintain it. SCS makes a major effort to interview flood plain residents to help them understand how a flood warning can reduce their specific flood losses. The major reasons that SCS is not extensively involved in flood warning systems are the short time between a flood warning and the necessary community response, and the large commitment required of local sponsors to operate and maintain the system after it is installed. SCS may participate in pilot projects to demonstrate new technology or to gain acceptance of innovative approaches using special funds available under the Resource Conservation Act. These funds are limited, and only one application has been made to date.

STATE CONSERVATIONISTS

ALABAMA
665 Opelika Road
Auburn, Alabama 36380

ALASKA
Suite 129, Professional Bldg.
2221 E. Northern Lights Blvd.
Anchorage, Alaska 99508

ARIZONA
Suite 200
201 E. Indianola Avenue
Phoenix, Arizona 85012

ARKANSAS
Federal Office Building
700 West Capitol Street
Little Rock, Arkansas 72201

CALIFORNIA
2828 Chiles Road
Davis, California 95616

COLORADO
Diamond Hill, Bldg. A, 3rd Fl.
2490 West 26th Avenue
Denver, Colorado 80211

CONNECTICUT
Mansfield Professional Park
Route 44A
Storrs, Connecticut 06268

DELAWARE
Treadway Towers, Ste. 210
9 East Loockerman Street
Dover, Delaware 19901

FLORIDA
Federal Bldg., Rm. 248
401 S.E., 1st Avenue
Gainesville, Florida 32601

GEORGIA
Federal Bldg., Box 13
355 East Hancock Avenue
Athens, Georgia 30601

HAWAII
300 Ala Moana Blvd.
Honolulu, Hawaii 96850

IDAHO
304 North 8th St., Rm. 345
Boise, Idaho 83702

ILLINOIS
Springer Federal Building
301 North Randolph Street
Champaign, Illinois 61820

INDIANA
Corporate Square-West
Suite 2200
5610 Crawfordsville Road
Indianapolis, Indiana 46224

IOWA
693 Federal Building
210 Walnut Street
Des Moines, Iowa 50309

KANSAS
760 South Broadway
Salina, Kansas 67401

KENTUCKY
333 Waller Avenue, Rm. 305
Lexington, Kentucky 40504

LOUISIANA
3737 Government Street
Alexandria, Louisiana 71301

MAINE
USDA Building
University of Maine
Orono, Maine 04473

MARYLAND
Hartwick Building, Rm. 522
4321 Hartwick Road
College Park, Maryland 20740

MASSACHUSETTS
451 West Street
Amherst, Massachusetts 01002

MICHIGAN
Room 101
1405 South Harrison Road
East Lansing, Michigan 48823

MINNESOTA
200 Federal Bldg. & U.S. Courthouse
316 North Robert Street
St. Paul, Minnesota 55101

MISSISSIPPI
Federal Bldg., Ste. 1321
100 West Capitol Street
Jackson, Mississippi 39269

MISSOURI
555 Vandiver Drive
Columbia, Missouri 65202

MONTANA
Federal Bldg., Rm. 443
10 East Babcock
Bozeman, Montana 59715

NEBRASKA
Federal Building, Rm. 345
100 Centennial Mall, N.
Lincoln, Nebraska

NEVADA
U.S. Post Office Building
50 S. Virginia Street
Reno, Nevada 89505

NEW HAMPSHIRE
Federal Building
P.O. Box G
Durham, New Hampshire 03824

NEW JERSEY
1370 Hamilton Street
Somerset, New Jersey 08873

NEW MEXICO
517 Gold Ave., S.W., Rm. 3301
Albuquerque, New Mexico 87102

NEW YORK
100 S. Clinton Street
Syracuse, New York 13260

NORTH CAROLINA
Federal Office Bldg, Rm. 535
310 New Bern Avenue
Raleigh, North Carolina 27601

NORTH DAKOTA
Federal Building, Rm. 522
Rosser Avenue & Third St.
P.O. Box 1458
Bismarck, North Dakota 58502

OHIO
200 North High St., Rm. 522
Columbus, Ohio 43215

OKLAHOMA
Agriculture Center Bldg.
Farm Road & Brumley Street
Stillwater, Oklahoma 74074

OREGON
Federal Bldg. 16th Floor
1220 S.W. 3rd Avenue
Portland, Oregon 97204

PENNSYLVANIA
Federal Bldg. & Courthouse
Box 985, Federal Sq. Station
Harrisburg, Pennsylvania 17108

PUERTO RICO
Director, Caribbean Area
Federal Bldg., Rm. 639
Chardon Avenue, GPO Box 4868
Harrisburg, Pennsylvania 17108

RHODE ISLAND
46 Quaker Lane
West Warwick, Rhode Island 02893

SOUTH CAROLINA
1835 Assembly St., Rm. 950
Strom Thurmond Federal Bldg.
Columbia, South Carolina 29201

SOUTH DAKOTA
Federal Building
200 4th Street, S.W.
Huron, South Dakota 57350

TENNESSEE
U.S. Courthouse, Rm. 675
801 Broadway Street
Nashville, Tennessee 37203

TEXAS
W.R. Poage Federal Building
101 S. Main Street
P.O. Box 648
Temple, Texas 76501

UTAH
4012 Federal Building
125 South State Street
Salt Lake City, Utah 84147

VERMONT
69 Union Street
Winooski, Vermont 05404

VIRGINIA
Federal Bldg., Rm. 9201
400 North 8th Street
P.O. Box 10026
Richmond, Virginia 23240

