Guidelines for Developing Comprehensive Flood Warning

Prepared by the Flood Warning Committee of the Arizona Floodplain Management Association

Presented at the

Arizona Floodplain Management Association
Fall Meeting - October 1996

and

Association of State Floodplain Managers, Inc.
20th Annual Conference - June 1996

GUIDELINES FOR DEVELOPING COMPREHENSIVE FLOOD WARNING

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

AFMA FLOOD WARNING COMMITTEE

Guidelines for Developing Comprehensive Flood Warning

ACRONYMS

AAUG	Arizona ALERT Users Group
ALERT	Automated Local Evaluation in Real-Time
AUG	ALERT Users Group
Corps	U.S. Army Corps of Engineers
CRS	Community Rating System
DCP	Data Collection Platform
EAP	Emergency Action Plan
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FPMS	Flood Plain Management Services
FTR	Flood Threat Recognition
LAN	local area network
MIC	Meteorologist-in-Charge
NFIP	National Flood Insurance Program's
NOAA	
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
ORE	Other Response Efforts
PAR	population at risk
SAAS	Southwest Association of ALERT Systems
USBR	U.S. Bureau of Reclamation
WAN	wide area network

GUIDELINES FOR DEVELOPING COMPREHENSIVE FLOOD WARNING[1]

By Laurie T. Miller[2], Tom Donaldson[3], Dallas Reigle[4], Jesùs Romero[5], Stephen D. Waters[6], Patricia Q. Deschamps[7], Sam A. Arrowood[8], and Wayne Cooley[9]

SECTION 1

INTRODUCTION

In recent years, there has been much progress in the development and implementation of local flood warning programs as a viable means of nonstructural flood control. Existing programs across the country offer a range of services and cover a variety of areas from very small to entire states. Despite vast differences in program components, there is one common frustration: the difficulty in progressing beyond collecting and monitoring data to actually removing people and property from a flood threat.

PURPOSE OF GUIDELINES

These guidelines are intended to serve two purposes. The first is to present the ***total commitment*** required to provide comprehensive flood warning services. The second is to offer suggestions on how to develop a customized, comprehensive program. It is hoped that these guidelines will assist communities in the early stages of program development as well as those which have operational programs but have not completely developed comprehensive services.

INTRODUCTION TO FLOOD WARNING PROGRAM ELEMENTS

A complete flood warning plan includes the development and coordination of three basic elements: 1) detection and evaluation of a flood threat; 2) dissemination of warnings; and 3) response to the warnings. A flood warning system must also account for potential failures in any of its components. Consideration needs to be given to planned redundancy and contingency in the system as backup in the event of a failure in any given functional area.

Successful flood warning must also include coordination between federal, state, and local government agencies and private sector organizations. As the system is used and tested, continual update and improvement of the flood warning plan is vital to maintaining an effective flood warning program.

---

[1]Paper presented at the Arizona Floodplain Management Association Fall Meeting, October 10-11, 1996, and the 20th Annual Conference of the Association of State Floodplain Managers, Inc., San Diego, California, June 10-14, 1996.

[2]Montgomery Watson Americas, Inc., Phoenix, Arizona.
[3]Lower Colorado River Authority, Austin, Texas.
[4]Salt River Project, Phoenix, Arizona.
[5]Yavapai County Flood Control District, Prescott, Arizona.
[6]Flood Control District of Maricopa County, Phoenix, Arizona.
[7]Geo. V. Sabol, Consulting Engineers, Inc., Scottsdale, Arizona.
[8]U.S. Army Corps of Engineers, Phoenix, Arizona.
[9]Arizona Department of Water Resources, Phoenix, Arizona.

Major components which must be addressed when planning and operating a comprehensive flood warning program include:

- Flood Threat Recognition
- Warning Dissemination
- Emergency Response
- Other Response Efforts
- Critical Facilities Planning
- Cost Components
- Maintenance
- Permits

Each of these components is introduced below. A more complete description is provided in later sections of these guidelines.

Flood Threat Recognition

A flood threat recognition system (FTR) is any system that is used to identify flood threat. It can be as simple as 24-hour monitoring of the NOAA Weather Radio, or can be a complex system of hardware and software which transfers real-time data to numerous locations. The effort required to install and maintain the FTR is typically significant. However, it is only the first step in achieving the end result of saving lives and property through flood warning.

Warning Dissemination

Dissemination of flood threat information is "getting the word out" *before* a flood occurs. Dissemination includes notification of emergency management, public works, and other essential personnel so that preventative steps may be taken to minimize the impacts of flooding.

Emergency Response

Emergency response is the community's action plan to respond to a potential flood threat and minimize loss of life and property. Ideally, a community's emergency response plan is initiated before flooding occurs to receive the maximum benefit of flood threat data and to minimize flood damages.

Other Response Efforts

Other Response Efforts (ORE) refers to efforts in a community's flood response plan which are not specifically tied to the flood warning program, but would significantly benefit flood fighting efforts in the event of a flood. Examples include identification in the flood response plan of specific tasks to be performed and by whom, and an inventory of resources along with what might be needed to fight a flood.

Critical Facilities Planning

Critical Facilities Planning is coordination of warning efforts with facilities which may have special needs or deserve special attention during a flood. Critical facilities include police and fire stations, hazardous materials storage, public and private utilities, hospitals, nursing homes, and schools.

Maintenance

A commitment to regular maintenance is required for the successful operation of any flood warning program. Maintenance of the FTR must be performed to minimize the occurrence of equipment failures during flood emergencies.

Cost Components

There are significant start-up costs to implement a flood warning program, and these costs vary widely according to the needs, size, and type of flood threat of the individual community. In addition to initial costs, there are significant on-going operational and maintenance costs incurred and event driven costs during and after a flood threat.

