AUTOMATED

LOCAL FLOOD

WARNING SYSTEMS

HANDBOOK

Weather Service Hydrology Handbook No. 2

February 1997

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
Office of Hydrology

Cover photo courtesy Scott Dine, *St. Louis Post-Dispatch*.

AUTOMATED

LOCAL FLOOD

WARNING SYSTEMS

HANDBOOK

Weather Service Hydrology Handbook No. 2

February 1997

Office of Hydrology
1325 East-West Highway
Silver Spring, MD   20910-3283

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE

TABLE OF CONTENTS

PREFACE

Communication systems and environmental monitoring and analysis capabilities have improved dramatically over the past decade. These advances provide opportunities for communities who wish to develop or enhance their flood warning programs in order to maxi-mize protection against devastating floods. The National Weather Service (NWS), through its Hydrologic Services Program, contributes to these efforts by cooperating with flood-affected communities that are developing and maintaining Local Flood Warning Systems (LFWS).

This Handbook on Automated Local Flood Warning Systems, Weather Service Hydrology Handbook No. 2 (WSHH#2), is designed to be maintained in a loose-leaf notebook format in order to efficiently incorporate changes. We have attempted to include all relevant topics pertaining to the understanding and implementation of LFWSs. For some users, there may be too much detail; for others, too little. ***We remind readers that WSHH#2 is a technical reference for users and is not intended to be used as a policy instrument.***

All users are encouraged to submit suggestions for improvements in the Handbook and the material presented. Additional information in existing or new topic areas is welcome as well as suggestions that may clarify any point.

Revisions will be issued as needed, but we anticipate that they may occur on an annual basis. Handbook suggestions or questions should be forwarded to the following address:

NOAA, National Weather Service
W/OH2 Office of Hydrology
SSMC2, 8th Floor
1325 East-West Highway
Silver Spring, Maryland 20910-3283

Phone: (301) 713-0006

ACRONYM LIST

ADVIS	Computer program title for the flash flood hydrologic forecast model
ALERT	Automated Local Evaluation in Real Time
ASFPM	Association of State Floodplain Managers
AUG	ALERT Users Group
AWIPS	Advanced Weather Interactive Processing System
C	Celsius
CRC	cyclic redundancy check
CRS	Community Rating System
dB	Decibels
EIF	Enhanced IFLOWS Format
F	Fahrenheit
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FFM	Flash Flood Manual
FIA	Federal Insurance Administration
FS	Flood stage
FSK	Frequency shift keying
FWU	Flood Warning Unit
HRFCG	Hydrologic Radio Frequency Coordination Group
Hz	Hertz
IACWD	Interagency Advisory Committee on Water Data
IFLOWS	Integrated Flood Observing and Warning System
IRAC	Interdepartment Radio Advisory Committee
KHz	Kilohertz
LFWS	Local Flood Warning System
MHz	Megahertz
MOU	Memorandum of Understanding
MSL	Mean sea level
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service)
NEXRAD	Next Generation Weather Radar
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
NWS	National Weather Service
RFC	River Forecast Center
RRRG	Radio reporting rain gage
SAAS	Southwestern Association of ALERT Systems
TVA	Tennessee Valley Authority
UHF	Ultra high frequency
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VHF	Very high frequency
WFO	Weather Forecast Office
WSFO	Weather Service Forecast Office
WSO	Weather Service Office

CHAPTER 1

OVERVIEW OF HANDBOOK

1.1 Purpose

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) has a responsibility to provide flood forecasts and warnings in support of its primary mission of protecting life and property. A basic tool in providing local flood warning capabilities is the local flood warning system (LFWS). Communities can facilitate the NWS in this objective by implementing the LFWS in coordination with NWS hydrologic programs.

The purpose of this Handbook is to provide Federal, state, county, and local governments, as well as the private sector, with a basic understanding of LFWSs and the types and levels of assistance that are available to implement such systems. This document addresses the range of the LFWS—from a simple inexpensive but effective manual flood forecast table to a slightly more complex flash flood alarm system to a computer-driven system usually referred to as an automated LFWS.

1.2 Contents

This Handbook provides a multitude of information associated with automated LFWSs including discussions on the different types of LFWSs and Federal agencies that provide assistance to communities who are establishing local flood warning programs. The Handbook contains 12 chapters and 2 appendices.

Chapter 2 presents a brief history of floods in this United States. Chapter 3 talks about mitigating flood damages through structural and nonstructural methods. Chapter 4 discusses using economic, hydrologic, and sociopolitical cost-benefit analyses to determine whether the LFWS might be a solution to a community's flood problem. Chapter 5 describes the types of LFWSs, and Chapter 6 tells how to get a flood warning system in place. Chapter 7 outlines standards that will make the systems compatible with NWS procedures and equipment. Chapters 8 and 9 address a community's response plan of action and the community rating system and flood insurance program. Chapter 10 describes NWS software that is available for flood warning systems. Chapter 11 addresses the roles that some agencies have in flood warning programs, and Chapter 12 references selected materials and identifies participants in the flood warning program. Appendix A provides sample Memorandums of Understanding (MOU) for both automated and manual LFWSs, and Appendix B contains a sample Flash Flood Manual that a community might use for forecast procedures.

CHAPTER 2

HISTORY OF FLOODS

2.1 General

Floods are a natural and inevitable part of life in the United States. Some floods are seasonal—as when winter or spring rains and melting snows drain down narrow tributaries and fill river basins with too much water, too quickly. Others are flash floods—raging torrents that rip through river beds after heavy rains, surge over the river banks, and sweep away everything in their paths. The transformation of tranquil rivers into destructive floods occurs many times each year across the country. No region of the United States is completely free from the threat of floods, and they may occur at any time of the year (see Table 2-1 for notable flooding that has occurred in the United States).

2.2 Flood Warning History

The NWS provided its first local flood warning capability shortly after World War II. The initial warning system was based on simple tables that related storm rainfall quantities to specific stage heights. Although these tables oversimplified the flood forecast generation process, they provided additional lead-times and effectively produced some reduction in flood damages and loss of life. Many of the manual systems still exist today in portions of the United States, particularly in small communities. In the early 1970s, an automated LFWS was installed by the U.S. Bureau of Reclamation (USBR) in northern California.

Also in the early 1970s, the NWS Office of Hydrology developed and implemented 70 flash flood alarm systems to communities throughout the country that are prone to flash floods. Growth of the automated LFWSs was slow until the late 1970s when the NWS California-Nevada River Forecast Center (RFC) developed the Automated Local Evaluation in Real Time (ALERT) system. Since then, ALERT has spread throughout the United States and into several other countries. During the late 1970s and early 1980s, the NWS, under congressional mandate, planned and developed regionally coordinated LFWSs in Appalachia called the Integrated Flood Observing and Warning System (IFLOWS).

Presently there are over 400 LFWSs in the United States, principally in California, Arizona, Texas, and the Appalachia area. The number of automated LFWSs is expected to increase as additional serious flash flood issues are addressed. Several Federal agencies have become more involved in automated LFWSs as a mechanism to combine structural/nonstructural solutions to the flash flood problem.

Flash floods are only one type of flood event requiring special consideration among the NWS, state and local governments, and the general populace. Main channel flooding also poses a threat to life and property in several areas of the country each year. The NWS's 13 RFCs have hydrologic forecasting responsibility for the main stem rivers and their larger tributaries. RFCs collect hydrometeorological data from a variety of sources, including many

LFWSs, for input to river basin models. At many points, particularly along larger streams, daily forecasts of river stage and/or discharge are routinely prepared for river-related activities such as navigation and water management. Reservoir inflow forecasts aid Federal, state, and local agencies in the operation of these reservoirs for water management activities. Forecasts of water temperatures and ice formation and breakup are prepared for selected locations. Forecasts of seasonal snowmelt or water-year runoff are prepared by the NWS and the Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service, during appropriate times of the year.

RFC hydrologists make appropriate modifications to the hydrographs generated by the model before distributing the forecasts to the local weather offices. The Weather Forecast Offices (WFO)[1] then prepare routine river forecasts and event-driven flood bulletins to the public for more than 3,000 specific locations across the United States. The flood products include forecasts of height and time of flood crest, when the stream is expected to overflow its banks, and when it will recede within its banks. Crest forecasts can be made a few hours in advance for communities on streams draining small areas, but it can be 2 or more weeks in advance for downstream sites on large rivers.

