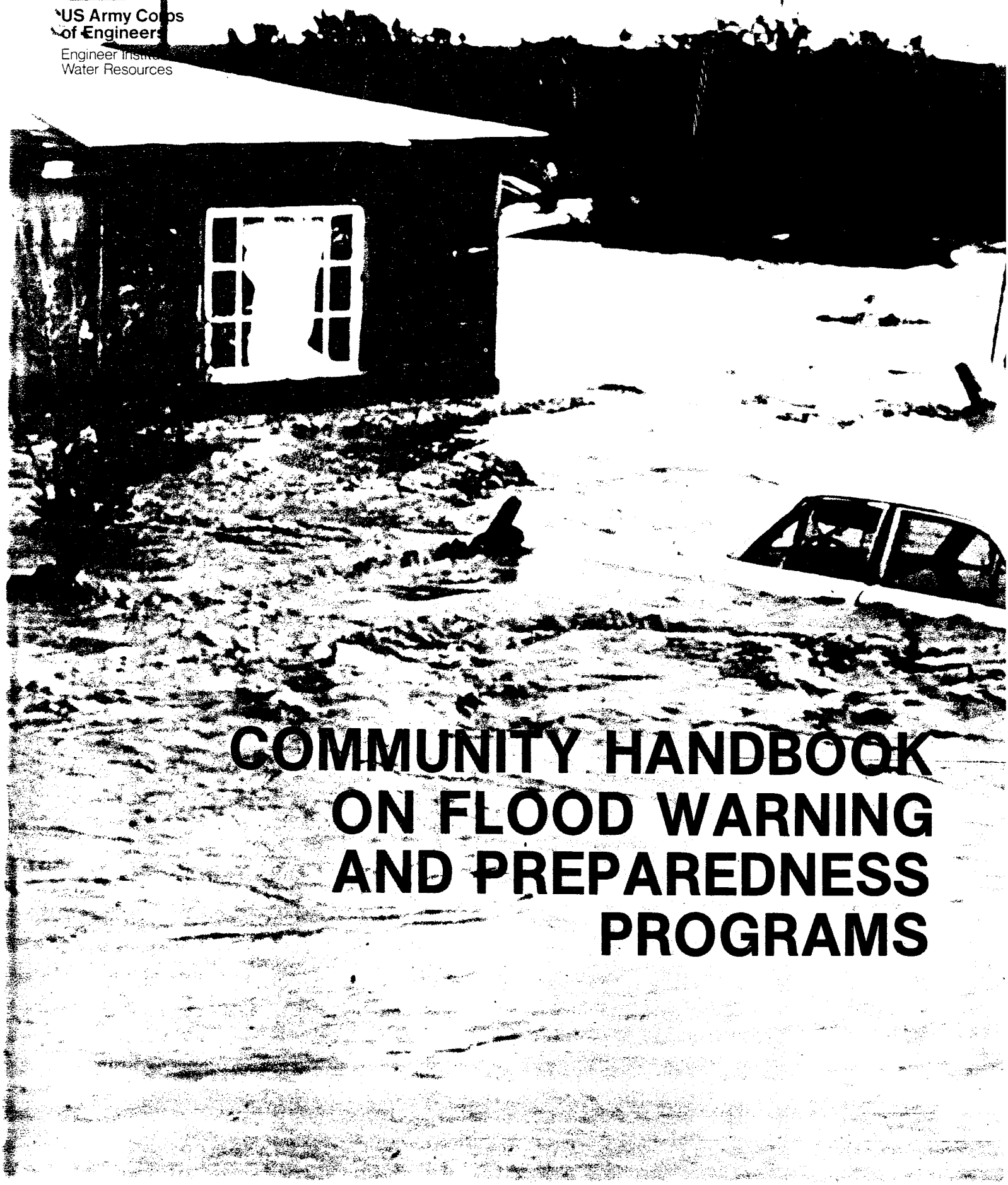
RESEARCH REPORT 81-RO6
AUGUST 1981

US Army Corps
of Engineers
Engineer Institute
Water Resources



COMMUNITY HANDBOOK ON FLOOD WARNING AND PREPAREDNESS PROGRAMS

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 81-R06	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Community Handbook on Flood Warning and Preparedness Programs		5. TYPE OF REPORT & PERIOD COVERED Research - 81-R06 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) H. James Owen and M. Wendell		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Owen and Wendell Associates 4145 Maybell Way Palo Alto, California 94306		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Corps of Engineers Institute for Water Resources Water Resources Support Center Fort Belvoir, Virginia 22060		12. REPORT DATE Aug. 1981 13. NUMBER OF PAGES 57
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/ DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Flood Warning	Recognition System	Examples
Preparedness Program	Sensor Systems	
National Weather Service	Decision-making	
Plan Execution	Maintenance	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the activities, procedures, and other factors which make up a local flood warning and preparedness program. The program can be divided into four major elements: flood recognition system; warning arrangements; preparedness plan; and arrangements for maintenance of the program. The program is credited with saving scores of lives and preventing millions of dollars of damage. Successful implementation of flood warning systems may result in saving lives and reduction in flood damages.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

COMMUNITY HANDBOOK

ON

FLOOD WARNING AND PREPAREDNESS PROGRAMS

a report
submitted to

Institute for Water Resources
Water Resources Support Center
U.S. Army Corps of Engineers
Kingman Building, Fort Belvoir, VA

by

H. James Owen and M. Wendell
Palo Alto, California

Aug. 1981

Research Report 81-R06

Copies may be purchased from:

National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22151

This report is not to be construed as necessarily representing the views of the Federal Government nor of the U.S. Army Corps of Engineers.

TABLE OF CONTENTS

LOCAL FLOOD WARNING AND PREPAREDNESS

INTRODUCTION

Common sense suggests that people in the path of floods should be warned so that they can take action to protect their lives and property. Over 20,000 populated areas in the United States are subject to some degree of flooding and several thousands of these communities would benefit greatly by some type of local flood warning and preparedness program. Only a few hundred communities already have such programs.

The concept of a local flood warning and preparedness program is straightforward. Rainfall amounts and/or stream levels upstream of the area to be protected are measured and the information is used to predict downstream flows. If the predicted flows are sufficient to cause flooding, appropriate warnings are then issued to the public in the affected area and to officials responsible for taking or directing preplanned protective action. The activities, procedures and other things which make up a local flood warning and preparedness program can be conveniently divided into four major elements, namely the:

1. Flood recognition system, consisting of the equipment, people and procedures to collect the data on rainfall and/or stream levels, analyze it, and make the prediction of downstream flows;

2. Warning arrangements, consisting of the procedures and means for interpreting predictions in terms of

any area(s) to be flooded and for issuing and disseminating warnings to affected parties:

3. Preparedness plan, describing the actions to be taken before, during and immediately after a flood to mitigate its impact: and

4. Arrangements for maintenance of the flood recognition system, warning arrangements and preparedness plan.

The local flood warning and preparedness programs developed to date work extremely well. They are credited with saving scores of lives and preventing millions of dollars of damage. The information made available through local flood warning and preparedness programs is also credited with enabling communities to avoid unnecessary evacuations and other overreactions when floods threatened but did not occur.

BENEFITS OF FLOOD WARNING AND PREPAREDNESS PROGRAMS

The overall purpose of flood warning and preparedness programs is to reduce the impact of flooding. The principal ways of accomplishing that purpose are by improving safety, reducing losses from property damage, and/or reducing economic losses other than property damage. Tables 1, 2, and 3 list some of the ways in which flood warning and preparedness programs may contribute to safety and loss reduction. The extent to which programs can provide the types of benefits cited in Tables 1 through 3 depends largely on the length of warning time that is made available and the nature of response actions which are preplanned.

TABLE 1
POTENTIAL BENEFITS OF FLOOD WARNING AND PREPAREDNESS PROGRAMS FOR SAFETY

* Evacuation of hazardous areas prior to flooding, thereby reducing risks to both evacuees and rescuers;

* Provision of early alerts and any needed assistance to individuals who are invalid or handicapped, and other persons or organizations which require more than the normal amount of time to evacuate;

* Provision of a basis for deciding the opening and closing of schools, transportation of students, and release of employees from work so as to minimize exposure to danger;

* Timely institution of appropriate traffic controls to prevent travel into hazardous areas and facilitate evacuation;

* Deployment of personnel and equipment to assure medical, fire, police, and other services are continued and available to all parts of the community;

* Emergency management of gas and electric services and other actions to avoid fire, explosion and other secondary problems; and

* Minimization of public health problems in the post-flood period.

TABLE 2
POTENTIAL BENEFITS OF FLOOD WARNING AND PREPAREDNESS PROGRAMS FOR REDUCTION OF PROPERTY DAMAGE

* Movement out of the flood plain or to a safe elevation of automobiles and other mobile equipment, furniture, valuable papers and documents.

business stocks, harvested crops, livestock and other property;

* Protection in place of fixed equipment by disconnection of electrical service, greasing, wrapping and other techniques;

* Protection of structures by sandbagging, anchoring, implementation of semi-permanent floodproofing measures, intentional flooding of basements and other means.

TABLE 3
POTENTIAL BENEFITS OF FLOOD WARNING AND PREPAREDNESS PROGRAMS
FOR
REDUCTION OF LOSSES OTHER THAN PROPERTY DAMAGE

* Orderly shutdown of production facilities or modifications in procedures to continue production;

* Faster and less expensive return to normality, resulting in reduced unemployment, smaller losses in sales, and less reduction in sales taxes collected;

* Prevention of undue reductions in property value and consequent reductions in tax revenues;

* Reduced costs due to fire, explosion, contamination of water supplies, sewage spills and other secondary problems;

* Reduced needs for overtime of employees for flood fighting, rehabilitation and other purposes;

* Elimination of costs for precautionary actions found later to have been unnecessary;

* Reduced costs for emergency shelter, care and public assistance for evacuees;

* Reduced risk of liability for injury to or death of patrons, students, patients, visitors and employees of public and private facilities; and

* Reduced costs for flood insurance through reduction in amounts of coverage required.

In addition to reducing risk to life and property, flood warning and preparedness programs may also be beneficial in other ways. For example, a program demonstrably capable of reducing flood damages to certain types of insurable property might result in reduction of the premium rate for coverage under the National Flood Insurance Program. Or availability of a good warning and preparedness program may reduce the needed size and cost of structural protective works. Such programs also provide local officials the facts to relieve anxieties about flood dangers and squash rumors.

Virtually any area with a significant flood problem can benefit from the availability of adequate flood warning and preparedness arrangements either alone or in conjunction with structural or other nonstructural measures. Even areas for which some level of protection has already been provided may benefit from supplementing existing protective measures with a warning and preparedness program. Local flood warning and preparedness programs are likely to be found economically beneficial in a wide variety of cases due to their relatively low cost.