Permits

A wide range of permitting requirements may exist within a single flood warning program. Permits are typically required for the installation, operation, and maintenance of field equipment. Specific requirements and the time it takes to get authorization are different for every community. Depending on the existing land use and ownership, permits may be imposed by local, state, or federal agencies, Indian reservations, or private property owners.

CONTENT OF GUIDELINES

The remainder of these guidelines focuses on the elements described above, and how each typically fits into a flood warning program. Also presented are time and cost commitments involved in developing and maintaining a flood warning program.

It is noted that these guidelines are organized in accordance with the credit evaluation criteria for Activity 610, Flood Warning, under the National Flood Insurance Program's (NFIP) Community Rating System (CRS).

SECTION 2

FLOOD THREAT RECOGNITION

The equipment used to detect and monitor flood threat forms the backbone of a flood warning system, and a wide variety of components are available for selection. A description of typical components are presented in this section.

IDENTIFICATION OF FLOOD THREAT CONDITIONS

When designing or expanding an FTR, it is necessary to first identify local flooding characteristics so that detection and monitoring components can be selected which are appropriate for the local flooding conditions.

Description of Watershed

A good physical description of the watershed is necessary to determine the types of flooding that occur, areas threatened, what type of equipment will work in a given area, and emergency response requirements. An example description is:

> "The Wickenburg watershed is in west central Arizona in Maricopa and Yavapai Counties between the Vulture and Date Creek Mountains. The watershed is within the Gila Water Resource Subregion of the Lower Colorado Region. The Lower Colorado Region includes the State of Arizona and parts of Nevada, Utah, and New Mexico. The Gila River, the largest surface water system in the Region, rises in western New Mexico and flows generally west through Arizona to the Colorado River at Yuma. The largest tributary to the Gila is the Salt River which provides water for the Region's largest population center, Phoenix, Arizona. Other principal tributaries are the San Pedro and the Santa Cruz Rivers in the south, and the Agua Fria and the Hassayampa Rivers in the north.
>
> "The watershed is divided into two physiographic units characterized by particular combinations or patterns of topography, soils, climate, water resources, land use, and vegetative cover. The hills unit, approximately 12 percent of the watershed, is primarily hills and mountains with slopes ranging from 10 percent to 75 percent. The plains unit makes up approximately 90 percent of the watershed and is primarily alluvial fans with some low hills.
>
> "The average annual precipitation at Wickenburg is 11 inches. Annual rainfall is usually about equally distributed between the winter months of December through March, and the summer months of July through September. Daily precipitation of over three inches has been recorded. The area is characterized by high intensity short duration thunderstorms during the summer months. These thunderstorms normally cover less than 100 square miles, and the intensity of rainfall can exceed one inch in one hour. The winter precipitation normally comes from general rain

with much lower intensity than the summer rains. Snowfall is generally limited to trace amounts.

"The major drainage conveyances through the Wickenburg area are the Hassayampa River with its tributaries Martinez Creek, Sols Wash with it's tributaries Hartman Wash, Flying E Wash, and Casandro Wash, Sunset Wash with it's tributary Sunnycove Wash, and Powder House Wash. The Hassayampa River and tributaries are the focus of the Flood Threat Recognition system for the area.

Type(s) of Flooding

The two types of flooding generally present which prompt flood warning systems are flash floods, with peaks occurring in less than 6 hours, and/or rapid riverine floods, with peaks major water courses occurring in less than 48 hours.

Identification of Areas Threatened by Flooding

The area affected by flooding should be shown on a map or otherwise described. The description needs to include information about the nature of the flood hazard, such as flood depths, velocities, warning times, historical flood problems and special hazards. The following types of items should be covered: number, types and, if available, elevations of the buildings; land use (e.g., residential, commercial, industrial, open space, etc.); critical facilities; and historical flood problems, such as health and safety hazards. An example paraphrased from the NFIP's CRF Coordinator's Manual is:

"The City of Planton has three areas affected by flooding: the Planton River and Little Creek floodplains which are shown on the Flood Insurance Rate Map (FIRM) as "A Zones" and the Eighth Street drainage area, which is not shown on the FIRM. An inventory of these areas shows the following:

- In the A Zones along the two streams there are 187 flood-prone buildings: 151 single family homes, 8 multi-family buildings with 32 units, and 28 business properties. Only 12 of these buildings have been built or improved since floodplain regulations went into effect in 1983. Many of the older buildings have basements.

- There are 20 single family homes in the Eighth Street drainage area, all with basements.

- The area subject to the greatest damage is the Little Creek floodplain upstream of Third Street. This area has 139 single family homes and two multi-family buildings.

- All of the 28 businesses are located downstream of Third Street, with the greatest concentration between Third and Front Streets.

"Six critical facilities exist within the three floodplains which deserve special attention because they are vital to the community or pose a special hazard during a flood. These are identified below:

- A 100-year flood would damage the control and laboratory building of the City's wastewater treatment plant. The City would then be without sewage treatment for weeks.

- Three bridges cross the two streams: State Route 41, Front Street and Third Street. The State Route 41 Bridge is high enough so it should still be usable during a 100-year flood, but it must be monitored to ensure that it is save to use. The Front Street bridge is flooded during a 25-year flood and the Third Street bridge went under during the 1979 40-year flood. Closure of the two City bridges isolates the northeastern 20-block area of town. Traffic can only reach this area by taking a two-mile circuitous route to the north that depends on the Highway 41 bridge being open.

- The City's Police and Fire Station is on the edge of the floodplain. A 100-year flood would cover Front Street to a depth of two feet in front of the station, cutting off vehicular access. It also probably would flood the building's basement, which includes the City's Emergency Operations Center (EOC).

- Chemicals stored in above-ground tanks at the Farm Service Company's agricultural chemical storage yard include fertilizers, pesticides, and herbicides, several of which are kept in toxic concentrations.