[1] The term "WFO" doesn't officially apply to the office until its Advanced Weather Interactive Processing System (AWIPS) is commissioned and Initial Stage 2 operations commence. In the two-tier, pre-NWS modernization and associated restructuring configuration, meteorological offices are referred to as Weather Service Forecast Offices (WSFO) and Weather Service Offices (WSO). With acceptance of the Next Generation Weather Radar (NEXRAD), those offices destined to become WFOs become NEXRAD WSFOs (NWSFO) and NEXRAD WSOs (NWSO), respectively, and begin Stage 1 operations. However, to simplify the terminology in this document, all of these offices are generically referred to as WFOs regardless of modernization stage.

Table 2-1. *Disastrous Floods in the United States*

The perspective of disastrous floods in the United States is evident from some of these historical examples:

Date	Location and Cause	Deaths	Damage ($ in millions)
Sept 1996	North Carolina, Virginia, West Virginia, Maryland, Pennsylvania - Hurricane Fran	34	3,200
Aug-Sept 1996	Puerto Rico - Hurricane Hortense	21	375
Feb 1996	Washington, Oregon, Idaho, and western Montana - 29 inches rain in less than 1 week	13	1,000
July 1994	Georgia, Alabama, and Florida - Tropical Storm Alberto - 21 inches of rain in 24 hours	33	750
May-Aug 1993	Mississippi River - heavy, prolonged rain (2-3 feet) over parts of nine states	48	15,000
Jun 1990	Shadyside, Ohio - 5 inches rain	26	8
May 1990	Texas, Oklahoma, Arkansas, and Louisiana - torrential rains over several weeks	13	1,000
Jan 1990	Washington and Oregon - heavy rain	3	60
Jun 1989	Texas and Louisiana - Tropical Storm Allison	11	500
May 1989	Texas and Louisiana - up to 16 inches rain	11	10+
Sep 1988	Florida - 18 inches rain	2	50+
Jul 1988	Texas - 10 inches rain	6	1
Feb 1988	Louisiana - 12 inches rain	3	2
Jan 1988	Hawaii - 23 inches rain	0	35
Dec 1987	South-central United States - 4 consecutive days heavy rains	4	17
Nov 1987	Louisiana - 21 inches rain	0	6
Aug 1987	Illinois and Wisconsin - remnants from tropical depression	4	100

Date	Location and Cause	Deaths	Damage ($ in millions)
Oct 1986	Michigan, Illinois, Missouri, and Kansas--up to 20 inches rain over several weeks	10	2,000
May 1986	Pennsylvania - heavy rain	9	23
May 1986	Missouri	3	50
Nov 1985	Appalachia - Hurricane Juan - 6 days rain	63	1,000
Aug 1985	Cheyenne, Wyoming - 6+ inches rain	12	65
May 1984	Tulsa, Oklahoma - 9.5 inches rain	13	130
Oct 1983	Southeast Arizona	10	100
Aug 1982	Kansas City, Missouri - 12 inches rain	4	30
Jan 1982	Central California	30	300
Oct 1981	Texas and Oklahoma	5	200
Feb 1980	California, Arizona, and New Mexico	22	300
Aug 1978	Central Texas - Hurricane Amelia	33	100
Nov 1977	Taccoa, Georgia - dam break	40	N
Sep 1977	Kansas City, Missouri - 13 inches rain	25	100
Jul 1977	Johnstown, Pennsylvania - 11 inches rain	76	200
Jul 1976	Big Thompson, Colorado - 12 inches rain	139	50
Jun 1976	Teton Dam, Idaho - dam failure	14	1,000
Jun 1972	Northeast United States - Hurricane Agnes	120	4,000
Jun 1972	Rapid City, South Dakota	254	N
Feb 1972	Buffalo Creek, West Virginia - dam break	118	N
Aug 1969	Virginia - Hurricane Camille	153	100
Jun 1903	Heppner, Oregon	247	N
May 1889	Johnstown, Pennsylvania - dam failure	2,000+	N

Note: N = damage not available

CHAPTER 3

FLOOD MITIGATION

3.1 Overview

Floods have been a problem even before the founding of the United States. Colonial periodicals and ships' logs depict floods in some detail. However, no attempt was made to mitigate floods in the United States until early in the nineteenth century when the Federal Government removed snags and cleared portions of waterways in the Ohio River Basin primarily for navigation. Just before the turn of the century, the Federal Government began to work with local communities to develop levees and revetments. Structural measures to reduce flood damages began in earnest after 1917 and continued until its peak in the 1960-1980 "golden age of dam construction."

In the mid-1950s, a group of consultants, interested citizens, and Federal and local government representatives met to discuss alternate methods of reducing flood damages in the United States. As a result of this meeting, they introduced the concept of nonstructural alternatives. The Tennessee Valley Authority (TVA) initiated a regional floodplain management assistance program in 1953 providing technical assistance to communities as the basis to encourage floodplain regulations. However, growth was slow until the mid-1960s when the Federal floodplain management services groups were implemented in the United States. In addition to floodplain management and Federal regulation of the Nation's floodplains, disaster preparedness and floodproofing came into vogue as nonstructural solutions. One particularly effective nonstructural means to minimize loss of life and property from floods (principally flash floods) is a flood warning system.

3.2 LFWS Development

The NWS has been a leader in developing technology for LFWSs. Early systems (some still operating) could monitor a single event and had only one sensor. These flash flood alarm systems prompted the development of continuous monitoring systems using the expanding technology of small computers. NWS uses two LFWS technologies: (1) the network-configured system, developed within various NWS components as IFLOWS, and (2) ALERT, developed at the NWS California-Nevada RFC. These NWS-developed systems include specific software loads that operate in a limited number of hardware environments.

IFLOWS is a federally funded NWS program that has cooperative arrangements with seven states in the Appalachia region. It is possible (and encouraged) for other communities and states to fund their own hardware (that meets LFWS standards in this Handbook) and use IFLOWS technology. ALERT systems are community funded or occasionally funded by other Federal or state agencies. Although the data collection capabilities of the two systems are identical, information output is different. ALERT generally provides a one-way alarm of a pending flood event, while IFLOWS provides continuous two-way communication of data and products among the NWS, state, and county offices so that appropriate actions may be coordinated. IFLOWS and/or NWS ALERT base stations have been installed in many NWS offices.

In the modernized NWS, AWIPS will integrate all sources of data and interface to all dissemination systems, including all automated LFWSs. High-resolution digital radar-based precipitation estimates will provide a means for calculating flood/flash flood potential and forecasting floods across most of the Nation—not just those areas covered by LFWS. Integration of technology and data sources encourages information exchange with LFWSs.

CHAPTER 4

DETERMINING THE NEED FOR A LOCAL FLOOD WARNING SYSTEM

4.0 Introduction

This chapter describes the complex process involved in determining whether the LFWS is part of a community's solution to mitigating a flood problem. The popularity and need of automated LFWSs will likely continue since they "sell themselves" for effectiveness in the community's total flood mitigation efforts. Unfortunately, many times they sell themselves **after** a disastrous flood strikes a community.

In this Handbook, community and county are interchangeable and are used to designate the NWS Cooperator who is the owner/operator of the LFWS.

4.1 Flood Risk

Flood damages continue to increase, with current annual average flood damages approaching $4 billion. As flooding continues to affect a greater portion of the growing population in the Nation, communities with persistent flood problems or with vulnerability to great losses when flooding does occur are continually seeking methods to mitigate flood losses. LFWSs are an attractive solution because of their low cost of operation and because they can enhance the operation of other flood mitigation methods such as reservoir floodgate operation, flood insurance, or floodplain zoning. There are also nonflood uses of LFWSs that include fire weather prediction, air quality monitoring, evapotranspiration rate monitoring for watering efficiency, and toxic spill monitoring.