NEED FOR LOCAL WARNING AND PREPAREDNESS PROGRAMS

Local flood warning and preparedness programs are needed generally for one or more of three reasons including inadequacies in:

Flood warnings normally provided by the National Weather Service;

- Existing local arrangements for handling flood warnings; and/or

- Existing local preparedness plans.

Inadequacies in NWS Warnings

The National Weather Service (NWS) routinely issues specific forecasts of flood stages for about 2,300 locations in the United States for which detailed information is available and for which forecasting procedures have been developed. Most of these locations are along the Nation's major rivers. For the thousands of other areas subject to flooding, the information provided on flood potential by the National Weather Service is limited to flood watches, flood warnings, and other types of generalized statements based on radar, sattelite imagery, synoptic data and scattered reports. Generalized warning statements usually cover several counties or streams and only advise that flooding could occur. They do not always provide a sufficiently accurate and reliable basis for undertaking evacuation or other protective actions which involve significant inconvenience, disruption or cost. In addition to the lack of data needed for specific forecasts of flooding, the National Weather Service is constrained in providing accurate and timely warnings for some areas due to other problems including:

- Lack of 24 hour operation of all NWS offices;

- Lack of sufficient personnel in some NWS offices to prepare and disseminate forecasts on a timely basis; and

- Incomplete coverage of the Nation by means for rapid dissemination of NWS warnings such as the NOAA Weather Wire and NOAA Weather Radio.

In addition, the value of the flood warnings which are available from the National Weather Service often is lessened by inadequate preparation for their receipt on the part of public officials, businesses and individuals. Not all communities routinely provide 24 hour a day monitoring of statements issued by the National Weather Service.

Inadequacies of Local Warning Arrangements

In order to make effective use of flood forecasts and warnings available from the National Weather Service, community officials must be able to interpret the information in terms relevant to the local area and distribute appropriate warnings. Interpretation of specific forecasts of stages requires identifying the area(s) which will be affected by each predicted flood height. Distribution of warnings requires the capability to deliver the warning message(s) on a timely basis to all affected parties. Common inadequacies in local warning arrangements include lack of:

- Information necessary to interpret NWS warnings in terms of the area(s) to be affected;

- Identification of all of the people and organizations affected by flooding of various areas;

- Specific and detailed procedures for carrying out the warning dissemination process; and

- Means for rapid distribution of warnings which are reliable under adverse conditions such as loss of regular sources of electrical power.

Inadequacies in Local Preparedness Plans

Most communities have some sort of generalized plan for dealing with emergencies. However, such plans are often oriented toward war related emergencies or to an "all hazards" approach. Various sorts of deficiencies may affect the adequacy of generalized preparedness plans including:

* Emphasis on recovery from disasters rather than on their mitigation;

* Emphasis on general coordination and communications activities rather than on those activities specifically relevant to flood emergencies;

* Failure to assess the need for and plan evacuation, traffic control, warning, and other activities in terms specific to flood situations;

* Failure to encompass adequate educational and informational activities to assure familiarity with the plan on the part of people and organizations making up the community;

* Failure to provide the equipment, personnel and supplies necessary for full and proper execution of the plan;

* Failure to implement the plan effectively through ordinances, contracts, memoranda of understanding and other ways; and

* Lack of familiarity with the plan on the part of elected and appointed officials responsible for directing its execution.

Not all of these deficiencies may affect a particular general preparedness plan but any of them which do may prove disasterous in the event of serious flood.

THE FLOOD RECOGNITION SYSTEM

The purpose of the flood recognition system element of a warning and preparedness program is to determine if a flood is impending and predict the time of its occurrence and its magnitude. The flood recognition step is vital to a warning and preparedness program because it provides the trigger for putting the warning arrangements and preparedness plan into action.

Two basic approaches are available for flood recognition. The one most commonly used is prediction of floods based on precipitation received in upstream areas. The alternative approach is prediction of flooding based on measurements of upstream water levels.

Approaches based on measurement of upstream water levels are generally the most accurate. However, they can only provide a length of warning time equivalent to the time required for flood waters to travel from the upstream point of

measurement to the protected area. Flood recognition systems based on rainfall generally provide longer warning times because of the additional time required for surface runoff to reach streams.

Various flood recognition systems can be developed by combining these basic approaches, the amount of data collected and the manner of data collection, the types of analyses performed, and the extent of automation or computerization employed in the system. The type of approach, equipment and degree of automation which are combined to make up a system, along with its comprehensiveness of coverage, determine the system's effectiveness.

The five basic types of flood recognition systems now in use can be categorized as: a) automatic upstream water level sensor systems; b) volunteer operated manual precipitation systems; c) volunteer operated manual crest-stage projection systems; d) automated precipitation systems; or e) combined systems.

Automatic Upstream Water-Level Sensor Systems

Automatic upsteam water-level sensor systems employ one or more upstream water-level sensors which signal a remote station, usually in the protected area, when a predetermined stream level is exceeded at the sensor location(s). A variety of equipment has been or is available for the purpose.

One item of this type is the Flash Flood Alarm. Use of a Flash Flood Alarm is illustrated in Figure 1. It consists

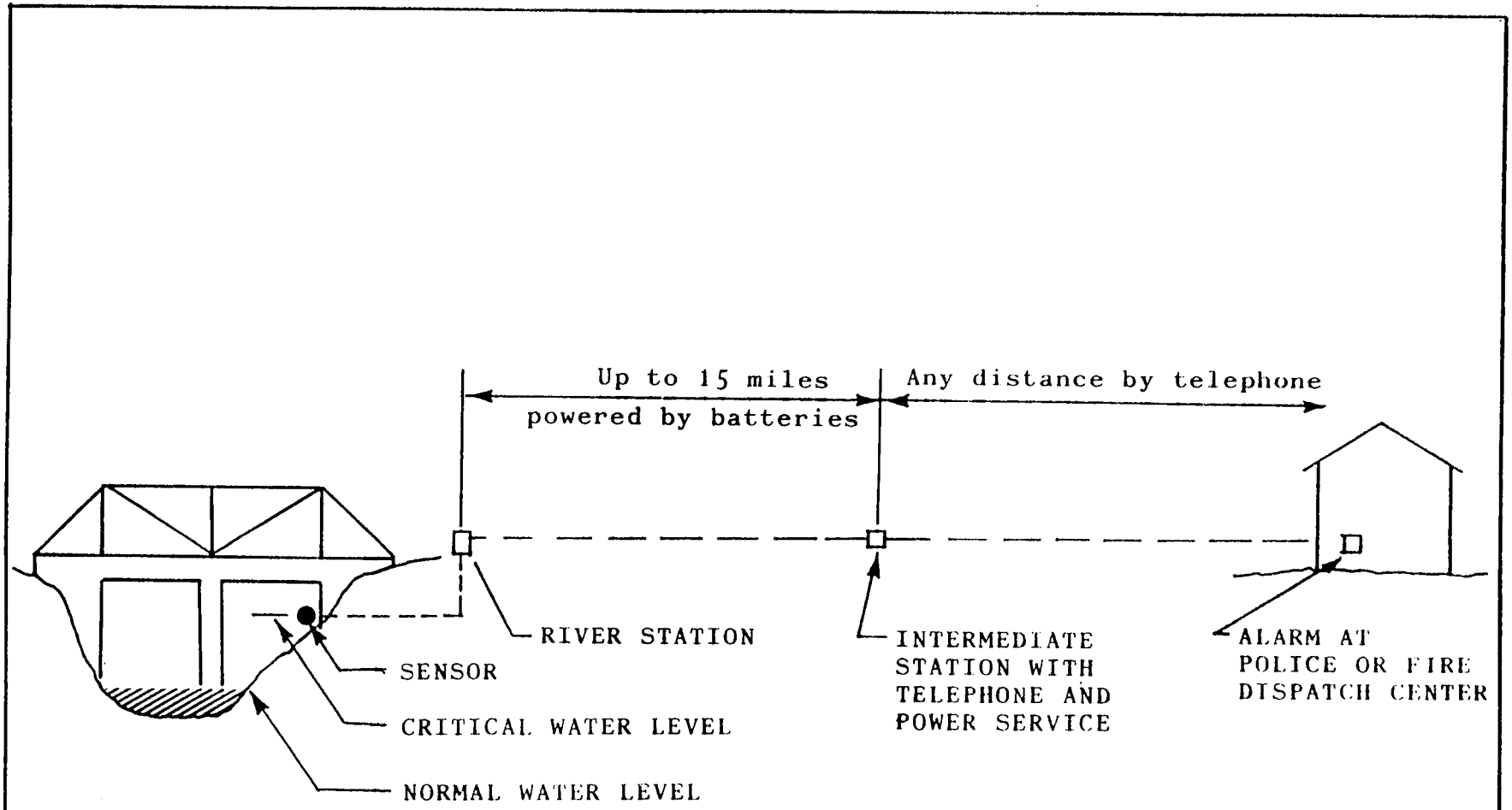


FIGURE 1
SCHEMATIC ILLUSTRATION
OF TYPICAL FLASH FLOOD
ALARM INSTALLATION

basically of a float operated switch which can be set to trigger at a stream stage corresponding to flows equal to or less than the amount which will cause flooding in the area to be warned. Transmission of the signal is usually over a dedicated telephone line and, for distances of up to 15 miles from telephone service, over battery operated lines.

Flash Flood Alarms used primarily are: a) as a basis for activation of a more complete flood recognition system; and b) to provide a minimal level of protection in areas for which the interval between intense rain and the onset of flooding is too short to carry out a more complete approach without expensive and sophisticated equipment.

However, Flash Flood Alarms are vulnerable to failure because of disruption of telephone and electrical service and other causes. To minimize downtime, alarm stations usually include the circuitry which automatically signals any disruptions in service. In addition, use of a Flash Flood Alarm is usually accompanied by establishment of a standard operating procedure which calls for dispatch of an observer to verify high water stages signaled by the system.

Systems for flood recognition which consist only of a Flash Flood Alarm provide only minimal information. They do not indicate the rate of rise of flood waters, their ultimate height, or the likely duration of flooding.

New types of automatic water level sensors which overcome some of the deficiencies of Flash Flood Alarms are now becoming available. The newer gages provide signaling of a variety of water levels and transmit signals by radio.

Volunteer Operated Manual Precipitation Systems

One of the most popular types of flood recognition systems is that employing volunteer rainfall observers equipped with inexpensive raingages. Its popularity is due to both the simplicity and low cost of such systems A system of this type is illustrated in Figure 2.