Needed/Available Lead Time

The amount of lead time needed between the recognition of a flood event and the successful response to a flood warning greatly influences the type of FTR system that is required. Studies of past flooding events show that the factors which most directly influence threat to human lives are the size of the population at risk (PAR), the amount of lead time prior to flooding, and severity of the flooding event. Other key factors include previous experience with flooding and population density of an area.

The U.S. Bureau of Reclamation (USBR) has adopted procedures that estimate loss of life due to flooding based on the number of PAR, the amount of lead time, and adjustments due to local conditions. USBR's analysis of historic cases shows that for cases with lead time greater than 90 minutes, PAR is a very good predictor of loss of life. However, for lead time less than 90 minutes, other factors such as the time of day, the occurrence of prior flooding, and the severity of flooding, have a greater influence on loss of life. USBR's studies emphasize the importance of lead time. Improving lead time to 90 minutes or more reduces fatalities by over 90 percent.

A study performed at the Oak Ridge National Laboratory for the Corps Institute for Water Resources also showed that PAR is a good predictor of loss of life for greater lead time and that loss of life is greatly reduced with longer lead time. The Oak Ridge Laboratory's study also

showed that population density of an area has a strong influence on loss of life. In less populated areas, the warning process is not as efficient in disseminating the warnings because of lack of public officials and resources and because there is a larger area to cover.

The available lead time for an area may be determined by hydrologic and hydraulic studies performed on observed records where available, supplemented by rainfall-runoff analysis of observed and hypothetical frequency events. Many technical manuals and computer programs are available to assist in performing the hydrology and hydraulics studies.

SELECTION OF APPROPRIATE SYSTEM COMPONENTS

The major issue surrounding monitoring and detection is how much information is needed to detect an impending emergency. The answer to this question hinges on a number of factors including the complexity of the watershed being monitored, the adequacy of scientific theory or intelligence to predict an emergency, the type of data assessment that must be performed, the level of confidence desired in that analysis, and the resources available to support detection and warning. These needs vary among flood types and locations.

Assistance in developing a flood warning program may be obtained from other agencies such as the National Weather Service (NWS) or the U.S. Army Corps of Engineers (Corps), from private consultants, and from professional organizations. In the southwestern U.S., organizations such as of the Southwest Association of ALERT Systems (SAAS), The California ALERT Users Group (AUG), and the Arizona ALERT Users Group (AAUG) are excellent resources. Following is a list of components that may be used, all or in part.

Observers

Volunteer observers and inexpensive equipment, such as plastic rain gages, are often the first and least complicated component of an FTR. Precipitation amounts and/or stream staff gage readings can be relayed to emergency personnel via telephone.

Automated Gages

The two basic types of flood detection gages are precipitation and surface water level. Many choices are available from various vendors for each type of gage. The final system design will be greatly influenced by the availability of funding.

Base Station Hardware and Software

Depending on the level of sophistication that is justifiable, the base station hardware can be as simple as a telephone instrument for receiving observer data or as complex as a full-blown computer based automated data receiving, storage and management station. There are also many hydrologic and hydraulic software packages on the market for use in design, forecasting and/or operation of the FTR.

Radar and Satellite Data

The detection of the formation, approach, and passage of storm systems can play a major role in the early warning of a potential flood emergency. The primary precipitation detection systems are based on radar, satellite and lightning technology. Again, there is a broad spectrum of choices from simply looking out the window, for which there is no substitute, all the way up to purchasing a full radar receiving site. Other less expensive options include monitoring the Weather Channel on cable TV or a dial-up product to receive radar and satellite data via telephone modem into a personal computer.

Meteorological Support

Meteorological support in most cases is provided by the National Weather Service in the form of weather forecasts, flood watches, and flood warnings. If more detailed, site-specific meteorologic information is required for providing an area with sufficient lead time to effect flood preparations, then adding a staff meteorologist or a meteorological consulting service are two options to consider.

Decision Aids

Once the data are available, how does the responsible agency determine when to issue a warning? The tools available to answer this question range from a very basic manual system to a fully automated computer system. Manual systems could consist of tables, graphs, and charts derived from average rainfall and flood indexes. Computer systems can include sophisticated data management, modeling, forecasting, and automated warning dissemination. Individual components from the basic to the complex may be fit together to satisfy the needs and constraints of a particular flood warning system. Many may be modified to improve the efficacy, reliability, and lead time provided by the system. A listing of some of those pieces are:

- 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

COMMUNICATIONS

There are three types of data transmission communications available on the market today: telephone, radio and satellite. The type or types used will be determined by the characteristics such as topography, availability of equipment, available funds, and lead time.

Telephones

Telephones may be used by observers to call in data to a person, to a recorder, or to a computer by touch tone keypad input. They may be used at a remote location by automatic equipment to dial into a computer on a scheduled interval, or may be event driven. They may be used by a computer to interrogate field gages, and are a means of communication for warning of flood emergencies from the base station either by the computer or individuals monitoring the base station. The principal drawback is that phone lines often do not exist in remote areas where gages are needed. Also, telephone services frequently fail during flood events.

Radio

Radios use UHF, VHF or microwave line of sight transmissions, often event driven, to transmit data to a base station receiver/decoder which converts the radio signal to digital format for use by the computer. In large drainage basins or areas without line of sight from the gage locations, repeaters may be necessary. Repeaters generally receive and transmit at different frequencies when they transmit data directly to the base station receiver, but may receive and transmit on the same frequency when relaying data to another repeater. The most common format for radio data collection in use across the western United States is the Automated Local Evaluation in Real-Time (ALERT). The organizations mentioned earlier may be contacted for detailed information about ALERT, or there are several vendors of ALERT hardware and software.

Satellite

In large riverine drainage basins where lead times exceed 24 hours, satellite transmission of data may be a viable alternative. Satellite data are normally transmitted on a scheduled interval of several hours and therefore is less effective for short-duration flood events. In areas where line of sight radio transmissions require an extensive system of repeaters and there are no telephone lines, satellite transmission may be the only solution. The USGS and Corps of Engineers use satellite data collection platforms extensively in their operations.