WASHINGTON
360 U.S. Courthouse
West 920 Riverside Ave.
Spokane, Washington 99201

WEST VIRGINIA
75 High Street, Rm. 310
Morgantown, WV 26505

WISCONSIN
4601 Hammersley Road
Madison, Wisconsin 53711

WYOMING
Federal Office Bldg.
100 East "B" St., Rm. 3124
Casper, Wyoming 82601

E. United States Geological Survey

The mission of the United States Geological Survey's Water Resources Division (WRD) is to provide the hydrologic information and understanding needed to best use and manage the Nation's water resources for the benefit of the people of the United States. To accomplish this, the Division assesses the Nation's water resources in terms of the quality, quantity, and use of water, and develops the knowledge and hydrologic understanding necessary to predict the consequences of alternative plans and policies for developing and using water resources. Much of this work is done through cooperation with and funding from Federal, State, and local agencies. Most of the cooperative work is based on a shared 50-50 funding with State or local agencies. During the 1983 fiscal year, the 50-50 matching program was carried out in working partnership with more than 800 State, regional, and local agencies. The data-collection component of the cooperative program provides the basic data needed for hydrologic investigations such as the establishment of a flood warning system.

The United States Geological Survey's Office of Water Data Coordination coordinates the acquisition, storage, and dissemination of water data. National Water Data Exchange (NAWDEX) assists users in the identification, location, and acquisition of water data. NAWDEX services are available through a nationwide network of 60 Assistance Centers located in 45 States and Puerto Rico. The Centers provide direct access to NAWDEX and make local-area expertise available to aid in identifying and locating needed data. NAWDEX provides a nationwide indexing of more than 375,000 sites for which water data are available from more than 400 organizations. A current directory containing the names, addresses, and telephone numbers of all Assistance

Centers is available free from the NAWDEX Program Office, United States Geological Survey, 421 National Center, Reston, Virginia 22092; telephone (703) 860-6031.

DISTRICT CHIEF OFFICES

Northeastern Region

ILLINOIS
Champaign County Bank Plaza
102 E. Main Street, 4th Fl.
Urbana, Illinois 61801

INDIANA
6023 Guion Road, Ste. 201
Indianapolis, Indiana 46254

MID-ATLANTIC DISTRICT
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204

NEW ENGLAND DISTRICT
150 Causeway Street
Suite 1309
Boston, Massachusetts 02114

MICHIGAN
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

MINNESOTA
702 Post Office Building
St. Paul Minnesota 55101

NEW JERSEY
Room 430, Federal Building
402 E. State Street
Trenton, New Jersey 08608

NEW YORK
P.O. Box 1350
343 U.S. Post Office
& Courthouse
Albany, New York 12201

OHIO
975 West Third Avenue
Columbus, Ohio 43212

PENNSYLVANIA
Post Office Box 1107
4th Floor, Federal Bldg.
228 Walnut Street
Harrisburg, Pennsylvania 17108

WEST VIRGINIA
Rm. 3416, Federal Bldg. &
U.S. Courthouse
500 Quarrier Street, East
Charleston, West Virginia 25301

WISCONSIN
1815 University Avenue
Madison, Wisconsin 53705

Southeastern Region

ALABAMA
520 19th Avenue
Tuscaloosa, Alabama 35401

ARKANSAS
Room 2301 Federal Office Bldg.
700 West Capitol Avenue
Little Rock, Arkansas 72201

FLORIDA
325 John Knox Road
Suite F-240
Tallahassee, Florida 32303

GEORGIA
6481 Peachtree Industrial Blvd.
Suite B
Doraville, Georgia 30360

KENTUCKY
Room 572, Federal Bldg.
600 Federal Place
Louisville, Kentucky 40202

LOUISIANA
P.O. Box 66492
Baton Rouge, Louisiana 70896

MISSISSIPPI
Suite 710, Federal Bldg.
100 West Capitol Street
Jackson, Mississippi 39269

NORTH CAROLINA
P.O. Box 3857
Room 436, Century Station,
300 Fayetteville St. Mall
Raleigh, NC 27602

PUERTO RICO
G.P.O. Box 4424
San Juan, Puerto Rico 00936

SOUTH CAROLINA
Strom Thurmond Federal Bldg.
Suite 658
1835 Assembly Street
Columbia, SC 29201

TENNESSEE
A413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Central Region

COLORADO
Building 53, Denver Federal
Center, MS 415, Box 25046
Lakewood, Colorado 80225

Central Region (Cont.)

IOWA
P.O. Box 1230
Room 269, Federal Bldg.
400 So. Clinton Street
Iowa City, Iowa

KANSAS
1950 Avenue A Campus West
University of Kansas
Lawrence, Kansas 66044

MISSOURI
1400 Independence Road
MS 200
Rolla, Missouri 65401

MONTANA
Federal Bldg., Drawer 10076
Helena, Montana 59626

NEBRASKA
Room 406, Federal Bldg.
& U.S. Courthouse
100 Centennial Mall North
Lincoln, Nebraska 68508

NEW MEXICO
Western Bank
505 Marquette N.W., Rm 720
Albuquerque, New Mexico 87102

NORTH DAKOTA
821 E. Interstate Avenue
Bismarck, North Dakota 58501

OKLAHOMA
Room 621
215 Dean A. McGeen St.
Oklahoma City, Oklahoma 73102

SOUTH DAKOTA
Room 317, Federal Bldg.
200 4th St., Southwest
Huron, South Dakota 57350

TEXAS
649 Federal Building
300 East 8th Street
Austin, Texas 78701

UTAH
1016 Administration Building
1745 West 1700 South
Salt Lake City, Utah 84104

WYOMING
P.O. Box 1125
J.C. O'Mahoney Federal Center
Room 4007
2120 Capitol Avenue
Cheyenne, Wyoming 82003

Western Region

ALASKA
1515 E. 13th Avenue
Anchorage, Alaska 99501

ARIZONA
Federal Building
301 W. Congress, FB-44
Tucson, Arizona 85701

CALIFORNIA
Room W-2235 Federal Bldg.
2800 Cottage Way
Sacramento, California 95825