Because of the potential for reducing flood damage via an economical nonstructural approach, LFWSs have been implemented in many communities around the United States. The NWS has taken the lead in the development of the LFWS in cooperation with state and local disaster and emergency services agencies and several Federal agencies, including the U.S. Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA). The use and function of the LFWS dictates the organizational structure necessary. Incorporating an LFWS into community preparedness activities strengthens local capabilities in making timely and accurate decisions for the protection of lives and property. Community leaders need to be aware of potentially dangerous heavy rain situations and the resulting disastrous flash floods that could occur in their locality. In contrast, the LFWS can minimize costly false alarms. The ultimate goal is to protect life and property by achieving and maintaining a high level of community preparedness, in cooperation with the NWS, by utilizing LFWSs to support local disaster and emergency services.

Flooding varies in frequency and magnitude. A minor flood may cause only inconvenience, while a major flood (such as the record flooding in The Great Flood of 1993 caused by 2 months of rainfall over the entire Midwest) can result in substantial loss of life and extensive damage. If the threat from flooding is persistent, or the potential losses are significant, community officials should take steps to mitigate flood losses. Installing the LFWS is one step that can effectively reduce flood losses.

4.2 Local Flood Warning Systems

Many factors influence a community's decision that an LFWS is needed and what type of system is appropriate to meet its needs. These factors include the hydrologic characteristics of the watershed, frequency of flooding, flood loss potential, relationship between warning time and benefits, need for other hydrologic capabilities, the community's interest and awareness, and the cost of the system—both capital investment and maintenance. Among the factors that affect the type of system selected are desired accuracy, lead-time, specificity, cost, and reliability of the system.

4.2.1 Definition of the LFWS

The LFWS is defined as a community-based or locally based system needed to warn local areas of flood danger and consists of many, if not all, of the following: rainfall, river, and other hydrologic gages; hydrologic models; a communications system; a community flood coordinator; and interested and capable volunteers. The primary purpose of the system is to provide emergency service officials with advance flood information that can be readily translated into response actions. A secondary but important function of the LFWS is to provide information for water resource management. Thus, LFWS information can be used to support daily decisions concerning allocation and use of water supplies.

4.2.2 Organization of the LFWS

The LFWS unit offers added support necessary to meet flash flood emergencies (see Figure 4-1). In those communities that have several streams and rivers prone to flash flooding (e.g., a county), more organization may be needed. In many LFWSs, either the local disaster and emergency services director or a dedicated flood coordinator is responsible for managing and maintaining a network of observers, acquiring data, using forecast tools, coordinating with the NWS, and notifying response agencies of expected flood conditions.

Figure 4-2 illustrates a typical LFWS organization chart that applies to many community programs. Notice the separation of different functions. NWS is the Federal agency authorized to issue public watch/warning products for possible or impending flash flooding. Data input (i.e., LFWS data) from the community is vital to the issuance and verification of flash flood warnings by the NWS. The WFO with warning responsibility for that community issues warnings that are disseminated via several real-time mechanisms (e.g., NOAA Weather Radio, NOAA Weather Wire or its successor) to the local disaster and emergency service agency. The local coordinator ensures that these warnings are disseminated to the widest extent possible.

LOCAL FLOOD WARNING UNIT

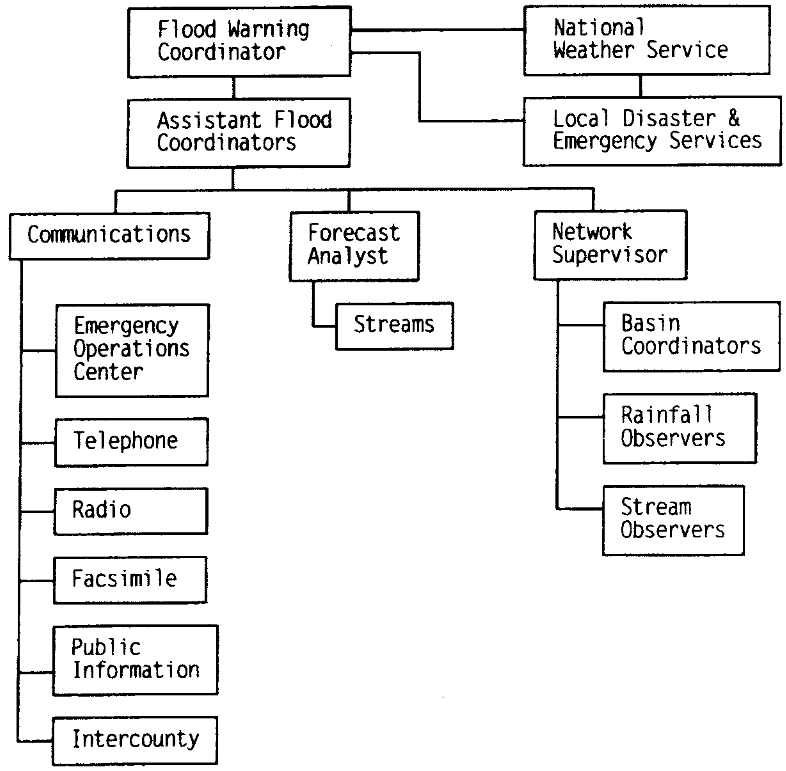

Figure 4-1. *Organization chart of a typical local flood warning unit.*

LOCAL FLASH FLOOD WARNING SYSTEM

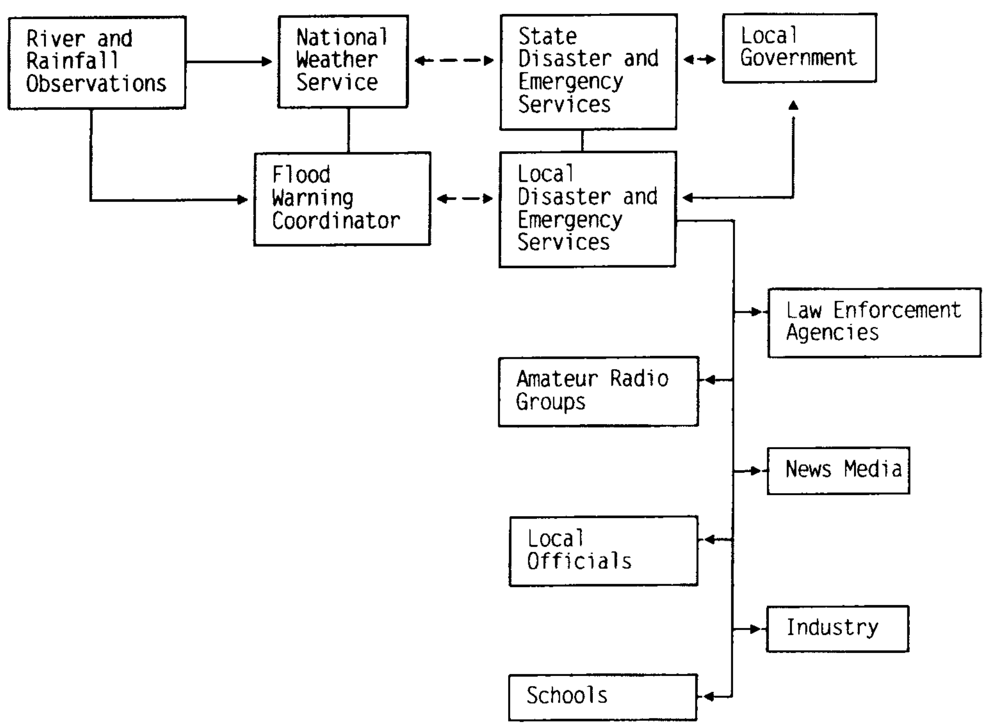

Figure 4-2. *Organization chart of a typical LFWS.*

Once a flood threat is recognized, then various response agencies are notified so they can take appropriate action prior to the onset of flooding. Response agencies (such as transportation, emergency response, and fire department personnel) can then provide valuable feedback about evolving flood conditions.

4.2.3 Goals of the LFWS

The basic goals of the LFWS are to (1) reduce the loss of life and property damage caused by flooding and (2) reduce disruption of commerce and human activities. The techniques for reaching these goals are the following:

1. Improve and maintain an effective communication system between "need-to-know" agencies and individuals;
2. Induce local community involvement and response planning;
3. Educate the public to respond and act accordingly to flash flood forecasts and watches/warnings;
4. Promote effective floodplain management; and
5. Minimize the response time from flash flood warning issuance.