Redundancy

Redundant communications equipment is always desirable when critical data are involved. Redundancy can be achieved by combining any of the previous data transmission methods at a single collection site, for example, a cellular phone backup at a satellite site. At very critical gage sites, it may be wise to install two sets of gage equipment (transmitters, sensors, batteries) and receive data from both.

SECTION 3

WARNING DISSEMINATION

Flood warnings are issued to reduce the risk to life and property through public and private channels. Before warnings can be issued, information pathways to the end-users of the warnings must be identified and optimized.

Flood warning dissemination provides critical linkage between recognition of an impending flood and execution of emergency response actions. The process consists of three primary functions: provisions for decision on whether or not to issue a warning (usually determined by preset criteria that is recognized by the FTR component), formulation of the warning message and identification of the appropriate audience, and means (radio, television, sirens, bull horns and door-to-door) of the distribution of the warning message.

Individuals perceived to be under threat of the impending flood should personally receive the warning message from a recognized person in a position of authority (i.e., mayor, law-enforcement personnel, fire fighters, designated block watch representative). The message, orally presented or distributed as a written handout, should state the time before the flooding occurs, its expected severity, and describe appropriate response actions (e.g., evacuation routes, safe shelters, protective actions).

IDENTIFICATION OF AGENCY GROUPS

The primary government agency responsible for flood warnings is the NWS. Existing local flood warning agencies rely heavily on interaction with the NWS for disseminating warnings to the general public. Very few, if any, local agencies warn the public directly. FTR and warning data are generally shared with the NWS via a local area network (LAN), dial-up connection, phone or fax, or by direct reception of the sensor data. Local agencies may provide FTR and warning data to state and local emergency management agencies, public safety agencies such as police, sheriff, and fire, and public works agencies such as street departments or hazmat teams.

Methods for communicating warnings to agencies and the public include broadcast via FM radio (in the case of NOAA Weather Radio), trailers on TV broadcasts, or activation of the Emergency Broadcast System, telephone trees, single-site or broadcast fax, transmission of computer files over modem, LANs, or wide area network (WANs), and two-way radio.

IDENTIFICATION OF TARGET PUBLIC GROUPS

In most cases, flood warnings to the general public are left to the National Weather Service. However, in some cases "target" groups are identified in areas which share a common serious flood threat and which might be missed by the casual TV watcher or radio listener. In these cases, a warning is first communicated by a public official by any of the above means to one or more designated individuals in the group. The designated individual initiates an existing

dissemination plan to warn the other group members. That plan could be a phone tree or a person physically traveling from house to house.

PUBLIC EDUCATION PROGRAM

When developing any warning dissemination program, public education should be addressed. Public education serves two purposes. First, a community who is aware of flood dangers will be less likely to require emergency rescues. Second, education will assist warning dissemination efforts because the public will have been informed on where to turn for flood information, what the warnings mean, and what actions to take. A continuing public education program is particularly important in communities which experience transient population trends, have infrequent floods, or both. Typical elements of such a program are discussed below.

News Media

The local news media can be an excellent format for public education programs. Local television and radio stations could participate in public service messages, timed to be aired prior to the flood season(s). Additionally, one radio and one television station should be designated for the public to tune in during a flood threat.

It is also beneficial to establish a relationship with the local news media so that during a flood, they can assist in the dissemination effort rather than distract emergency response staff and possibly hinder response efforts.

Videos

A professionally-produced video can be very useful in educating the public to local flood dangers. The video can be made available to various community groups including schools, colleges, libraries, homeowners associations, block watches, professional organizations, and others. It may be possible to enlist a local television or radio personality to narrate the video, thus increasing its credibility and professionalism in the public's eyes.

Pamphlets

Dissemination of flood threat information to the public in a non-emergency format can be easily and cheaply done through pamphlets. Material can include some simple definitions, what to do in case of a flood, and where to turn for additional information during an emergency or non-emergency. Pamphlets could be distributed at local schools, libraries, community centers, government offices, and special events such as fairs.

Children's Material

Many communities have developed children's material to educate them about floods. The most popular formats are coloring books and comic books. These also could be distributed at local schools, libraries, government offices, and special events.

Other programs could be developed for children in conjunction with printed material, such as preparing a talk on flooding to address groups such as boy/girl scouts and individual school classrooms.

SECTION 4

EMERGENCY RESPONSE

The essential element of warning dissemination for any community is a working Emergency Action Plan (EAP). Most communities have in place an EAP which covers many types of emergencies, including floods. However, the information may not be as specific to flood threat as desired. In order to assess its effectiveness from a flood warning operator's perspective, a few basic questions should be asked:

- What are the goals of the EAP?
- What are the goals of the flood warning program?
- Do the procedures in the EAP for flood emergencies meet its goals or the goals of the flood warning program?
- What is the outcome of acting on the procedures identified in the EAP?
- Is the EAP reactive or proactive?

DEVELOPMENT OF AN EMERGENCY ACTION PLAN

In answering the questions above, three major tasks are identified for developing or customizing an EAP. These tasks are identified and discussed below.

Identify Goals Of Emergency Response

The first step in developing or revising emergency procedures is to identify the goals of the existing EAP. Consider what the current EAP will cause the emergency manager to do (e.g., monitor flood hazards). Is the action consistent with the established goals?

Second, the flood warning program goals should be identified. These goals are typically to move people and property out of harm's way prior to a flood event. Are these goals met by the existing EAP?

Finally, once the EAP and flood warning program goals have been identified, the flood hazards should be identified as well as any operational or response constraints. Examples of response constraints may be a severely short time between flood detection and flooding, access to certain areas during severe storms, or distance between emergency resources and flood hazard.

Specific structures which require monitoring or areas affected by riverine or flash flooding should be inventoried. The means to achieve the goals for each hazard can be established, as described herein.