HAWAII
300 Ala Moana Blvd., Rm. 6110
Honolulu, Hawaii 96850

IDAHO-NEVADA
230 Collins Road
Boise, Idaho 83702

OREGON
847 NE 19th Ave., Suite 300
Portland, Oregon 97232

WASHINGTON
1201 Pacific Avenue, Ste. 600
Tacoma, Washington 98402

F. National Weather Service

The National Weather Service (NWS), Hydrologic Service program has two basic goals: 1) to warn the public about weather and floods in order to save lives and property; and 2) to report on the Nation's rivers in order to support water resources management for the benefit of all sectors of the economy. These goals are in accordance with the Congressional Organic Act of 1890, which designates the NWS as responsible for "...the forecasting of weather and flood signals for the benefit of agriculture, commerce, and navigation, the gaging and reporting of rivers...".

To meet the first goal, the NWS has established a flood forecast and warning service. This service consists of Weather Service Forecast offices, which collect hydrologic data and relay it to NWS River Forecast Centers. The River Forecast Centers (RFCs) are staffed with professional hydrologists who are responsible for the quality control of data, the input of data into computerized hydrologic models, the analysis of the model output, and the relay of flood forecasts back to the local Weather Service Forecast office for dissemination to the public, other agencies, and the media. These forecasts can usually be achieved only for the larger river basins with crest times greater than 12 hours. For communities located on small flashy streams with crest times of less than 12 hours, the NWS provides generalized flash flood watches and warnings and works with communities to establish local flood warning and response systems.

The NWS recognizes the importance of local flood warning and response systems in improving flood warning service to communities, and provides technical assistance to communities with flood problems. Technical support involves recommending alternative flood warning systems appropriate to the economic capabilities of the community; helping communities in the design, installation, and implementation of warning and response systems and the training of personnel; and providing operational support to responsible community officials. In the case of automated systems, the NWS provides site selection of the hydrologic observation network, radio path analysis, generic standards for automated local flood warning systems, consulting service on the calibration of hydrologic models, and when the system is operational, additional weather information.

Any individual desiring information on local flood warning systems should contact the local Weather Service Office.

G. Tennessee Valley Authority

As part of its local flood damage abatement program, the Tennessee Valley Authority (TVA) provides flood plain management assistance to flood-prone communities within the Tennessee River watershed. This assistance includes working with community officials or their designated representatives to determine the feasibility of local flood warning and response systems, and providing the technical information needed to implement local flood warning and response systems.

TVA is cooperating with the National Weather Service (NWS) in the development of local flood warning and response systems and in the past has provided financial assistance in support of NWS efforts to implement a computer-based flood warning system known as IFLOWS in the Tennessee Valley. TVA has also participated directly in the development and construction of local flood warning and response systems at several locations in the Tennessee River watershed. These systems include both flash flood alarm gages and an automated real-time forecast of flood elevations based on a continuous computer analysis of recorded rain and streamflow.

Communities in the Tennessee River watershed may contact TVA for information and assistance by writing to:

Tennessee Valley Authority
Flood Protection Branch
Liberty Building
Knoxville, Tennessee 37902

H. Federal Emergency Management Agency (FEMA)

Planning for emergencies, responding to them, and recovering from them are responsibilities shared by Federal, State, and local governments, and the private sector. The capability of meeting an emergency must be based essentially at the local level, with State and local governments providing guidance and support in all aspects of the emergency management process. Through coordination of planning and preparedness activities and the provision of financial and technical support, the Federal Emergency Management Agency (FEMA) encourages the development of predisaster and postdisaster emergency preparedness and response plans.

Among FEMA's activities are:

- Supporting State and local governments in a wide range of disaster planning, preparedness, mitigation, response, and recover efforts. As necessary, the agency provides funding, technical assistance, services, supplies, equipment, and direct Federal support for fulfilling state and local government emergency management responsibilities. Various States, including Illinois and Minnesota, have included detailed planning for local flood warning systems in their State emergency preparedness plan.

  Additional services and products that FEMA may fund include:

  1. An inventory of properties and structures in flood-prone areas.
  2. A statewide flood hazard mitigation plan developed in a predisaster context.
  3. Public awareness media presentations on flood hazards.
  4. Handbooks or other technical assistance on a variety of flood

hazard topics, which may include flood warning systems.

Administering the National Flood Insurance Program (NFIP). The NFIP provides insurance coverage to property owners in communities with flood hazards in exchange for community agreement to adopt flood plain management measures to protect lives and reduce property losses. Technical assistance is provided to communities in both flood plain management and postdisaster hazard mitigation activities, such as encouragement of new construction away from flood-prone areas. At present, there are approximately 17,000 communities participating in the NFIP and nearly 2 million insurance policies in effect. FEMA has published detailed flood plain mapping for about 50 percent of the communities and approximate flood plain delineations for most of the remainder. A detailed Flood Insurance study and backup materials are also available.

Developing community awareness programs for weather emergencies and home safety.

Regional Offices

There are 10 FEMA Regional Offices. Each office is headed by a Regional Director who reports to the FEMA Director and is responsible for all FEMA programs in the region.