Communities with LFWSs can and do communicate field observations quickly and efficiently to a flood warning unit (FWU). The FWU in turn reports and coordinates information of heavy rains and/or swollen streams to the NWS. Lead-time in the early stages of storm development is crucial for a quick evaluation of the flood potential. When adequate data are available, the NWS, in close coordination with the FWU, can issue timely flash flood watches/warnings that may result in substantial savings in lives and property damage.

The frequency of a flash flood occurring in a given community varies greatly, depending on location and types of streams. There may be long times between events, so the NWS must maintain a high level of interest in the LFWS by personal visits, network meetings, and drills. Communications must continue among all parties of the LFWS as well as with other agencies participating in community preparedness.

4.3 Analysis

This section addresses the following considerations of implementing an LFWS: economic (benefit-cost) analysis, hydrologic (frequency and magnitude of floods) analysis, and sociopolitical (key roles and resources) analysis.

4.3.1 Economic Analysis

A benefit-cost analysis to assess potential benefits of an LFWS is highly recommended. It does not make sense to pay $100,000 for an LFWS to save $50,000 in potential flood damages. Calculation of the benefit-cost ratio for an LFWS is difficult but still should be attempted. Benefits are computed by determining the reduction in losses, both from flood damages and deaths, that would result from implementation of an LFWS. Determining the number of flood deaths prevented is difficult because deaths are primarily caused during short-fused floods when people underestimate or are unaware of the life-threatening situation until it is too late. Increasing lead-time by enhancing flood warning capabilities will save lives. At present, however, many flood deaths occur when people attempt to drive across flooded areas regardless of whether or not a flood warning has been issued. Nonetheless, one can estimate the approximate number of lives saved by assuming that the general populace will react properly to a timely flood warning. Analysis of flood information indicates that if the LFWS provides at least 30 minutes of lead-time, lives will be saved. Reduction in the risk to life is often in itself adequate justification for an LFWS.

Increasing lead-time can substantially reduce flood damages but also may be difficult to quantify. There is no empirical basis for estimating damages prevented by flood warnings that is comprehensive enough to use for general application. However, estimation methods have been applied in specific cases. A number of documented cases show large percentages of damage reduction by effective flood warning. These cases relate specific actions that were taken to reduce flood losses as a result of specific forecasts. The famous Lycoming County, Pennsylvania, Sprout Waldron manual LFWS claims 90 percent reduction of flood damages by linking warning lead-time with floodproofing measures. A comprehensive study to determine flood damage reduction associated with a flood forecasting system was conducted in four communities in the Connecticut River Basin. This study, conducted by Day and Lee, is described in *NOAA Technical Memorandum NWS Hydro-28*, "Flood Damage Reduction Potential of River Forecast Services in the Connecticut River Basin," February 1976. Many will find the approach used in that study useful in conducting their own cost-benefit study. It is essential that all damage reduction actions assumed in an economic analysis be incorporated into a community's response plan, which should associate proper actions with various flood warning lead-times. If possible, the economic analysis should estimate the amount and value of removable property (individual homes as well as businesses) that could be relocated under varying warning lead-times. For a number of communities, useful damage assessment information can be obtained through FEMA's flood insurance and disaster assistance programs.

Another task in determining benefits of the LFWS is determining nonphysical (indirect) costs of flooding. Indirect costs, such as income losses, can be as significant as physical losses. Closing an industrial plant for 1 month can create huge costs that may never be recovered. Indirect costs, which many times are not factored into benefits equations, could provide overwhelming evidence by which every flood-prone community could benefit significantly from local flood warning enhancement. The benefits from flood warning enhancement can also be increased by linking lead-time to operating flood-control structures.

4.3.2 Hydrologic Analysis

Flooding is a natural hazard that can occur at any time. The frequency and magnitude of flooding varies from minor flooding, causing only inconvenience, to major flooding, resulting in loss of life and extensive damage to agriculture, industry, transportation, and commercial and residential segments of society.

The LFWS can provide early recognition that flooding will occur though it may not be effective in reducing flood losses in all communities. Several evaluation factors can determine if an LFWS is appropriate: (1) hydrologic characteristics of the watershed, (2) frequency of flooding, (3) flood loss potential, and (4) warning time in relation to benefits realized.

Hydrologic Characteristics

The first step in evaluating potential benefits is to identify the various sources of flood threat. Sources vary from large, slowly responding rivers that take days or weeks to crest to small creeks that crest in minutes. Each watershed has a unique set of hydrologic characteristics (topography, stream slope, soil type, amount of channel debris) that describe its response to rainfall.

As rainfall or snowmelt occurs over watersheds, runoff begins and streams rise. Depending on characteristics of the watershed, streams can crest within an hour to several hours. Many flashy streams crest immediately after the most intense rainfall, which may be well before the rain ends completely. After the crest, the stream begins to fall and eventually recedes to a low level. An effective LFWS accounts for the individual areas that will flood and facilitates an advance warning for those areas. A well-calibrated forecast model, working in conjunction with an LFWS, also projects the time when flooding is first expected, when the flood will crest, and what the flood crest stage will be.

Many communities realize additional benefits from the LFWS by using their data for other applications. For example, LFWS data are used in the management of reservoirs; allocation of water for municipal, irrigation, and agricultural purposes; and water management and water-quality forecasting. In addition, LFWSs are used to provide weather data during the spring and summer months when dry conditions make some areas vulnerable to fire. Many automated LFWSs include other meteorological sensors that assist in determining direction and extent of potential burns.

Frequency of Flooding

Another factor in evaluating the potential benefits of the LFWS is the likelihood of a damaging flood. The key questions are:

1. What are the potential damages, including loss of life, at various flood levels?
2. What is the likelihood that such a flood will occur?

The benefits of a flood warning system increase as the likelihood of damaging floods increases. The rarer a flood event with damaging potential, the more difficult it is to maintain community awareness and an operationally ready LFWS. An excellent reference source describing the standard techniques used in determining the frequency of flooding is *Hydrology for Engineers*, third edition, by R.K. Linseley, M.A. Kohler, and J.L.H. Paulhus, published by McGraw-Hill, New York, 1982.

Flood Loss Potential

Flood loss potential is described as the potential for loss of life and property damage from the occurrence of various magnitudes of floods. Evaluating flood loss potential is done by assessing the resident population and damageable property located on the floodplain that would be directly affected by flooding. Many communities have established stage damage charts that show the relationship between river stage and flood damage. These charts must be kept current to reflect changes in urban development. The relationship of river stage to inundation area is important in determining flood loss potential. Community flood studies, such as those developed for flood insurance, provide profiles and maps that reveal the magnitude of flooding expected and permit the identification of critical public services that are vulnerable to flooding.

A number of questions must be answered when evaluating flood loss potential:

1. Is there a potential for loss of life associated with floods?
2. What structures are located within the floodplain?
3. What are the annual flood damages?
4. What is the potential flood damage for a particularly severe flood?
5. What percentage of property can be temporarily relocated?
6. Where are the safe evacuation routes in relation to the area of inundation?

In many instances, data are not available to answer all of these questions; however, the more questions answered, the more certainty there will be in determining both the need for an LFWS and the cost effectiveness of a particular system. FEMA can provide services and data (refer to Section 11.7) that may be useful in determining flood loss potential. Cost effectiveness is calculated by comparing the benefits (reduction of damages and loss of life) to the costs associated with purchasing and maintaining a system. Such an analysis is also helpful in selecting the appropriate type of LFWS for a given community. Frequently, the NWS can assist the community to establish the preliminary cost estimate of implementing an LFWS. This may help to avoid a situation where substantially higher costs are involved in determining the cost effectiveness of an LFWS than are involved in implementing one.