Identify Lines Of Communication

It will be necessary to identify what lines of communication and what actions would achieve the flood warning program goals. For example, in order to provide flood warning services downstream of a dam, the following lines of communication and necessary steps could be required:

1. At some point, a flood threat is recognized and the dam operator is notified.
2. Inundation maps and other available data are retrieved.
3. The dam operator notifies an on-call crew.
4. The on-call crew drives to the dam and reports in at regular intervals by radio, with a cellular telephone as back-up.
5. The crew reports any noticeable problems (e.g., piping on the face of the dam) as they occur.
6. Observed problems trigger mobilization of emergency crews and possible evacuation procedures.

Once communication needs are established, a detailed plan can be developed to include names, telephone numbers, and duties of the appropriate staff, as well as methods of communication.

Develop Criteria For Emergency Response

In order to provide consistent response and minimize chaos during a flood emergency, it is advantageous to develop pre-set criteria to act as triggers during a flood threat. For example, response to a dam emergency would be triggered by water level, rate of change of water level, or by special problems such as piping. Other flood hazards may require stage gage levels as triggers or results from a hydrologic model simulation using real-time precipitation data.

It is helpful to summarize all calculations and decision triggers in a chart which shows situation versus action. A simple graphical summary is very useful in emergency situations and the decision-making and response time is reduced.

Although consideration should be given to basing response decisions on real-time or model output, it must be recognized that model output data are less accurate, and confidence in the results should be correspondingly lower. In addition, it is very important to verify the stage data or hydrologic model data. A rating curve must be established for stage gages and revised as appropriate. Hydrologic models should be calibrated to historical flooding events.

INCORPORATION OF FLOOD WARNING IN AN EMERGENCY ACTION PLAN

In preparing these guidelines, it was assumed that an EAP already exists for an individual community. Therefore, the existing EAP would already have in place the following necessary components:

- Identification of the designated head of emergency management and back-up personnel
- An organization chart which identifies responsibilities of designated staff
- Inundation maps for various flood stages
- Emergency Operations Center
- Identification of outside agency coordination (local, state, and federal)
- Identification of post-emergency activities

If not already part of the existing EAP, flood warning program activities should be incorporated. The portion of the EAP which covers floods could be enhanced, or perhaps an appendix specific to flood warning and flood emergencies could be attached.

It is more advantageous to work within an existing EAP and not develop an independent document for the following reasons:

- No separate ordinance or approval is required for an existing EAP which has already been adopted
- Staff has familiarity with the existing EAP and its procedures
- The EAP will have been tested and is a "known commodity"
- There would be a mechanism already in-place for periodically verifying and updating information such as contact names and phone numbers

MAINTENANCE OF AN EMERGENCY ACTION PLAN

Like flood warning equipment, emergency response activities require periodic maintenance to verify that the components will work in a real emergency. It is essential to any program that practice drills are held at least annually in years where no flood occurs. Also, the EAP should be updated periodically, at least annually, to include any changes in staff, telephone numbers, and responsibilities.

It can be very helpful to invite outside agencies to participate in periodic drills. Inclusion of outside agencies (e.g., a city participates in the county's drill) is a better simulation of actual flood emergency situations and can help the flood warning operator better identify areas where the EAP should be enhanced.

After a drill is completed or flood occurs, it is important to hold debriefings and implement any necessary changes which may be discovered during the practice drill or actual flood.

SECTION 5

OTHER RESPONSE EFFORTS

One of the most challenging tasks in preparing an emergency response plan is to identify tasks and responsibilities which are specific enough to be useful, yet are not so specific that they become quickly outdated or do not allow flexibility needed in an ever-changing emergency situation. Theoretically, an emergency response plan would address all emergency situations. In addition, the response plan should accommodate resource information which could be easily retrieved in an emergency. Suggestions to accomplish these goals are identified in this section.

FLOOD-SPECIFIC RESPONSE PLAN

A community's emergency response plan should include a separate section for flood emergencies. Each major task would be assigned to an office, department, or individual. It is important that, in large organizations, an individual be identified as the person responsible for communication with other departments, as well as carrying out the task. A typical flood response section would address the following:

- What are the specific tasks to be performed?
- Who is responsible for each task?
- What is the method of communication?
- What are the names and phone numbers (including back-up persons) of responsible parties?

Summary Comparison of Resources

For each task in the flood response plan, it is very helpful if a summary comparison of resources is kept on file. Data to be collected include a list of what resources are needed to complete each task, the time required to perform the task, and the source(s) available to complete each task. For example, if a dike requires sandbagging during a flood, required tasks could include:

1. Notify designated responsible party
2. Pick up bags
3. Deliver bags to sand resource
4. Fill bags
5. Deliver bags to dike

Who performs these individual tasks? Where are the bags stored and where is sand available? Are there volunteer organizations (e.g., homeowners association, block watch groups) on-call to assist in the labor-intensive task of filling sandbags? These activities should be set up in advance in order to quantify needs and resources to better handle a flood emergency. A sample summary (**Table 1**) is presented below which could be used to quantify needs and resources in advance of a flood emergency.

Table 1
Sample Comparison of Resources

ERP Task	Responsible Party	Phone No.	Required Resource	Location	Alternate Location

SECTION 6

CRITICAL FACILITIES PLANNING

Critical Facilities Planning is the coordination of warning efforts with facilities which may have special needs or require special attention during a flood. Critical facilities include police and fire stations, hazardous materials storage, public and private utilities, hospitals, nursing homes, and schools.

It is important to identify critical facilities in order to provide timely evacuation if necessary. Obviously, it is very important to maintain an up-to-date, accurate list if individuals to contact in case of an emergency, including names and phone numbers of back-up personnel.