Region I (Boston)
442 J.W. McCormack, POCH
Boston, Massachusetts 02109

Region II (New York)
26 Federal Plaza
New York, New York 10278

Region III (Philadelphia)
Curtis Building, 7th Floor
6th & Walnut Streets
Philadelphia, Pennsylvania 19106

Region IV (Atlanta)
Seventh Floor
1371 Peachtree Street, N.E.
Atlanta, Georgia 30309

Region V (Chicago)
300 South Wacker Drive (24th Floor)
Chicago, Illinois 60606

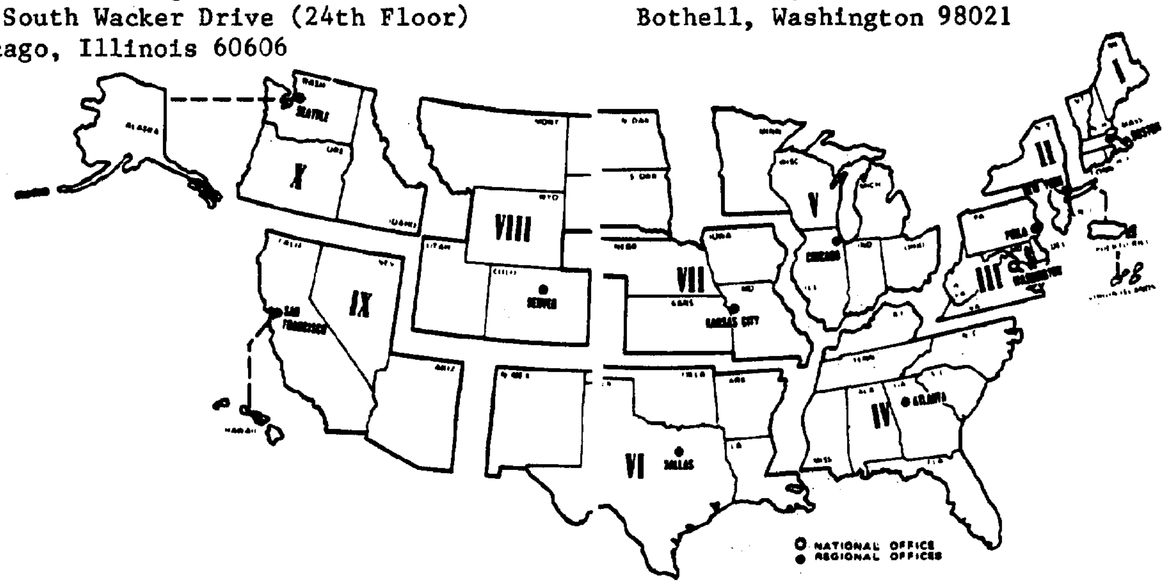
Region VI (Dallas)
Federal Regional Center
Denton, Texas 76201

Region VII (Kansas City)
Old Federal Office Bldg., Rm. 300
Kansas City, Missouri 64106

Region VIII (Denver)
Federal Regional Center, Bldg. 710
Denver, Colorado 80225

Region IX (San Francisco)
Building 105
Presidio of San Francisco
San Francisco, California 94129

Region X (Seattle)
Federal Regional Center
Bothell, Washington 98021



I. National Park Service (NPS)

The National Park System is made up of 334 units covering some 79 million acres. These park units are of such historic or natural significance as to justify special recognition and protection by the Congress. New park units are continually being added to the system by the Congress. Many of these units are subject to flooding from rivers, lakes, oceans, and tsunamis. Flooding problems are sometimes aggravated by improper development within flood plains, by dam failures, and by unanticipated rises at reservoirs.

Every year, millions of dollars are spent to repair flood-damaged areas within the National Park System. Occasionally, loss of life occurs because of park flooding. To minimize losses, the National Park Service (NPS) has implemented policies on flood plains and dam safety in accordance with Executive Orders. As part of these policies, both manual and automatic local flood warning and response systems are being installed.

The Engineering and Safety Services Division of the NPS has responsibility for the Safety of Dams Program. With technical review assistance from the Bureau of Reclamation, parks are installing flood warning systems on their high dams and dams with significant hazard potential as part of required emergency action plans.

The Air and Water Quality Division promulgates NPS guidelines for implementing the Flood Plain Management and Wetland Protection Executive Orders. Several of these warning systems have been installed with the assistance of the National Weather Service and the Army Corps of Engineers.

For additional information about the use of local flood warning and response systems on flood plains or at dam locations, contact the appropriate NPS Division.

J. State Assistance

Generally, two types of assistance are available from a State agency: technical and financial. The availability of either or both varies, however, according to the individual State and its particular resources.

A local municipality seeking financial assistance from a State may have to contact several State agencies. Funding may be available from the State emergency management agency, or from another agency such as a the natural resources or community affairs department. Funding may have to be packaged from several State sources to make a project viable. It is also possible that financial assistance is not available.

Technical assistance in various forms is available from most States. The agency responsible for the State's flood plain management, National Flood Insurance Program activities, and/or state emergency management will usually be able to provide information on local flood warning and response systems and to advise a local municipality interested in developing such a system. The type and extent of assistance will vary with the capabilities and resources of each State.

Chapter VII. Other Related Activities

A. Dam Safety Activities

Local flood warning and response systems are an essential part of emergency action plans prepared for dams. Federal involvement in emergency action plans as well as other dam safety issues are coordinated among the various Federal agencies by the Interagency Committee on Dam Safety (ICODS). ICODS has developed guidelines for emergency action plans that address emergencies at dams and downstream of dams.

Flood emergencies at dams are very different from flood emergencies that do not involve a dam. The most notable difference is the size and speed of a flood wave associated with the failure of a dam.

Local flood warning and response systems in areas that could experience dam failure must be based on consideration of both floods that could occur without dam failure and those associated with dam failure. Failure is unlikely at dams designed according to current hydrologic and structural standards, but should it occur, the failure is often sudden as well as unexpected.

B. Principles and Guidelines

The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (U.S. Water Resources Council, 1973) is applicable to water resource plans of the Corps of Engineers, the Bureau of Reclamation, the Soil Conservation Service, and the Tennessee Valley Authority.

The P&G require specifically that, in the planning of projects, consideration be given to nonstructural measures as a means to address the problems and opportunities of each project. Nonstructural measures are interpreted to include, among other things, a local flood warning and response system.