Warning Time as Related to Benefits

Warning time is a critical factor in mitigating flood losses. The more lead-time available for appropriate action, the greater the reduction in flood damages that can be achieved. In order to compute the economic benefits of implementing an LFWS, a reduction of damage versus warning lead-time relationship must be derived for each community (an example is shown in Figure 4-3 below). The relationship is based on the Day curve described in detail in *ESSA [Weather Service] Technical Memorandum WBTM Hydro 10*, "Flood Warning Benefit Evaluation-Susquehanna River Basin (urban residences)," March 1970.

In this example, if the present lead-time is 4 hours and the installation of an automated LFWS would increase the lead-time to 14 hours, the percent reduction in flood damages would increase from 11 percent to 23 percent. The net reduction in flood damages would be 12 percent if lead-time is increased by 10 hours.

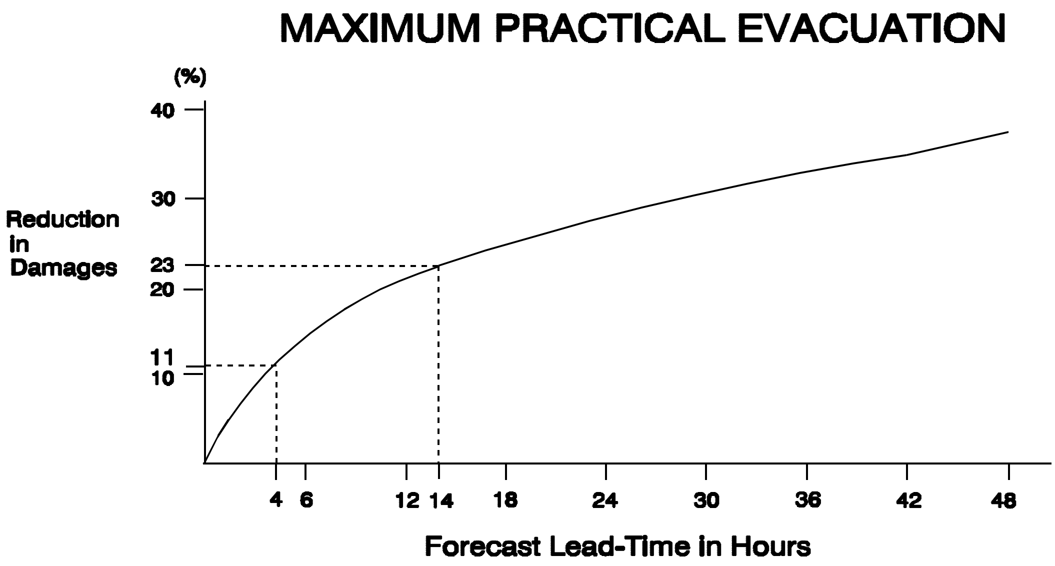

Figure 4-3. *Relationship of lead-time to damage loss.*

<u>Need for Other Hydrological Capabilities</u>

Some communities use automated warning systems for other purposes (also refer to Section 6.2). A hydrologic analysis may include a study related to water management for municipal and/or irrigation purposes. Water quality analysis, including a pollution abatement program, may be needed. In addition, LFWS technology could support monitoring and operation of storm drainage facilities.

4.3.3 Sociopolitical Analysis

The availability of key individuals and the resources of the community are important factors in influencing the type of local flood warning capability that a community selects. Key questions to ask are the following:

1. Is there sufficient sustained interest by community leaders to coordinate and operate a system?
2. Are individuals who will be operating the system qualified and enthusiastic?
3. Is there a good location to operate the LFWS?
4. Will there be adequate resources to purchase and maintain a flood warning enhancement (service or system)?

A "no" to any of these questions can be a good reason not to attempt to implement an LFWS or to implement only a very basic one.

CHAPTER 5

TYPES OF LOCAL FLOOD WARNING SYSTEMS

5.0 Introduction

Determining the most effective type of LFWS for a community is a complicated problem. The type of system used will depend on the familiarity and comfort of community officials with the technological options. Perhaps their confidence in vendors' presentations or recommendations by surrounding communities that have a successful LFWS will be enough information to choose a system. Quite often, though, communities do not know they have options. There are two basic types of LFWSs: manual systems and automated systems.

5.1 Manual LFWS

Many of the LFWSs in operation today are manual self-help systems that are inexpensive and simple to operate. The manual self-help system is comprised of a local data collection system, a community flood coordinator, a simple-to-use flood forecast procedure, a communication network to distribute warnings, and a response plan.

The simplest and least expensive approach to data collection is to recruit volunteer observers to collect rainfall and stream/river stage data. Inexpensive, plastic rain gages may be supplied by the NWS to volunteer observers who report rainfall amounts to a community flood coordinator. The flood coordinator maintains the volunteer networks. More sophisticated automated rain gages may be necessary in remote areas or in situations where observers are not available. Stream gages also vary in sophistication from staff gages to Limited Automatic Remote Collection systems, radios, etc.

An RFC, at the request of and through the Meteorologist in Charge at the appropriate WFO, can provide the cooperator's representative (flood coordinator) with a simple, easy-to-use forecast procedure. This procedure normally consists of tables, graphs, or charts that use observed and/or forecast rainfall and an index for flood potential to estimate a flood forecast. These indices for flood potential (known as Headwater Advisory Guidance) are determined by the RFC and are provided to the appropriate WFO; the WFO in turn provides them to the cooperator(s). Flood forecasts vary from a categorical forecast of flooding to a numerical crest value. Forecasts may also include the time remaining before flood stage will be reached or the time when the crest will occur.

5.2 Automated LFWS

An automated LFWS is composed of sensors that report environmental conditions to a computer using an observation platform communication protocol and a second communication protocol by which information is sent between the base station and other computer system(s). An automated LFWS has either a stand-alone configuration or a network configuration and can consist of the following equipment: automatic reporting river and rainfall gages, a communications system, automated data collection and processing equipment, a microprocessor, and analysis and forecasting software.

Some automatic rainfall gages report rainfall data every time a tipping bucket tips. This is known as event-type rainfall sampling. For river stage, every time a change in stage of a preselected increment is measured, a new river stage value is transmitted from the sensor to a base station.

Automated LFWSs have been designed, developed, and implemented by the NWS, other Federal agencies, state and local governments, and private vendors; and they vary in design, capability, and operation. A community must assess its needs to determine the level of sophistication (and associated costs) required. Automated system operation may vary from a simple flash flood alarm gage that audibly announces imminent flooding to a continuous computerized analysis of precipitation and streamflow and a hydrologic model to forecast flood levels.

In the past decade, a substantial growth in technology and a decrease in the cost of microcomputer systems have resulted in the development of automated flood warning systems. Three of the more prominent automated LFWSs described below include flash flood alarm systems, ALERT, and IFLOWS.

5.2.1 Flash Flood Alarm System

A flash flood alarm system consists of a water-level sensor(s) connected to an audible and/or visible alarm device located at a community agency with 24-hour operation. Water levels exceeding one or more preset levels trigger the alarm. If the system is configured to detect two preset levels, the rate of rise can be determined. The water level sensor(s) is set at a predetermined critical water level and is located a sufficient distance upstream of a community to provide adequate lead-time to issue a warning. Rain gages can also be located upstream of a community; each gage is preset with alarms that sound when a predetermined flood-causing rainfall amount is exceeded. Communication between the sensor(s) and a base station can be via radio or telephone.

5.2.2 Automated Local Evaluation in Real Time

The ALERT system was developed by the California-Nevada RFC in Sacramento, California, and consists of automated event-reporting meteorological and hydrologic sensors, communications equipment, and computer software and hardware. In its simplest form, ALERT sensors transmit coded signals, usually via very high frequency (VHF) and ultra high frequency (UHF) radio, to a base station, often through one or more relay or radio repeater sites (refer to Figure 5-1). The base station, which consists of radio receiving equipment and a microprocessor running ALERT software, collects these coded signals and processes them into meaningful hydrometeorological information. Processed information can be displayed on a computer screen according to various preset criteria, with both visual and audible alarms activated when these criteria are reached. Some systems have the capability of dialing up preselected lists of individuals or initiating other programmed actions when preset criteria are exceeded.