The network of rainfall observers is usually activated by a telephone call from a system coordinator or automatically upon receipt of some preestablished amount of rainfall at an observer's location. Observers' reports are normally submitted by telephone or radio. Systems which depend on telephone for transmission of observers' reports sometimes provide for dispatch of police, other public mobile radio units, or amateur radio mobile units to the observers' locations in the event telephone service is disrupted.

Following assembly of observers' precipitation reports at a central location, data are analyzed, usually by hand, and the flood prediction prepared. Analysis consists of determining an average value for precipitation in the drainage area, estimation of runoff, and use of the estimated runoff value to predict flood magnitude. Estimation of runoff normally employs a "Final Index" for the drainage area which accounts for the effects of ground cover, antecedent moisture and other factors. Final index values are provided weekly for each area by the NWS.

Data can be analyzed rapidly using charts or tables to relate precipitation, runoff and flood magnitude. Some systems result in predictions of "slight", "moderate", or "severe"

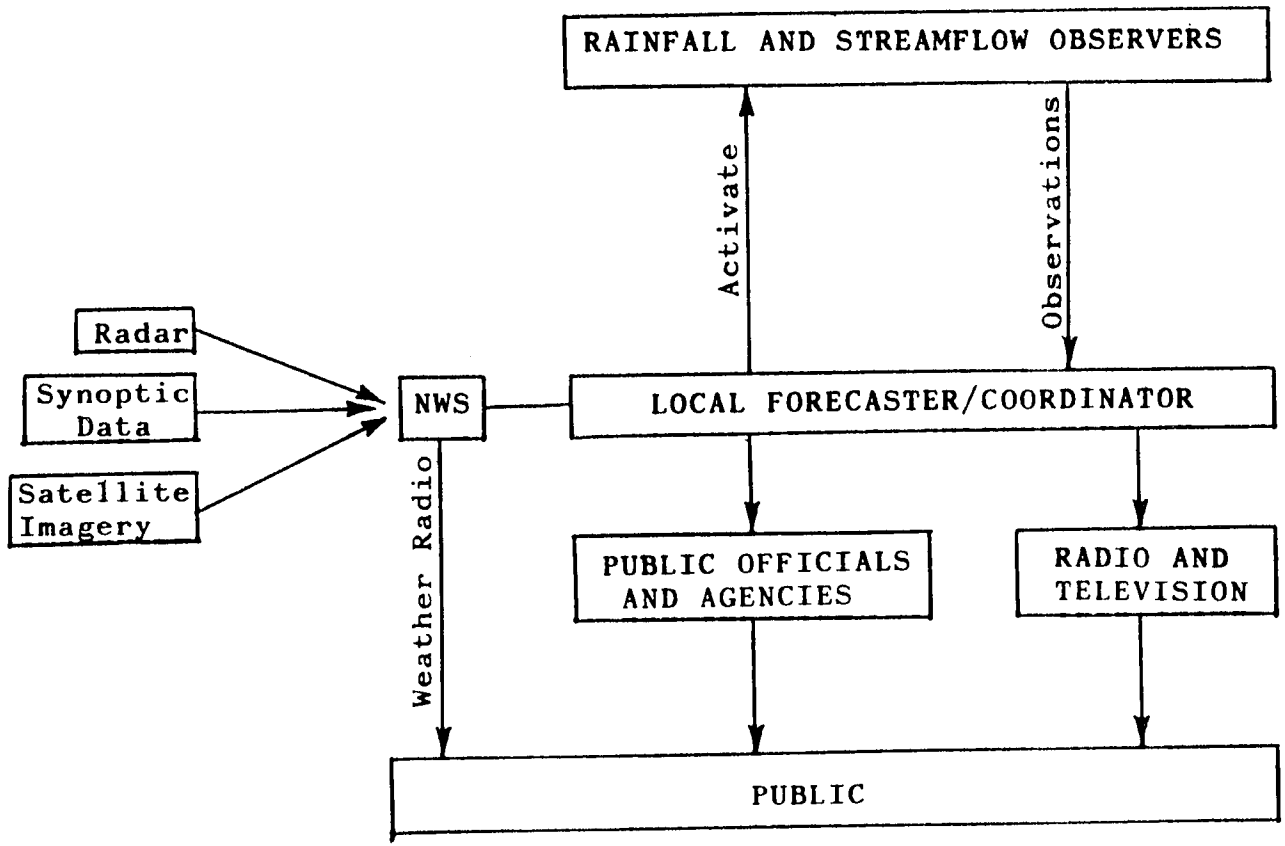


FIGURE 2
SCHEMATIC ILLUSTRATION
OF TYPICAL FLOOD
WARNING SYSTEM

flooding while others yield a prediction in terms of feet above flood stage for a particular location.

Volunteer Operated Manual Crest-Stage Systems

For some situations it is most convenient to base flood predictions on the water level already attained at one or more upstream points. Downstream flows can be predicted relatively well from such information so long as contributions to the flood flow from intervening areas are not significant. Basic information on travel times makes it possible to also predict the timing of impending flows.

As in the case of volunteer operated precipitation systems, observers are activated by a system coordinator or on the basis of preestablished procedures, or dispatched from the downstream area. The detailed arrangements for obtaining the necessary observations depend on the availability of volunteers, location of the site to be observed and available means for data transmission.

Stream level data assembled from observers is interpreted with the aid of simple charts or tables relating stages between the upstream measurement point(s) and the area to be protected. Usually only one observation point is necessary on each stream which flows through the area to be protected or which is a major tributary to a stream flowing through the area. Some areas may be adequately served by a single observation point while others require data from several locations. Use of additional observation points to cover a

greater range of tributary streams improves accuracy and enables lengthening the warning time.

The types of stream-stage gages commonly used in flood warning systems are: a) gages painted on bridge piers or other vertical surfaces in or near the stream channel; and b) inexpensive staff gages either mounted on some fixed surface or freestanding. Both types of gages can present problems of debris collection which obscures the gage markings. In addition, freestanding gages are vulnerable to destruction by ice and water borne debris. Unless properly positioned, gages which serve satisfactorily during low flows may become useless during high flows because of inundation of vantage points for their observation. In order to avoid both this problem and the need for very tall freestanding installations, gages are sometimes stairstepped outward on the flood plain so that at least one gage is useful at any anticipated flood level.

Automated Precipitation Systems

Various equipment is available for remote collection of precipitation data. In general, it is of two types. One type must be interrogated, usually by telephone, while the other automatically reports, either by radio or telephone, whenever an increment of precipitation is received.

Systems using precipitation gages which must be interrogated must provide for interrogation be carried out continually when conditions favor rain or for the system operator to have some other means of knowing if rain is occurring in any part of the watershed. Self-reporting gages avoid these sorts of problems.

Transmission of data from automated precipitation gages also encounters the same risks of disruption that threaten transmission of data from observers. Transmissions over telephone systems are especially vulnerable to interruption.

Following assembly of the rainfall data from automated gages, analysis can be identical to that employed in the case of data collected by observers. However, automated gages are particularly adaptable to use of computers to perform monitoring and analysis activities.

Combined Systems

Flood recognition systems can combine two or more of the approaches for data collection. None of the approaches are mutually exclusive and the use of several approaches frequently enables better tailoring of the system to the needs of a particular area.

For example, the inclusion of automatic upstream water level sensors in a system enables protection of areas along streams not covered by measurements of rainfall or stream levels. They also provide a means of protecting areas upstream of the locations at which rainfall or stream level data are collected.

Stream level and rainfall gages can also be effectively combined. The advantages of both with respect to accuracy and length of warning time can be obtained by relying on

precipitation information for the earliest warning and for estimates of the general magnitude and duration of floods, and by relying on measurements of upstream water levels for more precise prediction of flood stages and their time of arrival.

Sophisticated Flood Recognition Systems

Flood recognition systems can be made very sophisticated. One highly responsive system is based on availability of continuous real-time precipitation data coupled with real-time computing capabilities provided through a small mini-computer.

Computerized systems for data collection and analysis can have a wide range of capabilities and advantages including:

* Use of data inputs from a wide variety of sources including observers, automated precipitation and water level gages, and National Weather Service;

* Use of precipitation data from self-reporting gages to automatically control the frequency of interrogation of gages;

* Rapid computation;

* Linkage with National Weather Service equipment and facilities;

* Ability to examine alternative futures; and

* Capability to account for a large range of variables and hydrologically complex situations.

Use of mini-computers with linkages to the large computer at a National Weather Service River Forecast Center provides several advantages. Local forecasts can, for instance, take advantage of satellite imagery, synoptic data and radar information available to the National Weather Service. Such linkages also enable putting the responsibility of forecasting and flood prediction in the hands of professionals with the local components of the system providing a back-up function.

Provisions for communication of data can be made comparably sophisticated. Collection of data from gage sites and transmission of data between local forecasting centers and National Weather Service offices can be accomplished by regular or dedicated telephone lines, radio and microwave. If needed because of rugged terrain or other reasons, data can also be transmitted via the GOES satellite system.

Increasing the level of sophistication of flood recognition systems normally increases their costs by a substantial amount. It also increases requirements for local technical capability to operate and maintain the system. The trade-offs between performance, cost and other requirements must be made on a case by case basis.

Supplementation of Flood Recognition Systems

Flood recognition systems which are limited to just the basic provisions for collecting and analyzing local precipitation and/or streamflow data are often inadequate. Unless the system includes at least some self-reporting gages, flash flood alarms, or provisions for continual monitoring, it may be possible for rains at night or in some remote part of the drainage area to go without official notice for a considerable period of time. The resulting late activation of the data collection system may cause a significant reduction in warning time.

Data collection systems which are operated continuously or which are activated promptly when rains begin may still be too limited since they only provide predictions based on rainfall or stream levels which have already occurred. In small, steep basins subject to flash floods, travel times for flood waters may be so short that warning times based on such information are inadequate. Also, of course, measurement of precipitation or stream levels gives no information about whether rains are likely to increase or how long they may continue.

These types of problems can be mitigated by supplementing local flood recognition systems with provisions for keeping abreast of weather conditions on a regional basis. The means usually employed include arrangements for provision of information from adjacent governmental units or for access to National Weather Service releases. Access to the NWS releases makes available longer range forecasts based on satellite

imagery, synoptic data and radar. Access to NWS releases is usually through use of NOAA weather radios, telephone hotlines like NAWAS, or subscription to a teletype service.

THE FLOOD WARNING ARRANGEMENTS

The purpose of the warning arrangements portion of a flood warning and preparedness program is to assure predictions and necessary instructions are made available to affected parties on a timely basis.