The P&G also require that, unless an exception is granted by the Secretary of the Department involved in the project, the plan selected for implementation must be the one that provides the maximum net economic benefits.

C. The Unified National Program for Flood Plain Management

In 1968, when the Congress enacted the National Flood Insurance Act, it recognized that a reduction in the Nation's escalating flood losses could be achieved only if all flood loss reduction programs -- structural and nonstructural; local, State, and Federal -- were brought to bear in a concerted effort focused on wise use of the Nation's flood plains. In the Act, the Congress directed the President to prepare a Unified National Program for Flood Plain Management. The Unified Program provides for establishment of a Federal Interagency Flood Plain Management Task Force to carry out recommendations set forth in the Program. Initially under the auspices of the United States Water Resources Council, the Unified Program and the Task Force is now assigned to the Federal Emergency Management Agency, which is also responsible for the National Flood Insurance Program.

The Task Force agencies are:

Department of Agriculture
Department of the Army
Department of Commerce
Department of Energy
Department of the Interior
Department of Housing and Urban Development
Department of Transportation
Environmental Protection Agency
Federal Emergency Management Agency
Tennessee Valley Authority

The Task Force has been responsible for the preparation of the various technical flood plain management documents published by the United States Water Resources Council and available through the National Technical Information Service. Each year, the Task Force holds several seminars on flood plain management issues.

The Task Force recognizes the importance and utility of local flood warning systems. In order to implement more effective strategies to reduce loss of life and property, the Task Force believes that greater attention must be given to local flood warning and response systems, and that, where practicable, these systems should be linked to regional and national warning systems.

D. Association of State Flood Plain Managers

The Association of State Flood Plain Managers is a national association of persons involved with flood plain management and related concerns such as flood hazard mitigation, flood preparedness, flood warning, and flood recovery.

One of the functions of the association is to facilitate cooperation and the exchange of information among State, local and Federal units of government and the private sector on innovative ideas and trends in flood plain management. The association also provides a forum for the education of those involved in flood plain management.

A municipality interested in or planning the establishment of a local flood warning and response system should contact the association for advice on resource persons and helpful materials. Financial assistance is not available from the association.

Regions

Region I
Dept. Environmental Mgmt.
100 Cambridge Street
Boston, MA 02002
(617) 727-5804

Region II
Dept. Environmental Protection
P.O. Box CN 029
Trenton, NJ 08625
(609) 292-2373

Region III
Flood Plain Mgmt. Division
551 Forum Building
Harrisburg, PA 17120
(717) 787-7403

Region VI
Soil & Water Conservation
One Capitol Mall, Suite 2D
Little Rock, AR 72201
(501) 371-1611

Region VII
Dept. Water, Air & Water Mngmt.
Wallace State Office Building
Des Moines, IA 50319
(515) 292-2373

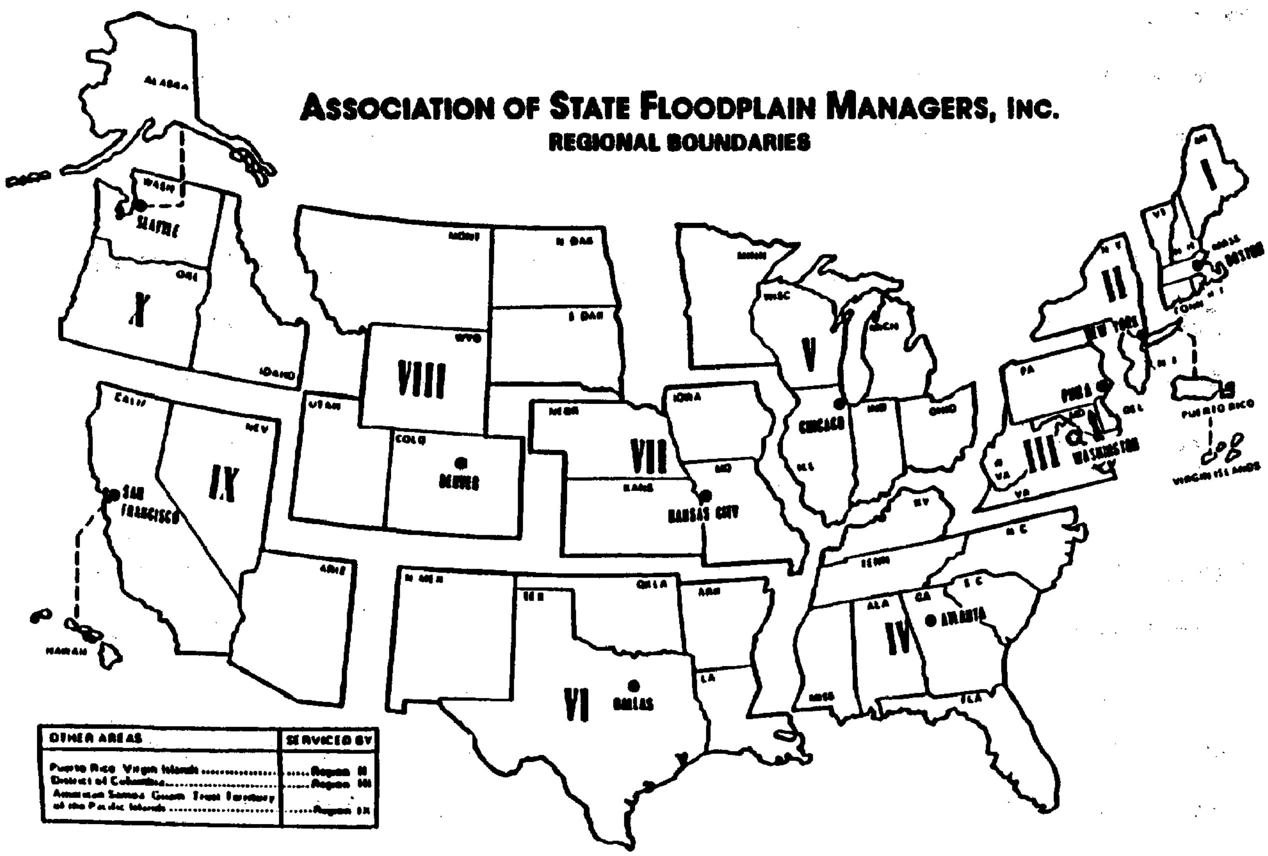
Region VIII
Disaster & Civil Defense
P.O. Box 1709
Cheyenne, WY 82003
(307) 777-7566