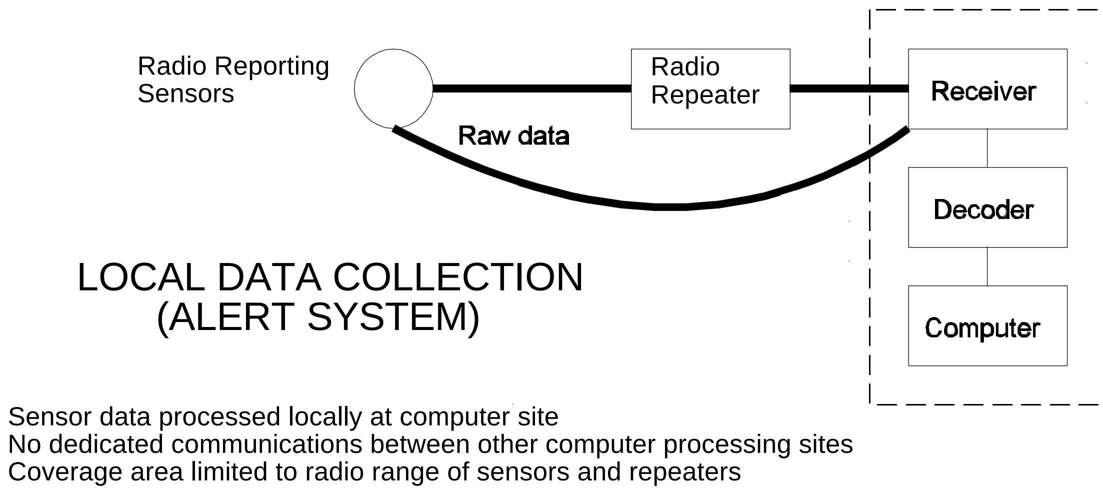

Figure 5-1. *Schematic of an ALERT system.*

ALERT systems in use today are quite sophisticated. Some have the capability to graphically display information, singly or in combination (such as the areal extent of flooding, inundation of roads, evacuation routes, supply depots, hospitals, population centers) on wall-size projection screens. A system can consist of more than one base station connected through repeater networks to pass along raw, unprocessed information from one user group to another. ALERT systems are basically one-way data collection systems developed to deal with specific local problems and normally have little or no computer networking capability.

ALERT systems are locally funded and supported. There are several very active and growing regional user groups. Many systems are owned or maintained by more than one participating organization with each ALERT participant owning or maintaining a small portion of the entire system. In many cases, the NWS does not own any of the equipment in a particular system. In some cases, local system sponsors have provided equipment to the NWS for use in its field offices because they recognize the benefits of NWS forecasts and warnings. NWS Western Region supports the NWS version of ALERT software and sets standards for support of this package. Private vendor versions of this software are also available and in use. ALERT systems are found throughout the United States and in some foreign countries.

5.2.3 Integrated Flood Observing and Warning System

IFLOWS is a wide-area network of ALERT-type systems with enhanced, full, two-way communications capability (voice, data, and text). If desired, IFLOWS can be configured as a stand-alone system for a local community. On the other hand, the ALERT system is normally configured as a stand-alone system for a local government entity. The potential user of the LFWS, in the design phase, should consider the network configuration with its associated area-wide capabilities and costs as well as the stand-alone configuration with its local capabilities. Chapter 7, Standards for Automated Local Flood Warning Systems, establishes baseline capabilities for both network and stand-alone configurations of automated LFWSs.

These systems serve as regional data collection and information dissemination networks (refer to Figure 5-2). In addition to performing real-time data acquisition and processing functions, IFLOWS software handles intercomputer networking and information transfer. IFLOWS computers collect and process remote sensor information; act as data concentrators, allowing more information to pass over a given communications channel in a fixed period of time; and serve as ports into regional communications networks. Not all ports into an IFLOWS network perform all of these functions continuously. They all, however, remain continuously on-line. In case of network failure, an IFLOWS computer can function as a stand-alone, ALERT-type base station.

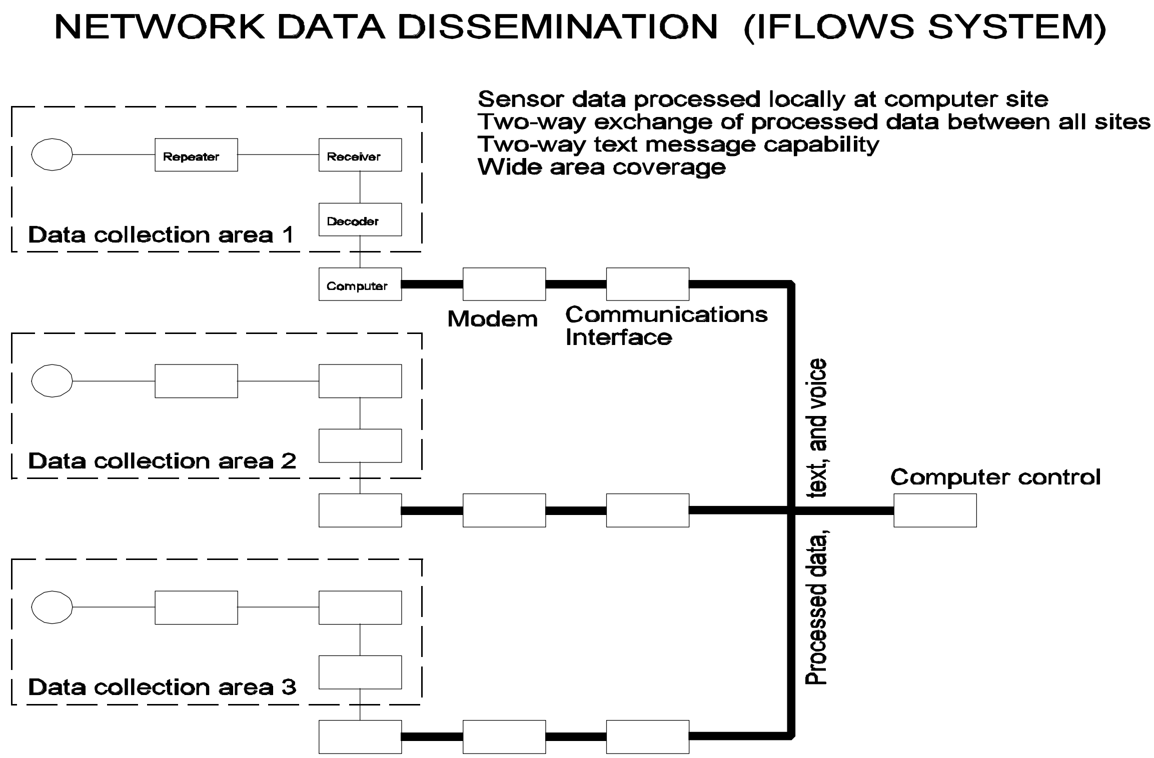

Figure 5-2. *Schematic of a regional IFLOWS.*

Sensor technology for both IFLOWS and ALERT networks is basically the same. IFLOWS software is presently limited to precipitation and river-stage gage applications, while ALERT can handle several other parameters. Section 10.2 provides additional details on IFLOWS software. IFLOWS networks have a backbone communications infrastructure. While the original IFLOWS concept envisioned an all-radio/microwave network, present systems employ leased telephone lines, satellites, VHF/UHF radios, and microwave communications links. IFLOWS networks presently extend into about 200 counties throughout 13 eastern states.

IFLOWS networks (software, hardware, and communications) are supported by the NWS IFLOWS Program. The Program has a defined, centralized management structure primarily located in the Office of Hydrology. NWS Eastern Region Headquarters manages the NWS portion of network operations. IFLOWS, by its very nature, integrates system administration and operation. Multiple levels of government and various agencies at each level of government are involved in operating the systems. Individual systems are usually networked at the state level. Connections between state systems are established at gateways, which are usually at WFOs.

5.3 Additional Considerations

The proliferation of automated system sensors, different hardware and software configurations, multiple hardware and software vendors, and multiple users of automated system data has presented some complex issues that should be addressed by Federal, state, and local agencies contemplating implementation of the LFWS. These issues can be system categorized into the broad elements of data, hydrologic models, and operations.