Types of Warning Arrangements

Warning arrangements may be separated into three general types according to their intended audience; namely:

1. Mass warning systems;

2. Warning systems for special recipients; and

3. Site-specific warning systems.

Mass Warning Systems

Mass warning systems are the most familiar approaches to warning dissemination. Their identifying characteristic is that the message conveyed is intended to be more or less equally available to all parties in the area. Mass warning systems use sirens, airhorns, radio, television, public address

systems and other means of dissemination which cover relatively wide areas. Any selectivity in warning only particular audiences is achieved by the choice of medium used, by only making public announcements in particular areas, or, if construction of the system permits, only activating particular sirens or airhorns. Mass warning systems are usually passive in the sense that no special effort is required on the part of the intended recipient to prepare for obtaining the warning. One exception to this is the NOAA Weather Radio system which broadcasts on frequencies beyond those available through regular AM and FM radios.

Mass warning systems provide the quickest way to reach large numbers of people. However, they have several disadvantages including:

* Inability of signals based on sound to reach the deaf;

* Unnecessary distribution of warnings to unaffected areas, causing unwarranted concern and stimulating travel to the threatened area by sight-seers;

* Relatively high cost of making siren systems highly reliable in operation; and

* Limitation, in the case of sirens and airhorns, of the complexity of message which can be conveyed.

Warning Systems for Special Recipients

Unlike mass warning systems which address the public at large, warning systems for special recipients are aimed at

conveying the warning message to selected individuals. The basis for the selection of recipients may include such things as: responsibility for conduct of mass warning or site-specific warning activities; need for unusually long warning times; inability to comprehend warnings disseminated via mass warning systems; and location outside the area covered by mass warning and site-specific warning systems.

Warning systems for special recipients make use of telephone, private radio, messengers, person-to-person contact, and other dissemination techniques with a high degree of selectivity in reaching a particular individual or organization. These means of dissemination also enable confirmation of the receipt and comprehension of the warning message by recipients to whom warning is particularly critical.

The dissemination of warnings in rural areas not covered by a mass warning system is usually a hybrid of mass warning and warning for special recipients. While the parties to be warned may be individually identified or contacted, the need for confirmation of the receipt and comprehension of warnings may be no greater than in cases for which mass warning systems are used. Some of the same techniques of dissemination used in mass warning systems, such as mobile public address systems, are therefore often employed.

Site-Specific Warning Systems

Some facilities or locations require a special warning system apart from that operated for the community as a

whole. Among others, these may include: buildings or areas in which mass warning systems are not likely to be heard due to sound attrition, high ambient noise levels, or lack of radios, television and other receiving equipment: hotels, motels and other areas where persons congregate who may be unfamiliar with the area and who therefore require special instructions; and areas where those to be warned cannot be contacted by the means ordinarily used for warning. Site-specific warning systems, as their name implies, are characterized by their focus on the occupants of a particular building, property or limited geographic area.

Characteristics of Warning Arrangements

Flood warning arrangements must provide for several basic activities including: a) determining whether the prediction developed through the flood recognition system warrants issuance of a warning; b) deciding the specific warning message to be issued; and c) delivery of the warning message to its intended recipients. The basic differences between warning systems with respect to how these activities are organized concern the assignment of responsibility for decision-making, whether or not the system is "staged", the degree of refinement of the warning procedures, and the means of disseminating warnings.

Responsibility for Decision-Making

Flood warning and preparedness programs usually provide for at least a part of the decision-making regarding issuance of warnings to be closely allied with coordination and operation of the data collection network and preparation

of flood predictions. If information and data collected through a local flood recognition system are provided to the National Weather Service for analysis and preparation of the flood prediction, that agency is normally depended on for the origination of warnings. In that event, warnings are usually released over television and radio at the discretion of the NWS and given directly by that agency to some local official by telephone, telegraph, radio or another available means. Local officials must then complete the decision-making process by deciding whether or not to mount any further warning dissemination effort.

If the analysis of data and preparation of the flood prediction is performed locally, decisions about warning dissemination are usually made entirely by local officials. In this case, the major variation in assignment of responsibility concerns whether the decision to issue and disseminate warnings is made by one person or through a chain of command. Each approach has advantages and drawbacks. The review provided by moving decisions through a chain of command serves to reduce errors and hasty judgments. However, it may seriously affect the timeliness with which warnings are finally made available.

Staging of Warnings

It is important that flood warnings issued to the public are timely and accurate. Warnings which are received too late are of little or no value. Warnings which are significantly in error may cause unwarranted complacency or result in expensive and troublesome overreaction. Shortcomings of either type erode the credibility of future warnings.

Warnings can generally be made more accurate by postponing their release until flooding is imminent and the magnitude and timing of the impending flows are obvious. But that defeats the objective of giving timely notice. The need for timeliness suggests that warnings be issued early in a potential flood episode, even if only incomplete data and information are available. The two criteria conflict except in unusual circumstances.

The need for timeliness frequently varies throughout the area served by a warning and preparedness alternative. Upstream portions of an area may need warnings considerably in advance of those further downstream. And the occupants of the lowest lying flood plains usually need warnings earlier in a flood episode than those at higher elevations. Other variations may occur depending on whether the area is rural or urban, residential or commercial, or whether topography and other factors make movement to safety an easy or difficult task.

The need for timeliness also depends on the nature of certain activities, the degree of risk presented by a flood, and the length of time required to take preparedness actions. Public officials, emergency services agencies, hospitals, schools, jails, certain industries, invalids and others may need far longer warning times than the general population to take whatever action is expected of them in a flood emergency.

The accuracy required to make a flood warning valuable also differs with respect to party, location, activity, and other factors. For example, determination that overbank flows will occur may be adequate for some very low lying areas

even in the absence of any accurate information as to the eventual maximum height of the flood crest. Occupants of higher areas may be reluctant to take action unless it is relatively certain that the flood will affect their property. Also, for example, public officials and private property managers may have available some preparedness actions which do not involve significant expense and which can therefore be taken on the basis on preliminary warnings while undertaking the commitments involved in other actions may require more certain knowledge that flooding will occur.

All of these diverse needs for timeliness and accuracy cannot often be satisfied by issuance of a single "flood--no flood" announcement. Reconciliation of the several needs is usually accomplished through staging of the warning arrangements. Staging provides for identification of several "levels", "stages", or "conditions" of flood, usually based on combinations of the certainty of the flood occurring and the magnitude of the anticipated flows. A simply staged warning plan may provide as few as three stages corresponding to normal (no flood expected), pre-emergency (potential flooding), and emergency (flooding certain or underway) situations. Other systems may provide a half-dozen or more stages developed differently for each of several sub-areas.

No single pattern of staging is universally applicable for flood warning arrangements. What is appropriate in a particular case depends on local preference as well as topographic, hydrologic, developmental and other considerations. The staging must also mesh with the arrangements for warning dissemination and the preparedness plan.

Degree of Refinement of Warning Procedures

Warning arrangements may be very basic in some situations. Nevertheless, prudence suggests that there be some established procedure of standing order so experienced staff are reminded and new personnel are made aware of the action to be taken and instructed in its accomplishment. In most areas, warning arrangements are somewhat complex and involve a number of people and organizations which must act in harmony if warnings are to be properly distributed to their intended recipients. The procedures to guide their coordinated actions must be correspondingly detailed.

The actions which must be taken to carry out a warning process are dictated by what is to be accomplished. The options available in preparing the necessary procedures concern the detail and fullness of the instructions for these actions.

Procedures for even complex warning plans may vary with respect to their detail. Objective oriented procedures may only identify what overall actions are to be accomplished and leave the manner of accomplishment to the discretion and innovation of the responsible party. Additional detail can be added to procedures by providing criteria to assist in deciding appropriate action, including lists of persons and their alternates to be issued warnings, provision of telephone numbers and addresses, and wording of the warning message(s) to be used. These same sorts of refinements can be included or not included in other portions of the procedures to vary their level of detail.

Procedures can also be made fuller and potentially more valuable through inclusion of information which may prove useful to deal with contingencies. This may include names and telephone numbers of staff in Federal and state disaster offices, listings of private contractors with potentially useful equipment, maps and plans, and mutual aid agreements.

The function of written procedures is to insure no serious errors or omissions are made. In deciding their appropriate level of detail and fullness, it must be borne in mind that the warning arrangements are likely to be executed under stressful and hurried conditions.

Means for Dissemination of Warnings

The means commonly employed for dissemination of flood warnings include use of vehicles equipped with sirens and public address systems, fixed siren or airhorn systems, radio, and television. These are sometimes supplemented with door-to-door contact by police, fire, or other personnel. Less frequently, warnings are disseminated by telephone calling arrangements, "block captains" or another system in which selected people are each responsible for notifying a group of others. Several or all of the techniques may be employed in a particular flood warning system. Selection of the means of warning dissemination for use in a particular area depends on a variety of factors including the means which are readily available, number of people to be warned, physical setting, and nature of anticipated flooding.

Use of police, fire, rescue and other emergency vehicles equipped with sirens and public address systems is probably

the most popular means of warning dissemination in small to medium size areas. In addition to 24 hour availability of the equipment, this approach has several advantages including: a) use of disciplined and well organized personnel who are trained and accustomed to following directions; b) capability of public address systems to convey instructions and other information instead of simply an alert; c) relatively low vulnerability to disruption; d) high degree of selectivity in the area to be warned; and e) potential for persons in the field doing the warning to use initiative in adapting procedures to the situation which exists. The principal drawbacks to this approach are: a) commitment of personnel and equipment to conduct of the warning process who might be needed elsewhere or for other purposes; and b) limitations on the size of area which can be covered on a timely basis.

Fixed siren or airhorn systems are widely available. They make an attractive choice for warning dissemination because their use involves no cost or complex procedural developments. However, they have numerous shortcomings including: a) few systems are regularly expanded to maintain full coverage as community growth takes place; b) many systems are not sized and powered to provide warnings loud enough to be identifiable during storms and inside some buildings; c) power supplies and activating circuits for sirens are often vulnerable to failure; and d) little flexibility exists to selectively warn particular areas. In addition, siren or airhorn systems can not convey an explicit message or instructions except by variations in the tone and/or pattern of noise produced.

Radio and television coverage is available in most areas and most homes and businesses are equipped to receive one or

both. Moreover, radio and television offer means of conveying detailed warnings and, if need be, lengthy instructions. The drawbacks to use of radio and television include: a) lack of operation in some areas during late night and early morning hours; b) lack of listeners during late night and early morning hours; c) vulnerability to failure during severe storms; and d) lack of selectivity in areas to be warned.

One frequently used combination of means for warning dissemination employs a fixed siren or airhorn system to alert people, followed by radio and television announcements to deliver the warning message. This overcomes some of the principal difficulties of using each means alone. However, the combined system still remains vulnerable to failure and has certain deficiencies common to both approaches. The combined approach also requires coordinating several individuals and organizations with a corresponding increase in the complexity of procedures for the warning process.