Region IV
Miss. Research & Dev. Cntr.
3825 Ridgewood Road
Jackson, MS 39211
(601) 982-6376

Region V
Div. of Waters, Land Use Management
444 Lafayette Rd., 3rd Floor
St. Paul, MN 55101
(612) 296-9226

Region IX
Dept. of Water Resources
99 E. Virginia Avenue
Phoenix, AZ 85004
(602) 255-1566

Region X
Idaho Dept. of Water Resources
Statehouse
Boise, ID 83720
(208) 334-4470



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Chapter IX Glossary, Acronyms and Abbreviations

Glossary

Backwater flooding is the backup of water into a stream from a river, lake, or ocean with a higher water elevation.

Bank full stage is the water elevation that reaches the top of the banks along a stream.

Base station is the central location for receiving flood data from sensors in the ALERT system.

Bubbler gage is an automated device that measures water pressure near the bottom of the stream; this pressure equates with water depth above the gage.

Cost effectiveness is the relationship between the benefits derived from a system and the cost of purchasing, operating, and maintaining it.

Crest is the maximum elevation of a flood at a specific location.

Critical public services typically consists of police and fire assistance, emergency medical services, communications, utilities, transportation, and public works.

Dambreak analysis is the use of a model to calculate the effects of a flood caused by the actual or hypothetical failure of a dam.

Emergency action plan is a detailed description of the actions that must be taken to reduce flood losses and to disseminate information about an actual or expected flood hazard.

Emergency operation center is the center of decisionmaking, information-gathering and dissemination, initiating of emergency actions, and coordinating responses to emergencies. The center may be part of a public service or safety unit in a local government or may be activated only when emergencies arise.

Event as used in data collection represents a point at which a gage reaches a preset value and records the occurrence or transmits it to a receiver.

Falling limb refers to the declining portion of a hydrograph following a crest.

Flash flood watch is the public notification issued by the National Weather Service when climatic, ground, and topographic conditions indicate that flash floods are likely to occur in a given area.

Flash flood is a flood that occurs a short time (minutes to hours) after the causative event.

Flash flood warning is the public notification issued by the National Weather Service on a county basis when flash flooding is imminent or has been reported.

Flood index is the amount of rainfall that will produce flood stage in 6 hours; it is calculated by measuring soil moisture.

Flood loss potential is the potential loss of life and property from flooding.

Gage datum is the elevation level that corresponds to stage 0.0 at a stream gage; it is often set at the stream bottom or the elevation of a very low flow.

Hydrograph is a chart that shows the relationship between streamflow or water elevation to time at a certain location.

Hydrologic characteristics of watershed are the parameters that control the runoff in a watershed. These include the basin size, ground cover conditions, slope of the land, stream lengths (and slopes), topographic and geologic features, and physical features constructed by man that alter runoff.

Hydrologic models are mathematical equations, algorithms, and/or logic that represent the rainfall runoff process in a watershed.

Hydrologist is a person who studies water on or through the earth's surface.

Land line for communications is typically telephone service but includes any communication lines.

Line-of-sight is an unobstructed straight line from a radio transmitter to a receiver site.

Mean sea level is the mean of all hourly ocean elevations over a 19-year period.

Meteor burst radio transmission uses the phenomenon of meteors entering the upper atmosphere to bounce signals back to earth.

Meteorological sensor data is collected weather data such as rainfall, humidity, temperature, and wind.

Microprocessor is a small computer that is usually more powerful in processing ability and more flexible in using other equipment than a typical home computer.

Microwave radio transmission is a frequency of transmission that requires line-of-sight. The frequency has high resistance to atmospheric interruption (telephone tower relay stations are an example).

Nonstructural methods of reducing damage from floods include local flood warning and response systems, temporary or permanent evacuation and relocation of people or property, emergency flood fighting and financial relief, land use regulations and building codes, floodproofing, area renewal and conversion to open space, and flood insurance.

Percent chance is a probability multiplied by 100.

Probability is the ratio of observed or expected events to all possible events; it is expressed as a decimal less than or equal to one.

Radio relays, or repeaters, are repeating or relaying devices that transfer data from a self-reporting gage to a base station.

Rain gages are instruments that collect and measure rainfall.

Rate of rise indicates how quickly a stream is rising, typically expressed in feet per hour or feet per day.

Recurrence interval is the average interval of time within which a given hydrological event is expected to be equaled or exceeded once.

Response system is the planned protective reaction to flooding or the threat of flooding.

Rising limb is the rising portion of a hydrograph preceding a crest.

River forecast centers are the organizational units within the National Weather Service that forecast floods.

Stream gages are instruments that measure the depth of the water in a stream.

Self-reporting gages are instruments that automatically transmit rainfall or stream stage data from a remote gage to a base station.

Staff gage is a vertical board or structure with a graduated scale for measuring the depth of a river in feet.

Stage is the depth of water in a river or stream above the gage datum, or 0.0 level.

Stage-damage graphs or charts show the relation between flood depth or elevation and damages in the area.