5.3.1 Data

The rapid increase in number and types of sensors and number of vendors associated with automated LFWS could become a concern if multiple gage formats are developed that restrict access to a very valuable database. LFWS sensor data format issues include the need for standard mark and space frequencies (see Section 7.2).

Another data issue is the need for data exchange between automated LFWSs or between community systems and external users. For instance, a community's automated LFWS may be collecting data needed by an adjacent community.

The NWS has a vested interest in working with communities on quality control of LFWS data, particularly for precipitation data that will be used in NWS forecast models and radar-based precipitation processing operations. Staff at the appropriate WFO and RFC can assist communities in site selection of gages including proper gage exposure (see Section 6.1.1) and in the proper ongoing maintenance of gages (see Section 6.6.2).

In most instances, hydrometeorological data collected by automated systems, such as precipitation data and river stage data, are archived only at the collecting site. These data are only archived to meet a short-term local need and are usually not available for use by other communities, Federal or state agencies, or universities. Data will be lost unless arrangements are made to centrally archive the rapidly expanding database. Long-term archival of hydrometeorological data is important to the NWS and other cooperators for calibrating hydrologic models.

5.3.2 Hydrologic Models

The adequacy of hydrologic model operation has always been an issue in establishing automated LFWSs. Which hydrologic model to use can be a difficult choice. There is a balance between using simplified versus more sophisticated and complicated models. Simplified models are easy to use but require more user input. Sophisticated hydrologic models require a fairly high level of hydrologic knowledge, both in the calibration of the models and in the tuning or adjustment of the soil moisture state variables. Both the initial calibration and the ongoing maintenance of parameters and state variables are extremely important to the accuracy and reliability of an automated LFWS that has hydrologic models as integral parts of the system. Currently the Sacramento rainfall/runoff model is available in the hydrometeorological program that is the NWS version of ALERT.

The NWS assists communities in selecting the proper flood forecast procedures for their needs, considering local as well as NWS support. The MOU (see examples in Appendix A), an agreement between NWS and the community, identifies the LFWS responsibilities of each party.

5.3.3 Operations

An automated LFWS is only one of many nonstructural methods of flood mitigation. There are many structural and nonstructural methods which, when coordinated in an overall comprehensive effort, can produce synergistic results and outperform each method executed separately. For example, the operation of floodgates can be optimized if the LFWS is established and the two are operated in a coordinated manner.

NWS hydrologists analyze a community's flash flood potential with respect to topography and watershed characteristics and also with regard to the location of commercial, residential, and camping areas. Then, the gaging network can be planned and installed. The NWS is a consultant to the community and can provide forecast tools and guidance to implement the LFWS. However, communities may be interested in additional support that NWS cannot provide. In some areas, the flash flooding problem is so significant that local FWUs have subscribed to commercial services that deliver automated radar, satellite, and other guidance material. Even in these cases, real-time coordination is necessary between the local NWS office and the community LFWS. The level of coordination is determined on a case-by-case basis.

Reports of precipitation and stream levels are relayed automatically by radio (or manually by observers) to the FWU. It is essential that this information is relayed in as near real time as possible to the appropriate WFO so NWS can issue timely flood forecasts and/or flash flood warnings. The FWU uses NWS guidance, forecast tools, and field reports to determine stream response. If at all possible, the Flood Warning Coordinator is instructed to coordinate the evaluation with the NWS before a local flood advisory is issued. The process continues until the rain ends and/or the stream crests. The issuance of local flood advisories and warnings by the FWU generally will depend on the capabilities of the FWU staff, regional NWS policy, and the normal response time of streams.

Once local requirements have been met, it is of utmost importance that the NWS have access to the local data in case watches or warnings need to be issued for other communities in the path of the storm. Thus, the community with the LFWS has a large responsibility to ensure that continuous data flows to the appropriate NWS office(s) and to continually coordinate activities, during and after the flash flood event, with the NWS and other "need-to-know" Federal and state agencies.

5.4 Interagency Cooperation

In November 1982, an Interagency Work Group on LFWSs was established by the Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data (IACWD). Subsequently, the name of the Working Group was revised to Local Flood Warning and Response Systems to provide a focus for information exchange on the LFWS. In late 1992, the Hydrology Subcommittee dissolved the Working Group and reassigned the function and responsibilities to the Hydrometeorology Working Group of the Office of the Federal Coordinator for Meteorological Services and Supporting Research. The agencies represented on this Working Group are the Federal Emergency Management Agency, National Aeronautics and Space Administration, National Weather Service, Natural Resources Conservation Service (formerly Soil Conservation Service), Nuclear Regulatory Commission, Tennessee Valley Authority, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and U.S. Geological Survey.

The telephone numbers for contacts at these agencies are as follows:

AGENCY	**PHONE**
Federal Emergency Management Agency	202/646-2753
National Aeronautics and Space Administration	202/358-0771
National Weather Service	301/713-0006
Natural Resources Conservation Service	202/720-4909
Nuclear Regulatory Commission	301/415-6502
Office of the Federal Coordinator for Meteorology	301/427-2002
Tennessee Valley Authority	423/632-4203
U.S. Army Corps of Engineers	202/761-0169
U.S. Bureau of Reclamation	303/236-0123x235
U.S. Geological Survey	703/648-5019

CHAPTER 6

IMPLEMENTING A LOCAL FLOOD WARNING SYSTEM

6.0 Introduction

This section describes the steps in the process of implementing a flood warning system. The LFWS needs to be linked to the response system to produce benefits of flood recognition. Steps to producing an effective response system are not discussed in this document.

- System Design
- Alternate Uses
- Memorandum of Understanding
- Procurement
- Installation
- Maintenance
- Backup System
- Transmitter Licenses

6.1 System Design

The process of determining the need and feasibility of implementing an LFWS will generate critical information required for its design. Through the support of the NWS, other Federal, state, and local agencies, and/or private consultants, the local flood risk will have been assessed, the type of local organization determined, and the financial and sociopolitical support defined. All of the following components of the warning system must be integrated into detailed design documents:

- Measurement and detection
- Data transmission
- Data processing and analysis
- Forecast preparation
- Forecast dissemination

Design may be accomplished through local resources supported by NWS or private consultants.

The software selection, such as NWS ALERT, IFLOWS, and private vendor offerings, will influence the system design. The types, number, and location of gages, as well as their transmission paths to collection points, must be specified.

Prior to the procurement of equipment and as part of system design, all transmitter license approvals must be obtained from the Federal Communication Commission (FCC) (see Section 6.8).

6.1.1 Rain Gages

Number. The number of rain gages installed in an LFWS directly affects its performance. Generally, the more gages, the better the chances of detecting flood-producing rainfall. The number of gages required will depend to a large extent on the rainfall variability in the local area. Therefore, to adequately depict rainfall over a basin, mountainous areas usually will require more gages than flat lands. Areas subject to local convective storms will require more gages than areas that generally experience larger-scale, frontal-type storms. Obviously, availability of funds must also be factored in when determining the number of gages to be installed.

Extensive studies have been made at the Massachusetts Institute of Technology, Stanford University, the NWS, and others, on the spatial variability of precipitation and the number of rain gages needed to predict flood crests. For planning purposes, the number of rain gages required to make a reasonably accurate flood prediction is dependent primarily on the river basin area. The following list suggests the minimum number of gages per river basin area (in square miles).

Number of Rain Gages	River Basin Area (square miles)
3	< 40
4	100
6	400
8	1,000

Exposure. Rain gages should be located on ground level and should not be located close to isolated obstructions, such as trees and buildings, that may cause erratic turbulence and affect the accuracy of the gage catch. Gages should also not be located in wide-open spaces or on elevated sites. The best location is where the gage is uniformly protected in all directions, such as an opening in a grove of trees. If a precipitation gage is near an object, then the distance between the gage and the object should be at least twice the height of the object.

6.1.2 Stream Gages

Stream gages provide information about the current state of the stream. In small watersheds, typical of those associated with LFWSs, streamflow observations are used to calibrate watershed models, verify forecasts from models, or trigger alarms when flooding is impending or occurring. The location of stream gages in an LFWS are guided by one or both of the following factors: (1) downstream public warning requirements and (2) forecast model requirements. Gages used for stage alarms should be located at key points of potential damage and at points that are far enough upstream to yield enough warning time for downstream locations.