THE PREPAREDNESS PLAN

The function of the flood preparedness plan portion of a warning and preparedness program is to guide and coordinate the response to a flood warning. The preparedness plan is an important part of any alternative since it normally provides a large share of the benefits which justify expenditures on the flood recognition system and warning arrangements.

The chief characteristics of flood preparedness plans which set them apart from one another are: a) their objectives; b) the number and type of activities included in the

plan to address the objective(s); and c) the extent to which local government assumes responsibility for execution of the plan. Variations of these three characteristics can give rise to widely divergent types of plans. The format of the plan, while not a vital characteristic, is also important because of its effect on the convenience of using the plan.

Range of Objectives

As noted earlier, the objectives to which flood preparedness plans are most often addressed include safety, reduction of damages, and reduction of costs other than damages. Almost all flood preparedness plans place first priority on reduction of the risk to life and many plans are limited to that single objective although they may incidentally produce benefits of other types.

Plan Contents

Activities included in preparedness plans for the purpose of safety vary according to the specific needs of the area at risk, the nature of anticipated flooding, and the fullness of the plan. Evacuation of threatened areas is usually a key measure. Other actions for protection against direct threats to safety may include: a) dispersal of medical, fire, police and other emergency services personnel and equipment to assure continued provision of vital services; b) curtailment of electrical and gas service to reduce the risk of fire, explosion and electrocution; and c) control of toxic or other dangerous materials on the flood plain. Preparedness plans

may also provide for safety against less direct threats stemming from flooding through provisions for vector and disease control and for demolition of unsafe structures in the immediate post-flood period. These and other principal measures may be supplemented by numerous other activities such as traffic control to expedite evacuation, provision of transportation assistance for evacuees, shelter and care of evacuees, and provision of security for evacuated areas to induce compliance with directives to evacuate. Even flood-fighting activities of various types may be an important part of the overall approach to safety under some conditions.

Activities included in preparedness plans for damage reduction often overlap those included for safety purposes. For example, dispersal of public equipment to assure continued provision of vital services may also serve to remove the equipment from the area of expected flooding and thereby reduce the potential for damage. Special utility management for safety purposes may also reduce damage done both to and by gas, electrical and other systems. Similarly, traffic control and floodfighting may have important relations to damage reduction efforts.

Other activities may be undertaken solely for the purpose of damage reduction such as temporary relocation of property and contingency floodproofing. Still others may be undertaken for damage reduction but also serve to reduce flood related costs and inconveniences apart from those caused by direct damages. Proper management of a water supply system may, for example, reduce the extent of decontamination required and hence the need to boil or import water in the

post-flood period or temporary relocation of property may reduce the post-flood costs for collection and disposal of debris. And, for instance, temporary protection of sewage pump stations may make the difference between immediate reestablishment of service and months of either releasing raw sewage or operating at a reduced level of service.

Activities can also be included in plans specifically for the reduction of costs other than through the prevention of direct damages. Such measures focus largely on the post-flood period and include such things as provisions for distribution of information on salvaging flood damaged property, prevention of losses due to lack of refrigeration or other secondary problems, and early restoration of normality.

Role of Government in Plan Execution

Some parts of a flood preparedness plan require governmental participation for proper execution. For example, private citizens and private organizations cannot ordinarily disperse emergency equipment, provide effective traffic control, or modify the normal operation of utility systems. However, individuals and private organizations can be left wholly responsible for their own evacuation, temporary relocation of their movable property, care and shelter of evacuees, and contingency floodproofing of private homes and other facilities.

Some of the activities which could be left for private sector performance can be done better by government or with governmental assistance. For example, evacuation might be

more completely and more rapidly accomplished if busses from the local transit system were made available. While care of evacuees could perhaps be provided by individuals, churches, and service organizations, it might be simplified if the kitchens, showers and other facilities of schools were used. And even though individuals could perhaps move a significant amount of their property out of a flood's path, local government's provision of a secured storage area could be important to the success of such an effort.

Opportunities for more or less governmental involvement exist for many aspects of preparedness plans. Selection of the appropriate level of governmental participation constitutes a major policy decision in plan formulation. The decision must, of course, be tempered by the amounts and types of personnel and physical resources available to local governments and the priority assigned to the plan's various objectives.

Format of Plans

The numerous activities of various parties which go into making up a preparedness plan lend themselves to presentation in a variety of formats. The three most popular formats are organization of the material by: a) agency or organization; b) stage of emergency or predicted flood level; and c) subplans for groups of related activities. None of the potential ways of organizing the plan is particularly superior to others and the choice is largely one of what works best for the case at hand. The more important point is that the plan must set forth in unmistakably clear language what is to be done, when or under what conditions each action is to be taken, and who is responsible for its accomplishment.

Preparedness plans are action documents intended for use under emergency conditions. This suggests that the plan be stripped of nonessential information, indexed and otherwise put together in a way which facilitates its convenient use. It should also be recognized in selecting a format for the plan that the intended participants in execution of the plan have differing needs for guidance. While a civil defense director responsible for orchestrating the community-wide response to a flood has need for the whole plan, the water plant supervisor may need only the instructions pertinent to operation of that utility. Some formats of plan presentation are better adopted than others to meeting these varying needs for information.

THE MAINTENANCE ARRANGEMENTS

The objectives, procedures, equipment, agreements and other things composing a flood warning and preparedness program require periodic attention if the effectiveness of the overall program is to be preserved. The function of the maintenance arrangements portion of a flood warning and preparedness alternative is to provide that necessary attention. The activities making up the maintenance arrangements can be subdivided into those for updating, testing, and education and information.

Updating

Updating is primarily a planning activity aimed at identifying and making modifications in the plan which are needed because of particular events which have taken place or because of the accumulation of minor changes which have occurred over time.

The portions of plans most likely to require updating are the minor items such as names and telephone numbers and those items of an expressly limited life such as contracts or memoranda of understanding. However, other needs for updating may also arise which are more complex and which require that some extent of replanning be done. For example, changes in land use in the watershed above a protected area or installation of upstream water control structures may change the timing or extent of the flood risk. Likewise, community growth or new development in the protected area may modify the flood hazard. Even changes in public attitude may result in a need to modify plans so as to make them serve some additional or other objective.

The appropriate frequency of updating depends upon the importance of the portion of the plan being considered, the penalty of relying on outdated information of various types and the resources required for updating.

Testing

Testing refers primarily to equipment, supplies, and other material items. Examples of testing activities include checking inventories of emergency supplies, testing gages and communication links, periodic trial of sirens and occasional operation of auxiliary generators.

The desirable frequency of testing depends on how often an item is used during the regular course of activities, its vulnerability to failure, the item's importance to the success of the alternative, and the resources required for testing.

Education and Information

Most preparedness plans depend to some extent on a knowledgeable public. At a minimum, the public may be expected to know that some preparedness plan and warning system exists and to recognize a particular signal. They may also be expected to know evacuation routes, the location of safe refuges and other information. Local officials and designated participants in the operation of the alternative are usually expected to have detailed knowledge about some parts of the alternative and the skills necessary to carry out their role.

Assuming that people have the knowledge and skills which the alternative assumes them to have requires an education and information program. Several types of activities may be necessary including programs for general public awareness, training persons for officials and practice sessions.

EXAMPLES OF LOCAL PROGRAMS

Data collection procedures, analytical procedures and warning arrangements can be assembled in an almost unlimited number of ways. The following examples describe facets of several local flood warning and preparedness programs which are in use in various areas. None of the examples are recommended as a specific pattern for other areas since the details of a program must be adapted to local circumstances. However, the examples illustrate broad types of arrangements which may merit consideration.

Howard County, Maryland

Severe flooding occurred in Howard County, Maryland in 1972 in association with Hurricane Agnes. Following the flood, the National Weather Service recommended development there of a local flood warning program. Local officials and others agreed with the recommendation and the present program was implemented through the cooperative efforts of the Howard County Office of Civil Defense, Howard County Central Alarm Communications Center, Howard County Department of Public Works and National Weather Service.

The flood recognition system consists of four flash flood alarms, several river level gages to be read by observers and a network of inexpensive plastic precipitation gages located at the county's 9 fire stations. In addition, the Communications Center and the Civil Defense Office, which are located together, receive information from the National Weather Service through the Maryland State Police teletype circuit. Figure 3 illustrates schematically the operation of the flood recognition system. A flash flood alarm is also located at the County's wastewater treatment plant to warn plant personnel of rising waters which could flood the access road to the plant.

The flash flood alarms provide continuous monitoring of conditions on major streams in the County. The remainder of the flood recognition system is activated whenever one of the flash flood alarms indicates at the Communications Center that water levels have risen significantly. The Communications Center alerts the Civil Defense and Department of Public Works personnel that a flash flood alarm has activated and notifies