A community could require that an individual emergency response plan be developed for critical facilities. This could be developed by the critical facility and reviewed by the agency, or developed for the facility by the agency. An advantage of individual response plans for critical facilities is that during an emergency, required effort by the emergency response team is reduced because the critical facilities are performing some or all of the response tasks themselves. This does create additional effort in setting up and/or maintaining the individual response plan, but alleviates the drain on resources during the actual emergency when those resources are in highest demand.

Annual emergency drills should be a requirement of any individual response plan of a critical facility.

SECTION 7

MAINTENANCE

There are two basic types of remote flood warning systems - manual and automatic - and they vary in cost and complexity from a simple hand-held measuring device to more sophisticated sensors that automatically gather and transmit data from remote locations. Maintenance of the different types of systems will also vary, but the same basic principles apply to both.

A manual system might consist of a simple measuring device - a rain gage or staff gage - usually monitored by a volunteer and the data are relayed via telephone or radio (CB or ham). An automatic system might consist of a sensor (precipitation or stage), encoder, and a radio or Data Collection Platform (DCP). The DCP is usually powered by a solar-charged battery system and the data are transmitted through an antenna specifically designed for that particular radio-telemetry system. Maintenance of the more complex system is naturally more comprehensive and more expensive.

Any gage that is part of a flood warning system should be checked daily for proper operation. If the gage is at a remote location and can not be easily examined, the data from that gage should be verified each day. A preventative maintenance schedule should be devised that will ensure proper operation of the gage during a flooding situation.

The processing equipment, or base station, receiving data from the remote site should also be checked daily and should also have a preventative maintenance schedule that ensures proper operation when it is most needed. Redundant systems should be considered and service maintenance contracts should provide some of the needed preventative maintenance.

There should be enough spare parts readily available to create, or repair, one complete remote site, and any radio-relay sites. Standardization of all components will reduce the costs of inventory. The items that require replacement more frequently (solar panel, battery and antenna) should be stocked in larger quantities, depending on the size of the flood warning system and the availability of those items.

The degree of vandalism at remote gages is usually dependent on the location of the site. There are many methods of protecting equipment against vandalism, but those measures must be weighed against the value and ease of replacement of the equipment. Remote sites in heavily used areas will likely require more attention.

SECTION 8

PERMITS

Installation of flood warning equipment on lands used by other agencies or private parties will most likely require a permit to allow permission to install, maintain, and operate a flood detection station. Agencies installing flood detection stations should seek legally binding permits because they guarantee long-term use and access to the site. Types of permits, the time required to secure a permit, and typical permitting requirements are discussed in this section.

TYPES OF PERMITS

There are generally two types of land use permits: one for government-owned or managed land and one for privately-owned land. Examples of the first type include those granted by the U.S. Forest Service, Bureau of Land Management, State, Counties, Cities, Indian Reservations, military bases, and railroads. (Although railroads are not a government agency, permit requirements are similar.) These agencies usually have a Real Estate or Land Management department and have existing permit forms specifically for structures sited on their lands. If flood detection equipment is located within a designated floodplain or Special Flood Hazard Area, then a floodplain development or use permit may be required. There is usually a fee involved in obtaining a government permit, either a one-time fee, an annual fee, or both.

For the second type of land use permit, where stations are sited on private land, it is helpful to develop a permit form for the property owner to sign. In many cases on private land, authorization can be obtained at little or no cost, and a private site can offer the advantage of information exchange over time with the property owner. Some landowners may hesitate to grant permission to locate equipment on their property if they feel they are being forced to cooperate or if they are concerned that they will not be able to change their minds at a later date. In these instances, it is helpful to note in the permit that the landowner has the authority to cancel the permit with a reasonable allowance for equipment retrieval.

Another required permit involves the licensing of any radio equipment in the system, and the assignment of a radio frequency(s) to the system. Radio licenses and frequencies are granted by the Federal Communications Commission through a federal sponsor. The Meteorologist-in-Charge (MIC) or the Service Hydrologist at the local NWS office can provide guidance for securing this type of permit. Other assistance may be available from federal agencies such as USGS, USBR, and the U.S. Forest Service.

TIME REQUIREMENTS TO SECURE PERMITS

The permit process can and usually does take a considerable amount of time, varying anywhere from a couple of weeks for a private party to a year or more for some federal agencies. Depending on conditions at the site, a government agency may require inspection by utilities, an archeologist, a botanist, and/or an environmental engineer. These stipulations take time to fulfill.

It is a good idea to begin the process of procuring permits as soon as station sites are selected so that they are in place when equipment is ready for installation.

TYPICAL PERMITTING REQUIREMENTS

Following is a list of information which is typically required when filling out a permit application for a government agency:

1. The name, address, and authorized agent of the applicant.
2. A brief description of the overall flood warning system and its purpose.
3. A detailed drawing or picture of the equipment being installed and a description of its function.
4. A map showing the station location and access routes.
5. A legal description of the site (i.e., township-range-section, the latitude/longitude, or both) and elevation.
6. The expected length of time the equipment will be in place.
7. Any expected operation and maintenance activities, their duration, and their frequency.
8. Any possible effects on wildlife or the environment, with documentation.
9. A statement of financial and technical ability to construct, operate, maintain, and terminate the proposed equipment.
10. Benefits (non-monetary) to the agency, environment, and public.
11. Opportunities for the agency to access or retrieve data collected at the site.

For private land use permits, it is also helpful to provide the information listed in items 1-8 above.

SECTION 9

COST COMPONENTS

An overview of cost components incurred in the implementation of a flood warning system is presented in this section. Actual dollar amounts have not been included because flood warning program needs are unique to each community and are affected by the size, complexity, and type of flood threat of the watershed. Instead, cost components within a typical program are identified and are categorized as follows:

- Initial costs to investigate, design, and implement the plan components
- Annual costs to maintain the program components in a state of readiness
- Event-driven costs to implement specific actions during and after a flood

Information is also provided on potential sources of technical assistance and system funding at the federal, state, and local levels.