Station identifier is information transmitted with data to identify the sending station.

Structural methods of reducing damage from floods include dams and reservoirs, levees, dikes, floodwalls, diversion channels, bridge modifications, channel alterations, pumping stations, and land treatment.

Tipping bucket precipitation gage is an electrical-mechanical device that accumulates a small, precise amount of rainfall before tipping to spill the water. The spill triggers an electrical signal that is counted and/or transmitted to a base station. Each count represents a preset rainfall accumulation amount (1 millimeter) and is tagged with the time of occurrence.

Twp, or potential warning time, is the maximum time available for warning local communities prior to impending flooding.

Tw, or actual warning time, is something less than potential warning time.

Unitgraph or unit hydrograph is a typical streamflow hydrograph of a river basin produced by 1 inch of surface runoff uniformly distributed over the watershed during a specified period of time.

UHF, or ultra high frequency, is a range for the transmission of signals; television channels above 13 are in this frequency.

VHF, or very high frequency, is a range for the transmission of signals; television channels 13 and below are in this frequency.

Acronyms and Abbreviations

ALERT	-	Automated Local Evaluation in Real Time
B/C	-	benefits divided by costs
cfs	-	cubic feet per second
Corps	-	U.S. Army Corps of Engineers
EAP	-	emergency action plan
EOC	-	emergency operations center
FEMA	-	Federal Emergency Management Agency
ICODS	-	Interagency Committee on Dam Safety
IEMS	-	Integrated Emergency Management System
IFLOWS	-	Integrated Flood Observing and Warning System
LFWS	-	local flood warning system
MSL	-	mean sea level
NAWDEX	-	National Water Data Exchange
NOAA	-	National Oceanic and Atmospheric Administration
NPS	-	National Park Service
NWS	-	National Weather Service
P&G	-	Principles and Guidelines
RFC	-	River Forecast Center
SCS	-	Soil Conservation Service
Twp	-	maximum potential warning time
Tr	-	time to recognize that rainfall is going to cause flooding
Ts	-	amount of time flooding occurs
TVA	-	Tennessee Valley Authority
Tw	-	actual warning time
USGS	-	U.S. Geological Survey

Chapter X. Appendix

A. Justification and Priority Setting

Flood warning systems require resources of money or manpower to design, install, operate and maintain. Since resources are limited in many organizations, priorities must be set and justification developed for adopting a system. A rational approach is to weigh the cost of a flood warning system against its potential benefits. This approach requires quantifying the benefits in dollars. When the ratio of the economic benefits (B) to the cost (C), or B/C, is greater than one, benefits exceed costs, and the system may be described as beneficial. A flood warning system with a B/C ratio of less than one (that is, costs exceed benefits) may still be beneficial, especially since some benefits (for example, reducing potential loss of life) may not be readily quantifiable in economic terms. To assign dollar values to an intangible such as loss of life is very difficult and may never be realistic, but a methodology is available for incorporating such intangibles into he calculation of benefits.

The analysis methodology for justification, or priority setting, is based on three classifications of the length of warning time:

1. Long warning times, when damageable property can be moved and a cost savings calculated. Immediate flood dangers are not present and there is ample time for egress.

2. Short warning times, when safety and security of egress is the dominant concern. Damageable property cannot be readily moved and a

B/C analysis is not usable.

3. <u>A length of time between these extremes</u>, when justification for both property damage and safety is needed.

For long warning times, the existing river and flood forecast services allow enough time to move belongings, and the potential flooding is not an immediate threat to life and community safety. The time available is typically adequate to bring motor vehicles in to aid in the transfer of portable belongings - industrial, commercial, and residential belongings to safer locations. Egress from the flood area is relatively slow, permitting the occupants to remove more belongings than would be possible with less warning times. It is possible that lengthening the warning time from 18 hours to 24 hours, for example, may accrue enough benefits to justify a warning system.

The B/C analysis begins to falter when short warning times are involved because they require quick egress of people with no time to move belongings. When little time is available, safety and social well-being become the dominant evaluation factors. The cost savings from moving damageable property is nil, and a typical B/C analysis is not usable. Saving lives becomes the dominant justification. Lengthening the warning time by 30 minutes may save lives in a flash flood area, and this benefit will dominate the concern of the residents.

A period of warning time somewhere between long and short may allow the movement of damageable property, but the risk of lingering too long may in itself present dangers. Although a warning system might extend the usable time in which to prepare for a flood, a community plan would be needed to ensure appropriate response time. In addition, the cost saving from relocating damageable property might be marginal compared to the saving of lives.

Classification of an area according to the lenth of warning time is site-specific and highly dependent on the following discriminators:

1. rate of rise
2. extent in area of flooding
3. depth and velocity of water
4. access to and egress from flooded area
5. public services available
6. time available to move property
7. implementation of a community flood disaster plan

These discriminators must focus on the safety of the residents and the prevention of damage to their belongings.

For short warning times, the rate of rise and the velocity and depth of the flooding will be the dominant discriminators. Consideration will also be given to the extent of flooding, egress, and the development of a flood emergency action plan. The justification will be a significant increase in warning time that will save lives and lessen the dangers associated with egress. As an example, a life-threatening situation could occur when the rate of rise is 10 feet per hour, depths exceed 3 feet, and velocities exceed 3 feet per second. People who recognize the danger and react quickly may get to safe places. People who react slowly may be swept off their feet if they try to walk, be trapped by pockets of deeper water, or swept downstream into hazardous situations if they attempt to paddle a boat, drive a car, or swim. People who do not react to the short warning will be trapped where they are. If high ground or structures are not immediately available, or if the occupied structures cannot withstand the velocity of the water, these residents are at risk of losing their lives.