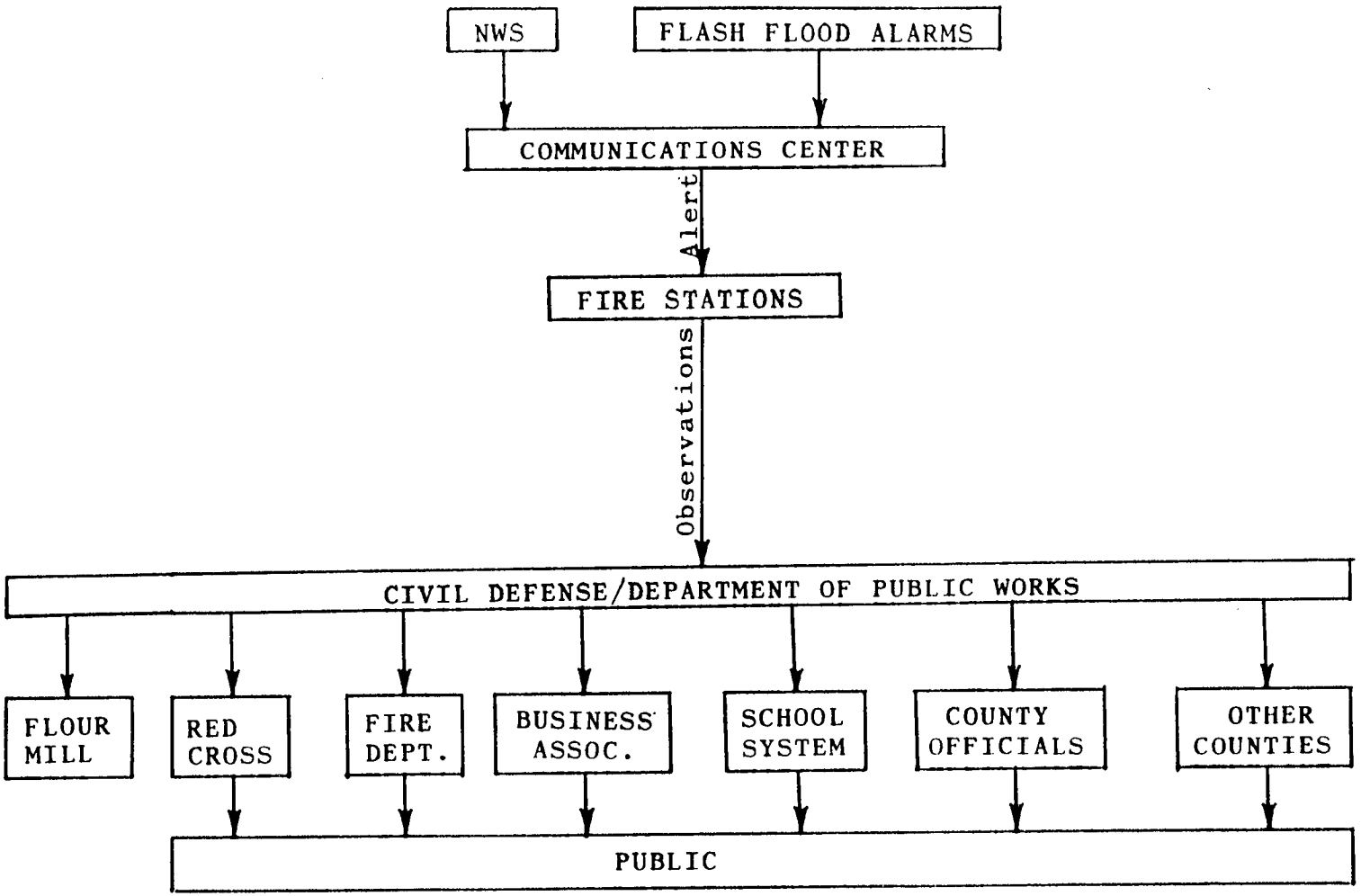


FIGURE 3
SCHEMATIC ILLUSTRATION
OF
HOWARD COUNTY, MARYLAND
FLOOD WARNING SYSTEM

the County's fire stations to begin making hourly reports on precipitation and half-hourly reports on stream stages at selected river level gages. Standard operating procedures also call for rainfall measurement and river level reporting by fire department personnel to begin automatically any time 1 inch of rain in 2 hours is noted at a fire station location.

Precipitation data provided through the system is used to determine whether increases in observed stages at key points along the stream are to be expected and/or whether monitoring of streams should be continued. As needed, reports on other river level gages are requested to add detail and confirm the available information. The predictions of impending flood stages for major damage centers are made by the Department of Public Works based on the flood stages reached at upstream points.

The warning system makes it possible to provide Ellicott City, Maryland, about 6-8 hours notice that some flooding will occur, and 2 1/2 hours notice of the expected crest stage. For the community of Elkridge, Maryland, which is downstream of Ellicott City, these warning times are extended about an additional 2 hours. Depending on their location, other developed areas in the County receive generalized warnings based on information from the National Weather Service or more specific warnings based on local information that flooding will occur, but without prediction of a specific crest level.

Flood warnings generated through the system are issued to the fire and police departments, county officials, the president of the Ellicott City Business Association and to several downstream counties. Each fire station maintains a

listing of all residences in flood prone areas within its district. Warnings are disseminated to occupants of affected areas by sirens on emergency services agencies' vehicles and by knocking on doors. The Ellicott City Business Association alerts business proprietors in Ellicott City. In addition, the Red Cross and county school system are issued warnings so that advance arrangements can be made for sheltering and feeding evacuees. One installation, a large flour mill located in Baltimore County across the Patapsco River from Ellicott City is provided warnings by a special arrangement between the mill and Howard County.

The original cost for purchase and installation of the flash flood alarms was approximately $3,000 each. National Weather Service provided two of the flash flood alarms and all of the precipitation gages. Howard County bought the remaining two flash flood alarms and installed the river level gages. Maintenance of the flash flood alarms costs about $500 annually for each unit. Operational costs for the four flash flood alarms include telephone and electrical service. Charges for electrical power are about $24 annually and are paid by the County. Charges for the telephone lines connecting the four alarms with the Communications Center total approximately $3,200 annually which is paid for half by the County and half by Federal funds passed through the State. There are no costs associated with operation and maintenance of the plastic precipitation gages except occasional replacement of a gage broken due to freezing of collected rainfall. About one-half man-day per month is required for overall maintenance and testing of the system.

New Braunfels, Texas

Implementation of the flood warning program now protecting the New Braunfels area was begun immediately after a 1972 flood which took seventeen lives and caused damages in excess of $25 million. The principal parts of the program are illustrated in schematic form in Figure 4. They include:

1. Radio communications club with 55 mobile units and two base stations;

2. Network of 10 rainfall observers equipped with plastic rain gages supplied by the National Weather Service; and

3. A flood forecasting system prepared by the National Weather Service which relates rainfall to expected stream stages.

The measurement and reporting of rainfall by observers is activated by the New Braunfels and Comal County Civil Defense coordinator upon receipt of information from National Weather Service by teletype, radio or telephone that heavy rains are expected. Standard operating procedures also provide for the flood recognition system to be activated any time an observer notes 2 inches or more of rain at his location. Observations are telephoned to the Emergency Operating Center where forecasts are prepared and periodically updated.

Members of the radio communications club are dispatched to observe the rivers and creeks in the area. As needed in the event of failure in telephone service between observers

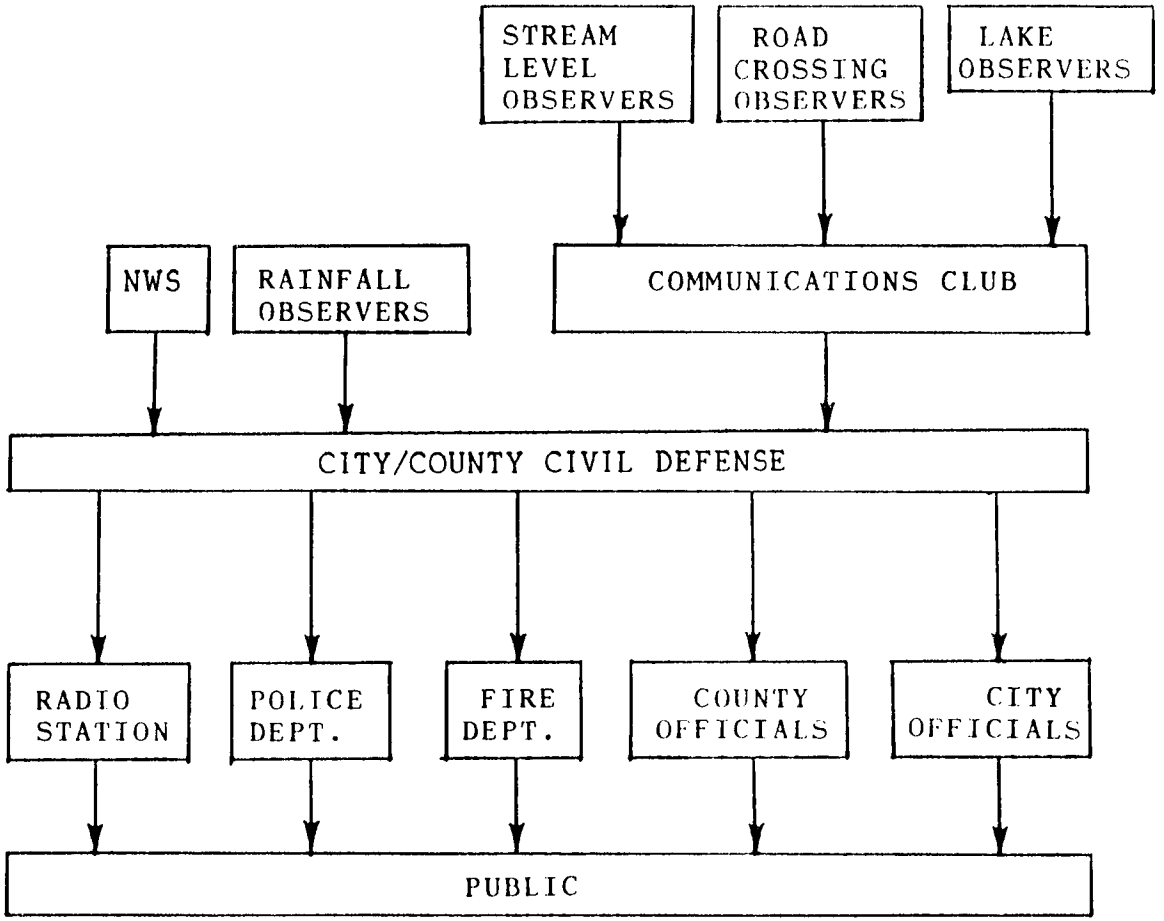


FIGURE 4
SCHEMATIC ILLUSTRATION
OF
NEW BRAUNFELS, TEXAS
FLOOD WARNING SYSTEM

and the Emergency Operating Center. mobile units are also dispatched to rainfall observer locations to transmit rainfall data.

Based on predicted flood levels, the Civil Defense Coordinator issues warnings to elected officials of New Braunfels and Comal County, New Braunfels police and fire departments, the radio station serving the area, and several downstream towns. Warnings are disseminated to the public by radio, use of mobile public address systems on police and fire department vehicles and by door-to-door contact.

Members of the communications club carry their own insurance at an annual cost of $4.05 per person for $10,000 life insurance and $1,000 medical insurance. The communications club has also been licensed as a Civil Defense Rescue Squad. Once qualified for use of surplus government property, the club obtained low-band radios for $30 each, expended an average of $120 each to put radios in servicable condition and provides them to members at the club's expense. The club has two base stations and two antennas, one linked by telephone to a base station located at the Emergency Operating Center.

The original cost to local government for the flood recognition system was approximately $100 for installation of a dedicated telephone line linking the Emergency Operating Center, County Sheriff and radio station. Ten raingages costing a total of $140 were furnished by the National Weather Service. The continuing costs for system operation and maintenance are approximately $250 annually for telephone line charges and toll telephone charges for calls from rainfall

observers, $25 of which is matched annually by the State using Federal funds.

Staff time to operate the flood recognition system is estimated to be 400 hours annually. Of this time, approximately 130 man-hours are devoted yearly to preparatory actions, practice and training of participants and the remainder for actual operation of the system during a flood threat. Since its inception, the system has been used some 15-20 times to predict flows when a flood threat existed.