INITIAL COST COMPONENTS

The first step in establishing an effective flood warning capability is the development of a comprehensive flood warning plan. The objectives are to perform an evaluation of the community's flood warning needs versus resources, to establish procedures which address those needs, to design a suitable flood warning system, and to develop funding strategies for system implementation.

The initial costs associated with the development of the flood warning plan are predicated on the detail and complexity involved, but would involve personnel costs and/or fees for professional services to perform the initial plan development. The cost of a flood warning system must be evaluated in conjunction with the benefit to the community in reducing personal and property damage.

As previously stated, the FTR component can range from basic operations such as 24-hour monitoring of the NOAA Weather Radio to a complex system of hardware and software which transfers real-time data to numerous locations. Clearly, associated costs vary significantly with the type and level of FTR selected as part of the overall flood warning plan. If the FTR component is comprised of a network of flood detection hard/software, the initial costs are significant. Additional costs are incurred in the necessary task of acquiring an inventory of spare parts and materials. Once the equipment is purchased, costs will be incurred to install the system, provide training, and obtain hardware/software technical service.

Less expensive detection options could be used in lieu of, or in conjunction with, flood detection equipment in the field. These options include, among others, acquiring access to available data from regional detection networks operated by other agencies or the development of a local cooperative observer network. The combination of flood prediction and detection options which

fit a community's needs and resources would be determined during the development of the flood warning plan. Cost considerations must be addressed at that time.

The need for meteorological support should also be assessed. In addition to NWS flood forecasts, watches, and warnings, more localized information may be available from public and/or private sources, or in-house forecasting capabilities could be established. The choices made regarding the type and complexity of data required directly impact the associated costs. Another factor to consider is that, in general, meteorological data can provide greater lead time but with reduced accuracy.

Warning dissemination is triggered by the recognition of an imminent flood event. Affected areas must be quickly determined and affected parties identified so that vital information can be communicated to them and appropriate response measures activated per the flood warning plan. Initial costs are those incurred to establish communication links with the appropriate parties and develop flood warning products that would be transmitted via those links. Again, costs are directly related to the level of sophistication required to meet the needs and fit the resources of the particular community.

The initial costs of the emergency response component are those incurred to allocate or acquire the necessary personnel, equipment, and financial resources to meet the needs identified in the flood warning plan. A detailed response plan must also include provisions for proper coordination between federal, state and local government agencies and private sector organizations. Costs are incurred in providing initial personnel training and in agency coordination activities. However, emergency response costs are typically considered in-kind services and are not directly attributed to flood warning program costs.

Finally, permit and/or licensing fees will most likely be required for installation and use of field and base station equipment.

ANNUAL COST COMPONENTS

The flood warning plan is considered a working document which benefits from periodic review and evaluation as the system is implemented and becomes fully functional. Required updates and/or improvements to any component(s) should be identified as the system is used and tested during simulated or actual flood emergencies. The goal is to optimize the effectiveness of the flood warning capability. Annual costs for flood warning plan management include the cost of the time spent in evaluating the system and the cost of implementing any recommended improvements.

The FTR component requires regular maintenance of field equipment and possibly replacement. The periodic evaluation of the overall effectiveness of the flood warning plan may lead to equipment upgrades and/or additional installations at new sites to expand the network or to develop system redundancy. As a result, periodic replacement or supplement of spare parts and materials would occur. Annual operation and maintenance costs vary with the amount and type of detection equipment involved.

Annual costs associated with the FTR can include the acquisition of hydrometeorological data and forecast products from public or private sources or the cost to maintain in-house meteorological capabilities. Another potential cost can include developing/refining hydrologic and hydraulic models for use in predicting lead times and determining high-risk flood areas. This information directly impacts the warning dissemination and emergency response components of the flood warning system.

In addition to annual costs for equipment, costs are associated with the management, processing, quality control, and storage and maintenance of the database created from detection data.

Annual costs are incurred to operate, maintain, and upgrade the communications equipment of the warning dissemination component. Additional costs can incurred to modify the communications network to develop system redundancy. Similarly, expanding the group of warning message recipients and/or warning products could add to cost.

Another important element of warning dissemination is the development of public awareness programs to inform the public about local flood hazards and the flood warning system. The development and distribution of public information products is a necessary annual cost. Such products include public service announcements for radio and television, educational videotapes, pamphlets, brochures, etc.

Annual emergency response costs are similar to the initial costs in that the periodic evaluation of the flood warning plan could lead to adjustments and improvements to the number of necessary personnel, equipment, and financial resources. Also, some costs would be incurred in staging regular training exercises and periodic drills.

Finally, in addition to initial permit and/or licensing fees, annual fees may be imposed.

EVENT-DRIVEN COSTS

During a flood event, certain vital services will need to be provided on a 24-hour basis. These may include:

- Temporary evacuation
- Search and rescue
- Mass care center operations
- Public property protection
- Flood fighting
- Maintenance of vital services

The emergency response personnel responsible for providing these services are sheriff, police, and fire department personnel and emergency relief organizations. It is difficult to distinguish between local flood warning response plan cost items that fall under existing agency operations and those activated during a flood emergency which are not otherwise tracked.

The following is a partial list of additional costs a community could expect in the event of a flood emergency:

- Personnel overtime and emergency hiring
- Equipment purchase and rental
- Transportation and storage of public property
- Material and supplies consumed during response efforts

The post-flood recovery effort would vary for each event and for each community. A partial list of post-recovery elements follows; each is a potential source of event driven costs:

- Evacuee return
- Debris clearance
- Return of services
- Damage assessment
- Provisions for assistance

POTENTIAL SOURCES OF FUNDING AND TECHNICAL ASSISTANCE

There are several potential funding and technical assistance sources available on the federal, state, and local levels, as described below. It is important to understand that funding is nearly always through cost-share agreements where the local community must fund a portion of the costs and also agree to operate and maintain the system once it is installed.