A flood warning system for short warning times should alleviate some or all of the dangers noted in the example. To calculate the benefits of such a system, quantify the rate of rise of flood waters in the developed areas, the velocity of flows through these areas, and the potential depths for various floods. Next, quantify, from this, any dangerous scenarios. Then determine critical warning, reaction, and egress times for the various floods. Improvements in the set times will be dependent on quick notification of residents. To assure this, the local community must immediately develop an emergency action plan that provides for notifying residents and obtaining their compliance for quick evacuation. When significant lessening of dangers can be quantified, the implementation of a warning system and emergency action plan can be justified.

For long warning times, justification will be based largely on the cost savings that will result from increasing the warning time. The primary discriminators will be access to and egress from the threatened areas, public services available before and during the flood, the time available to move property, and the timely implementation of a flood disaster plan. The rate of rise of the flood waters and the extent of flooding may be significant discriminators when flooding approaches a critical egress time. These parameters will be used to evaluate the benefits of increasing the time to evacuate or remove property. The savings to be accrued from the increased time, plus other savings, should be calculated according to appropriate State, local, or agency guidelines. Next, the cost of installation, operation, and maintenance (including periodic replacement of hardware) for the life of the system is determined. The benefits and costs are annualized, and the ratio of benefits to costs is determined. If the B/C is greater than 1.0, the system is usually justified.

For warning times between the two described above, a mix of justifications is undertaken. The relative importance of one type of justification over another will become apparent upon analysis of all the discriminators. Calculating the benefits for this classification of warning time will be more complex, since the life-threatening situations may materialize as belongings are being moved. Safeguards against a false sense of security are paramount, and a flood disaster plan is a must for this scenario.

To assure both economic justification and quick egress from dangerous floods, all warning systems require two essential components. If these components are not part of the overall plan, the system may create problems, dangers, and a false sense of security. Therefore, for a flood warning system to achieve its claims of cost savings and safe, timely egress, the following components are essential:

1. An emergency action plan designed to be implemented by local residents to aid in the timely, orderly movement of belongings and people.
2. The monitoring of available evacuation time to assure that people leave the threatened areas while critical time remains.

B. Lycoming County, Pennsylvania - An Example of an Integrated System

B.1. Hydrology of the Area

Lycoming County, Pennsylvania, is one of the most completely studied and thoroughly managed watersheds in the country. Lycoming County is predominantly rural, encompassing 1200 square miles in north central Pennsylvania. According to the 1980 census, a total of 118,416 people reside in the county, the majority in or near the Susquehanna River Valley, in the Williamsport urban area, and in the valley areas of the Susquehanna's tributary streams that flow to the river within the county.

Average rainfall varies throughout the watershed; the range is 35-40 inches per year. Flooding usually occurs when there is heavy rainfall in short time periods or when snowmelt combines with rain in the early spring. Ice jams may also cause flooding.

B.2. Background

A major effort was conducted to mitigate flood losses for the residents, businesses, and industries located in the flood plain of Lycoming Creek in the county through the development of an integrated local flood warning and response system. The system was developed because the area involved is considered critical to the county's future economic development and because it experiences costly annual flooding and threats of flooding that limit the achievement of its full potential. The goals of the integrated system development were to: (1) reduce yearly flood damages along the stream; and (2) improve emergency preparedness in the five most heavily populated political subdivisions involved.

The system has proved to be quite effective since its inception in 1976. During a flood event in March 1979, for example, the system was credited with reducing flood damages along the creek by $750,000. Residents, businesses, and industries received adequate warning of impending inundation and, as a result, had time to evacuate and relocate property that would otherwise have been damaged.

B.3. The Local Flood Warning System

Early flood warning has been provided to residents and property owners of the stream valley through a manual local flood warning system since 1976. A well established network of volunteer stream and gage observers provides the data necessary to make accurate flood forecasts. The county's manual system consists of more than 100 volunteer observers, a county flash flood coordinator and a flood prediction procedure developed by the National Weather Service. Data collected by the observers is compiled, interpreted, and used in the flood prediction procedure to determine whether a flood will occur, the time of its occurrence, and the magnitude expected. Appropriate notice (including projected water heights, areas of inundation, and warning and evacuation times) is given to the public and responsible officials so that protective actions can be initiated. The Lycoming Creek manual network, which is a subset of the county network, provides data from a system of four rain gages and three stream gages.

Late in 1982, the manual system was augmented by several automatic stream and precipitation gages provided by the National Weather Service to give warning of particularly heavy precipitation accumulations in remote areas or of sudden stream rises at night. Two flash flood alarm gages and four automatic precipitation gages were installed as part of the Integrated Flood Observing and Warning System. The alarm gages are located upstream of a location with high potential for flash flooding and are programmed to ring automatically in a home about 100 feet from their location and simultaneously in the county's communication center (EOC).

The county system can be activated in at least three ways. First, the system is activated if an observer or network coordinator notifies the county's Emergency Management Agency that a particular location has received 1 inch of rain in 12 hours in the winter or 2 inches in rain in 12 hours at any other time of the year. Second, the system is activated if the National Weather Service or a private weather forecasting service predicts conditions that could lead to flooding. Third, the system is activated if the flash flood alarm gages record critical stream levels.

The overall effectiveness of the system is enhanced by built-in backup systems. Because of possible errors in measuring watershed rainfall and computing runoff and stream height, and the vulnerability of any data collection and transmittal system, it is undesirable to depend heavily on a single aspect of the system. Thus, a series of backup communication devices, personnel, and additional data collection methods were included to provide the most accurate information possible.

Using hydrologic data, streamflow history, and United States Geological Survey (USGS) gage records, the Baltimore district of the Corps of Engineers, in conjunction with personnel from the County Planning Commission's Emergency Services staff, compiled detailed flood stage mapping for five densely and is using land-use controls aimed at discouraging inappropriate development in flood-prone areas.

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