Apart from their participation in the flood prediction system, rainfall observers are separately activated about 20-30 times annually to provide rainfall information to the radio station for local weather reports. This frequent use of the observer system negates the need for continuing training and practice. The Civil Defense Coordinator holds two meetings annually with the communications club for coordination and the National Weather Service inspects precipitation gages about once a year to assure their satisfactory condition.

Reliability of operation of the flood recognition system is provided through redundency of communication links, observation of upstream water levels to confirm impending flooding and availability of multiple persons capable of interpreting rainfall data and predicting flood heights. Evacuation is based on visual confirmation of flooding in upstream areas by observation of staff gages by members of the communications club. Altogether, the system adds about 30 minutes to the warning time which would otherwise be available. All pertinent city departments have standard operating procedures for response to flood warnings which are

coordinated through a joint city and county Civil Defense Emergency Plan.

Santa Ynez River, California

Implementation of the Santa Ynez River flood warning program was begun shortly after a flood in January 1969 which caused in excess of $5.7 million damage to public and private property. The program was developed by the Santa Barbara County Flood Control and Water Conservation District. Figure 5 shows a schematic illustration of the program.

The flood recognition system portion of the program includes automatic collection of data from 10 precipitation stations, 3 reservoir level gages, 10 gages on flood gates at Gibralter and Bradbury Dams, and 1 stream stage gage on the Santa Ynez River located at Lompoc, California. The data collection system provides for three modes of operation including automatic reporting on a "change of status" basis, interrogation by telephone, and automatic reporting on an elapsed time basis. All data transmissions are over dedicated telephone lines to the District's offices in Santa Barbara, California. Collected data may be either printed directly by teletype or entered automatically into a NOVA 12 mini computer system for analysis and reduction before printing. Processed information on precipitation and reservoir releases may be input into a watershed model operated on a Hewlett Packard 9830 computer for prediction of flows at various points in the watershed, including inflow to Bradbury Dam.

Based on predicted flows, the District issues warnings in accord with an emergency procedures manual. The manual

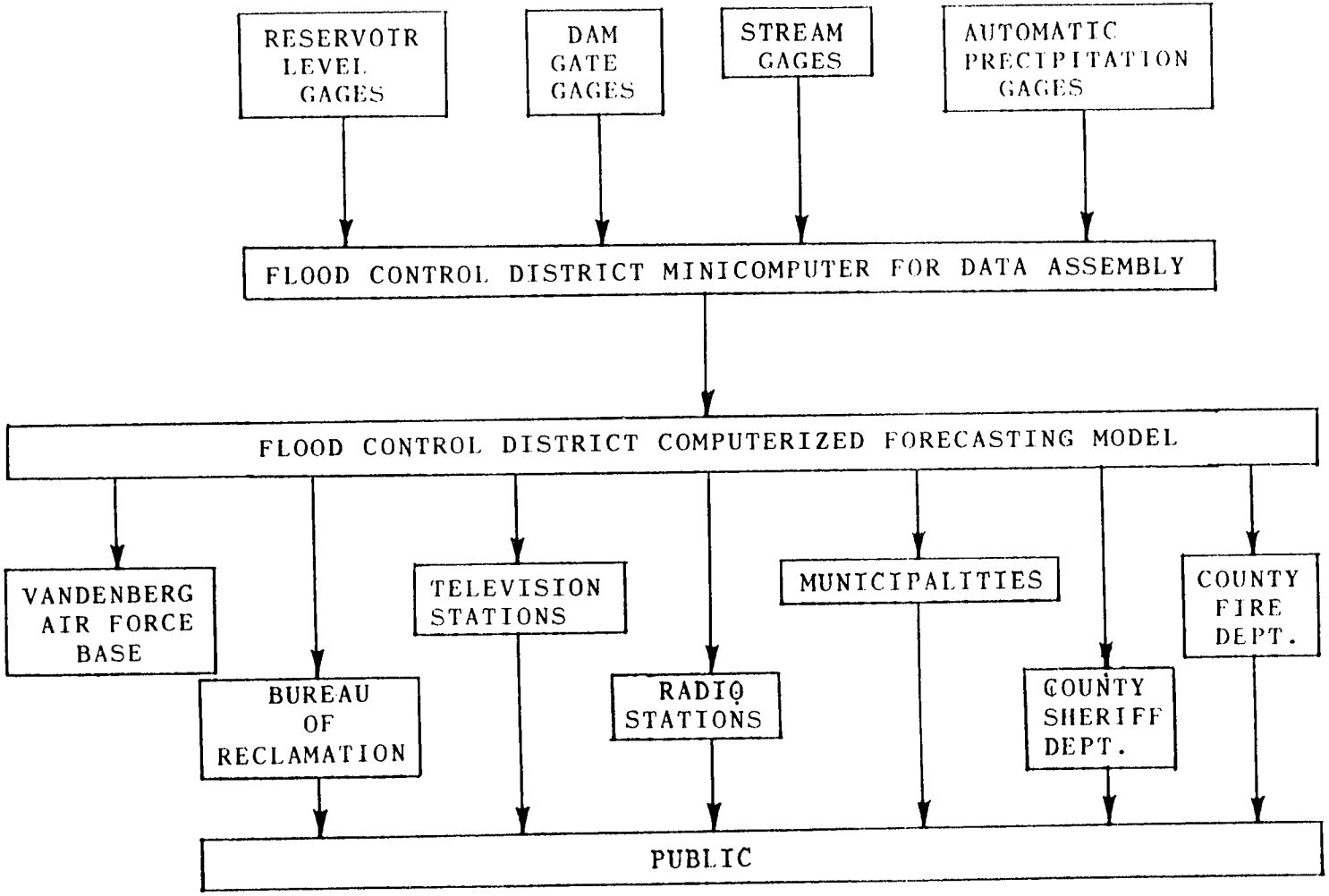


FIGURE 5
SCHEMATIC ILLUSTRATION
OF
SANTA YNEZ RIVER
FLOOD WARNING SYSTEM

specifies actions to be taken and parties to be contacted for each of several predicted flow levels for various portions of the watershed. The emergency procedures manual also includes directions for action in event of sudden failure of Bradbury and other dams in the watershed, standardized warning messages, and maps showing areas of the watershed inundated by various flows.

The primary recipients of flood warnings issued by the District include Santa Barbara County Sheriff, City of Lompoc, Santa Barbara County Fire Department, Vandenberg Air Force Base, County supervisors, U.S. Bureau of Reclamation (Bradbury Dam operator), and radio and television stations serving the area. Warnings are disseminated to the public by radio and television stations, sirens, public address systems on police and fire vehicles, and by telephone.

Original cost of the Santa Ynez River flood warning program was approximately $50,000 including acquisition and installation of equipment, development of the watershed model and associated staff time. Original costs were met largely by the Flood Control and Water Conservation District with contributions from the U.S. Air Force and other anticipated beneficiaries of the program. Annual costs for operation and maintenance of the program vary according to the amount of time the flood recognition system is in use but are estimated to be about $1,000 excluding staff time. Estimated staff time devoted to the operation and maintenance of the system is estimated to range from 1/3 to 1/2 man-year annually. Major beneficiaries of warnings assist in meeting operation and maintenance costs.

Wise County, Virginia

The impetus for establishment of the Wise County Flood Warning Program was the flooding experience in nearby Nelson County which had received 22 inches of rain in 24 hours when Hurricane Camille struck in 1969. Recognizing that Wise County was similarly vulnerable to severe flooding and that early warnings would be beneficial, the Wise County Director of Civil Defense began development of the existing system. Figure 6 shows a schematic illustration of the existing system. The first precipitation gage, costing $3.00 was purchased in 1971. Simultaneously, LENOWISCO, a regional planning commission for Lee, Wise and Scott Counties organized a joint effort with the three counties, the Tennessee Valley Authority, and the National Weather Service to perform hydrologic studies and develop flood prediction charts.

Flood recognition system equipment now in place in Wise County includes 15 plastic rain gages and 8 observer read river-level gages. Rain gages are located at the Wise County Emergency Operating Center, at homes of civil defense staff members, officials of the several communities served by the system, and with other volunteers scattered throughout the county. Most of the gages are equipped to be read remotely so observers can take readings without leaving their homes. River level gages are either painted on bridge abutments or metal tapes mounted on wood posts. In addition, there are two stream level recording gages on county streams which can be accessed by telephone. These gages were installed and are maintained by the Corps of Engineers.

Weather information provided by the National Weather Service is received at the civil defense office over the

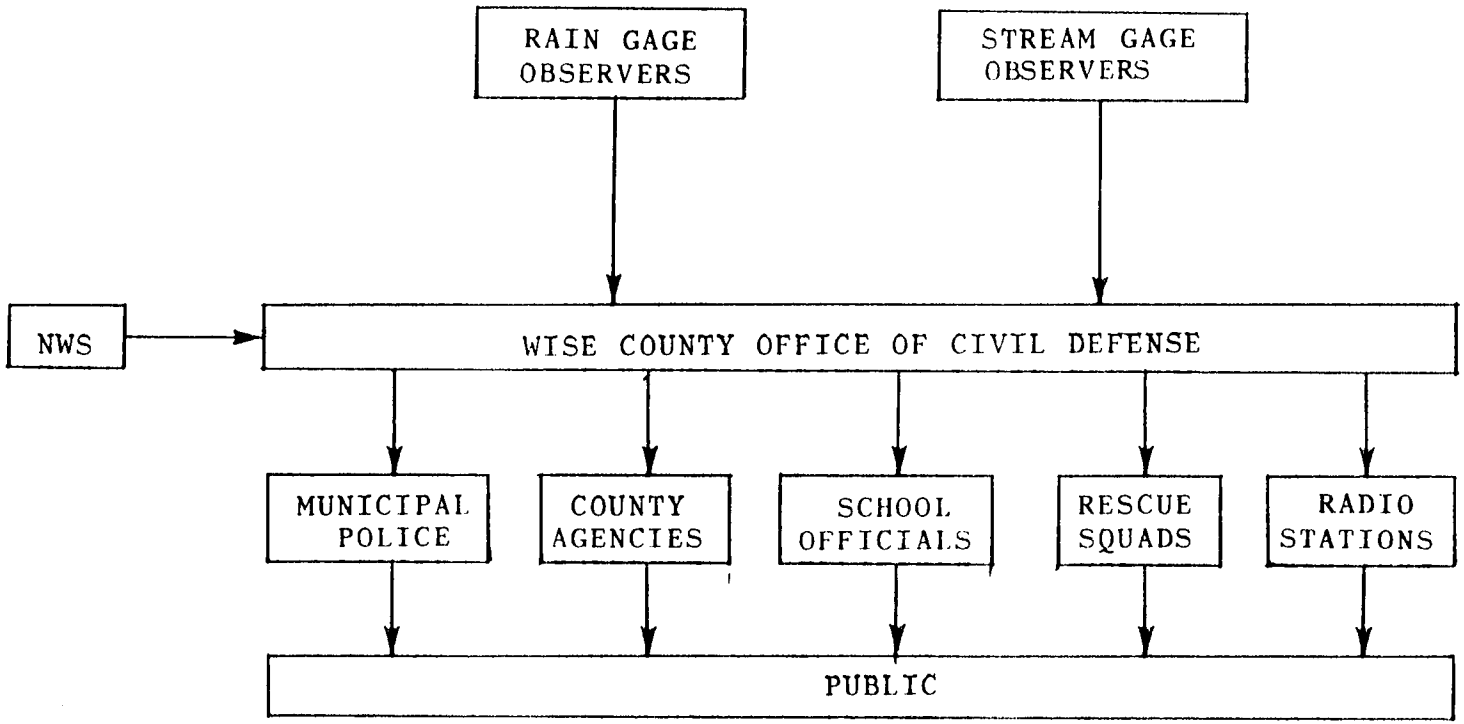


FIGURE 6
SCHEMATIC ILLUSTRATION
OF
WISE COUNTY, VIRGINIA
FLOOD WARNING SYSTEM

Virginia State Police teletype, NAWAS telephone circuit and weather radio. The flood recognition system is activated by the civil defense director, civil defense coordinator, or other senior staff member when information such as a NWS announcement of a flash flood watch indicates heavy rains are anticipated. The system can also be activated by any of the observers who note rainfall in excess of 2 inches in 24 hours at their location. Communications with observers are by telephone, backed up by police radio for key observers. As needed, police furnish mobile radio contact at all observer locations.