U.S. Army Corps of Engineers

The Corps can assist communities in two ways: 1) provide technical services and planning guidance on floods and floodplain issues; and 2) provide emergency flood fighting during an event when the situation is beyond the resources of the state.

The Corps' Flood Plain Management Services (FPMS) staff are available to assist federal, state, and local government agencies and others in implementing flood warning/preparedness programs. The focus is to define the existing conditions and arrangements, postulate potential enhancements, and evaluate and recommend specific actions.

The investigation of flood warning/preparedness programs is covered under existing authorities and Corps regulations related to the FPMS program. Under this program the Corps is authorized, upon request by other federal or non-federal entities, to provide a full range of technical services and planning guidance on floods and floodplain issues under the general umbrella of floodplain management. Flood warning/preparedness planning is included in these services.

The other function the Corps during flood events is emergency response. Its focus is on major events; it does not become involved until after a state or presidential declaration has been made. Following a declaration, the state can request assistance from the Corps for emergency flood fighting. Typical flood fighting activities performed by the Corps or its pre-selected contractors include sand bag placement, remedial repair of levee breaks, or raising levee height. In the case of a presidential declaration, The Corps may become involved as part of the federal response plan coordinated by the Federal Emergency Management Agency (FEMA).

National Weather Service

The NWS is a key resource for technical assistance in developing and operating a flood warning program. The NWS has been authorized by Congress to issue of meteorological and hydrological forecasts and flood watches and warnings. To accomplish its mission, the NWS gathers data from a variety of sources and uses that information to determine the potential hazard for any given area from events such as tornadoes, severe thunderstorms, winter storms, and floods. A partial list of information sources includes surface observations, balloon observations, severe weather spotters, law enforcement agencies, remote automatic sensors, radar and satellites.

The NWS produces and issues various hydrometeorological forecasts and warnings. These include routine forecasts, special or severe weather forecasts/warnings, and stream or river forecasts. Additionally, NWS receives vast amounts of outside agency hydrometeorological data and makes that data, as well as NWS data, available to users.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) recognizes the use of flood warning systems along with other nonstructural and structural measures as means of reducing flood damages. NRCS 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), NRCS can fund up to 80 percent of the installation costs for a flood warning system. Similar funding authorities are available under the Resource Conservation and Development Program. Because the principles and guidelines of this program are applicable to the watershed program, flood warning systems must be economically justified to be eligible for cost-share assistance. 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 dissemination system.

The NRCS may participate in pilot projects to demonstrate new technology or to gain acceptance of innovative approaches using special limited funds available under the Resource Conservation Act.

State and Local Agencies

Funding and technical support on the state level varies from state to state, but typically includes state departments such as Water Resources and Emergency Management. Valuable technical

assistance can be provided to procure, install, and troubleshoot equipment and to provide training on the operation of equipment, and emergency response training. Maintenance agreements may also be available.

Similar technical assistance may be available from local agencies with operational systems such as flood control districts or nearby cities. Exchange of information is very helpful, programming support may be available, and maintenance agreements can be economical, depending on the relative locations of flood warning program boundaries.

Technical assistance can also be obtained from regional and local professional or organizations such as SAAS, California AUG, or AAUG.

SECTION 10

SUMMARY

A common frustration among operators of flood warning systems is the difficulty in evolving from a data collection and monitoring system to one that saves lives and property from flood threat. These guidelines offer a description of the total commitment required to develop comprehensive flood warning services, and suggestions on how that goal might be achieved.

A complete flood warning plan includes flood detection and evaluation of a flood threat, dissemination of warnings, and response to those warnings. Information was provided on a broad range of components so that individual communities could use the data as "building blocks" suited to their specific needs, opportunities, and constraints.

Potential cost components were identified which would need to be considered when seeking funding for a flood warning program. Actual dollar amounts were not included because specific needs are unique to each community and are influenced by the watershed size, complexity, and type of flood threat. Costs were identified as initial, annual, and event driven costs. Finally, funding and technical support sources were identified to assist in financing and operating a flood warning program.

It is hoped that those considering creating a flood warning system might have a better understanding of the steps involved in implementing a system and those already involved in flood warning may discover some ways in which their existing system can be improved.

AFMA FLOOD WARNING COMMITTEE

Guidelines for Developing Comprehensive Flood Warning

REFERENCES

Arizona Floodplain Management Association Flood Warning Committee, "Applying for CRS Flood Warning Credit: It *Can* Be Worth It", 1994.

Communication of Emergency Public Warnings; Dennis S. Mileti and John H, Sorensen, 1990.

Curtis, David C., "The Cost of Flood Warning Systems", presented at the Conference of the Southwestern Association of ALERT System, October 1994.

Federal Emergency Management Agency, "National Flood Insurance Program Community Rating System Coordinator's Manual", June 1993.

Flood Control District of Maricopa County, Arizona, "Wickenburg Flood Warning Plan" working document, 96.

Geo. V. Sabol Consulting Engineers, Inc., "Statewide Hydrologic Data Collection/ Dissemination Network", Flood Control District of Maricopa County, Arizona, 1995.

Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data, "Guidelines on Community Local Flood Warning and Response Systems", 1985.

Montgomery Watson, "Flood Warning Services Market Survey Study", Flood Control District of Maricopa County, Arizona, 1990.

Naud, Bob, Flood Control District of Maricopa County, Telephone Communication, 1996.

U.S. Army Corps of Engineers, "Arizona Flood Control Study, Arizona - Reconnaissance Report", September 1994.

U.S. Army Corps of Engineers, "General Guidelines for Comprehensive Flood Warning/ Preparedness Studies", 1988.

U.S. Army Corps of Engineers, "Proceedings of a Seminar on Local Flood Warning - Response Systems", 1986.

U.S. Water Resources Council, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies", 1983.

Urban Drainage and Flood Control Dsitrict, "Ralston Creek Flood Warning Plan, City of Arvada and Jefferson County, Colorado", 1994.