Information on rainfall received from observers is used to forecast flood stages. Forecasts are issued to police dispatchers, rescue squads and community officials in the area concerned, to county agencies and officials, to school system officials, and to radio stations serving the area.

Information relating predicted flood heights to areas inundated has been assembled for most areas. Individual communities disseminate warnings to persons in affected areas by sirens and public address systems on police and rescue vehicles and by knocking on doors. Reports from staff gage observers are used to confirm early predictions of flood stages.

The cost of installing the staff gages for the system was approximately $25 each including labor. The precipitation gages which are now used cost approximately $15 each. It is estimated by the Wise County Civil Defense Director that the entire system could be installed from scratch by two persons in one week for less than $1,000. Maintenance cost to the County for the system is about $100 annually, mainly for

replacement of staff gages which are washed out. About 40 man-hours per year are required to inspect and maintain the system.

Swatara Creek, Pennsylvania

The Susquehanna River Basin Commission held a conference shortly after the widespread flooding caused by Hurricane Eloise in 1975 for the purpose of identifying problems which had been encountered and needed actions. Lack of warning was identified as a serious problem which contributed to losses throughout the area and Swatara Creek watershed was ranked as the part of the area where improvement of flood warning arrangements was most urgently needed. The Commission subsequently undertook to stimulate development of a flood warning system for Swatara Creek through development of a plan for the proposed system and hosting of meetings with various officials from the three affected counties. Agreement was reached among the three counties to operate the flood warning system and, six months later, the system became operational. Figure 7 illustrates the operation of the system.

The concept of operation of the Swatara Creek flood warning system is:

1. Use of information provided by 6 volunteer rainfall observers to predict flood stages at Harpers Tavern, Pennsylvania;

2. Use of crest-stage relationships between Harpers Tavern and downstream locations to predict crest

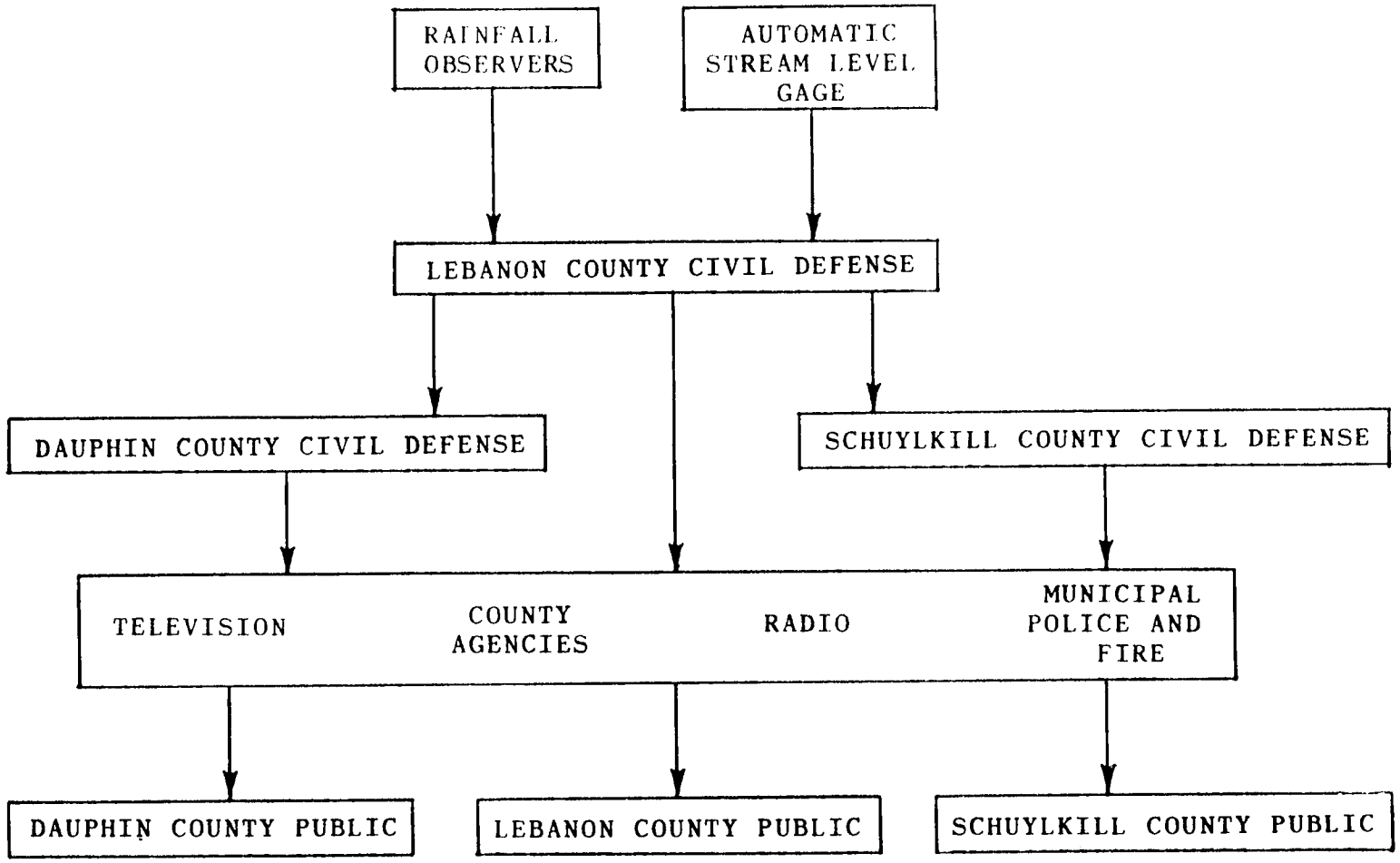


FIGURE 7
SCHEMATIC ILLUSTRATION
OF
SWATARA CREED, PENNSYLVANIA
FLOOD WARNING SYSTEM

stage and time of flooding for other vulnerable places;

3. Use of an automatic stream stage recorder at Harpers Tavern to confirm flood forecasts; and

4. Distribution of warnings from County Civil Defense agencies to various municipalities and, through them, to the public.

Technical aspects of the flood recognition system were developed by the National Weather Service. The Susquehanna River Basin Commission provided precipitation gages and installed 10 river level gages at various stream crossings to provide information for calibration of the system. Original cost for purchase and installation of the several river level gages was $15,000, including labor, paid for by the Susquehanna River Basin Commission. Annual operating and maintenance costs for the river level gages of about $1,500 are shared by the Pennsylvania Department of Environmental Resources and the U.S. Geological Survey.

Coordination of the flood recognition system and preparation of flood forecasts are provided by the Lebanon County Civil Defense Director. Rainfall observers are alerted to begin rainfall measurements whenever information received from the National Weather Service by teletype or radio indicates heavy rains are expected. The observer network is also activated upon request of the Civil Defense Director of any of the three participating counties in the event locally heavy rains occur. Rainfall observers also have a standard operating procedure for self-activation of the system if more than 1 inch of rainfall is received in any 24 hour period.

After their preparation, flood forecasts are distributed by radio from the Lebanon County Civil Defense Director to the Civil Defense Directors of Dauphin and Schuylkill Counties. All civil defense directors then issue appropriate warnings to local fire, police and other emergency services agencies and to radio and television stations. Warnings to the general public are provided by radio and television and by police and fire vehicles with public address systems. The warning system provides a general warning time of about 10 hours in the central portion of the watershed and about 15 hours at Middletown. Confirmation of flood flows through observation of staff gages enables about a 1 hour of highly accurate warning of flooding.

The system has been used three times since becoming operational in 1976. Other than when it is active, no county staff time is devoted to the system.

REFERENCES

California Department of Water Resources. Division of Planning. Levee Patrolling and Flood Fight Methods. Sacramento, CA (Undated).

Healy, Richard J. "Industrial Preparedness: The Need for Planning". Foresight. January-February 1976 (Continued Foresight, Spring 1976).

McLuckie, Benjamin F. The Warning System: A Social Perspective. U.S. Department of Commerce. National Weather Service. Southern Region. March 1973.

Owen, H. James. Guide for Flood and Flash Flood Preparedness Planning. Prepared for the U.S. Department of Commerce, National Weather Service. May 1977.

U.S. Department of Defense, Office of Civil Defense. Principles of Sound and Their Application to Outdoor Warning Systems. December 1966.

Wright, Stewart K. Neighborhood Flash Flood Warning Program Manual. Susquehana River Basin Commission. Publication No. 45. Mechanicsburg, PA October 14, 1976.

Wright, Stewart K. Planning Guide for a Self-Help Flood Forecasting and Warning Program for the Swatara Creek Watershed, Pennsylvania. Susquehanna River Basin Commission. Publication No. 42. Mechanicsburg, PA. November 1976.

Owen, H. James and M. Wendell

Community handbook on flood warning and preparedness programs / by H.James Owen and M. Wendell --(Palo Alto, California), 1981.

(57) p. : ill. ; 27 cm.--(IWR research report : 81-R06)

"June, 1981"
Bibliography: p. 57.

1. Flood damage prevention. 2. Flood warning systems. I. Title. II Series.

HD1694 .A42U548r no. 81-R06

GPO 884-542