6.1.3 Communication Media

LFWSs generally impose few restrictions upon communications design. Consequently, communications design varies depending on the desired area of coverage and resources available for transmission equipment. Currently, LFWSs exist which use VHF or UHF radio, microwave, satellite, dedicated leased telephone lines, or a combination thereof. A brief description of the more common communication elements for automated data collection follows.

Event-Reporting Hydrometeorological Sensors. These sensors are battery-powered, microprocessor-controlled counters interfaced with a modulator and VHF-FM radio transmitter.

Single-Frequency Repeater. The single-frequency repeater is used to extend the radio transmission range of event-reporting sensors. It receives an incoming signal, waits until the entire signal has been received, and regenerates and retransmits it on the same radio frequency.

Microwave Radio System. A microwave system is a series of back-to-back repeater transceivers that are capable of carrying many independent channels at the same time over long distances. Any site in a microwave system can, with the proper interfaces, provide audio communication with one or more sites in the system.

Radio Transceiver. Generally, a radio transceiver is used to extend communications beyond the limit of a microwave or other backbone communications system. Transceivers located at mountaintop sites are called “repeaters,” and transceivers located at endpoints in the system are called “base stations.”

Base Station. A base station is a final destination in the LFWS communications network. Data directly from sensors or repeaters, telephone lines, etc., are received by appropriate interface equipment and transmitted to the base station microcomputer. The computer accepts observation reports, processes and validates information, displays it as required by the users, and forwards data to the appropriate NWS computer, such as AWIPS.

Once local warning and response requirements have been determined, communication engineering expertise should be solicited to define the various communications media options that are available to meet requirements and their associated costs.

6.2 Alternate Uses

Increasing numbers of Federal, state, and local agencies are becoming involved in the implementation and operation of LFWS technology. These programs cover a broad spectrum of real-time environmental sensing. Applications cover highway safety, pollution control, and water management, for example. It may prove more efficient and cost effective for an organization to integrate flood recognition with other local program needs. At the very least, several programs could share the cost and utility of the various data collected. Another very important advantage is that a multipurpose system tends to be used and maintained regularly, ensuring reliable operations during flood episodes.

6.3 Memorandum of Understanding

When implementing an LFWS, both the NWS and the LFWS operator will benefit from an MOU that describes how the parties will cooperate and share in the support for the LFWS. A sample MOU for an automated LFWS and a manual LFWS are contained in Appendix A.

6.4 Procurement

There are two basic approaches for local procurement of the hardware for the LFWS. The first is to purchase the various hardware components from individual vendors (e.g., gages, radio repeaters, and modems from one vendor; computers from another; and possibly a network transceiver from a third vendor). The second approach is to purchase all required hardware from a single vendor specializing in supplying integrated warning system configurations. Information on possible vendors may be obtained from the ALERT Users Group (AUG), the Southwestern Association of ALERT Systems (SAAS), and IFLOWS Management (refer to Sections 11.11, 11.12, and 11.14, respectively) or from various hydrometeorological professional societies.

6.5 Installation

Communities may find it feasible and cost effective to use local government support (such as the highway department, civil works department, or others) to install much of the hardware for the LFWS. It may be necessary to supplement resident support with local vendor support, particularly for installing and testing data transmission equipment. There are vendors who specialize in both supplying and installing complete warning system configurations.

A limited amount of software installation support for NWS-provided software can be provided by NWS. The local U.S. Geological Survey (USGS) office can provide guidance on proper installation procedures for stream-level sensors.

6.6 Maintenance

Proper maintenance of the LFWS is essential for its successful operation. The maintenance program must cover all elements of the LFWS: gages, data transmission system, software and computer, and preparedness/response system. Preventive (routine) maintenance schedules associated with the various hardware components should be followed. Because of the events-reporting nature of sensor platforms, the sensors and system must be operational at all times. Periodic testing of equipment is important. Some diagnostic "tools" are built into ALERT/IFLOWS equipment and software. The ALERT/IFLOWS gage transmitters are programmed to transmit twice a day for diagnostic purposes. There are diagnostic routines in the IFLOWS software that indicate potential radio communication problems.

Those users associated with the local FWU must be trained and kept current on their roles and responsibilities. Conducting practice drills in concert with the NWS, at routine intervals, has proven valuable in keeping the system at a high level of readiness. The local agency must prepare for life-cycle equipment replacement. The gages and communication equipment have useful (maintainable) life spans of about 10 years. The computer hardware life span is about 3 to 5 years. Generally, maintenance and life-cycle replacement costs each run around 10 percent of capital investment per year.

6.6.1 Funds for Maintenance

A community may use various funding sources (general local tax base, special surcharge, general/private donations, etc., or combinations thereof) to fund maintenance. Whichever method is chosen, it is important that it can produce recurring funds for the long term. As mentioned above, a rough estimate for maintenance funding is 10 percent per year of the initial capital cost of the LFWS.

6.6.2 Recommended Routine and Preventative Hardware Maintenance

Routine maintenance for all field sites should be scheduled at least once, and preferably twice, each year for servicing of the following equipment:

<u>ALERT/IFLOWS Battery Gage</u>

1. Set up a rotating battery-change schedule at least twice per year, less frequently if solar panels are used.
2. Check battery voltage, every visit. Check voltage before and during transmission.
3. Check battery terminals for corrosion or loose terminals/connections, every visit.
4. Check battery level to avoid dropping below manufacturer's specifications, every visit.
5. Follow battery manufacturer's instructions for discharging battery prior to recharging.

Note: A solar panel charging system is highly recommended as part of the field installation.

<u>Antenna</u>

1. Position antenna elements so that they are not directly above the rain gage's collector.
2. Check reflective power in and out.
3. Do visual inspection for gunshots or missing elements. Look for broken or exposed antenna cable.

4. Check antenna clamps to be sure bolts are tight and verify antenna direction.
5. Plug top of antenna mast; keep water out of standpipe.

Rain Gage Unit

1. Check rain gage tipping bucket mechanism for proper balance, every visit.
2. Check for spider webs, wasp nests, bird droppings, or other debris in the funnel, every visit.
3. Check rain gage housing to be sure it is secured, every visit.
4. Calibrate and clean rain gage tipping bucket, at least once per year.
5. Seal bottom of tipping bucket housing with waterproof sealer.
6. Make sure all holding screws are in place and tight so that the tipping bucket remains level in high winds and/or with some pushing on the standpipe.

Water Level Sensor (Shaft Encoder)

1. Check reed switches when unit will not hold calibration.
2. Rotate wheel several turns to make sure chain doesn't jump off sprocket, every visit.
3. Check wires at terminal block and plug with ohmmeter, every visit.
4. Calibrate to ensure accuracy, every visit.

Water Level Pressure Transducer

1. Check for vandalism and for biological fouling, silting, sand, wood, plastic, etc, every visit.
2. Check to make sure straps are holding, every visit. Replace straps or add more if movement is noticed.
3. Check pressure transducer plug at transmitter for loose or broken wires, every visit.
4. Reseal any electronic components in a liquid epoxy, when necessary.

Sensor Transmitter

1. Clean radio frequency link device, once per year.
2. Disconnect, clean, and reconnect the connections between main board, back board, and plug-in sockets to ensure positive electrical contact, once per year.
3. Measure output in watts, every visit.
4. Replace desiccant pack, once per year.

Standpipes

1. Re-level pipes if required.
2. Seal any gunshot holes.

Base Station (Computer/Software/Radios)

1. Check station, daily.
2. Execute all commands and run all menu selections to make sure all are working properly, twice a month.
3. Switch to standby power on a regular schedule to ensure proper operation.

Repeater

1. Check battery and connections, every visit.
2. Check antennae for damage, every visit.
3. Check coaxial transmission line and connectors to antennae for damage, every visit.
4. Check commercial power and/or solar panel and connecting cables, every visit.

Spare Equipment

1. Keep spares on hand (at least 10 percent recommended) of each type of equipment used in the overall LFWS.
2. Exchange or test spare equipment, monthly.
3. Store equipment in a clean, dry environment.

Additional maintenance information is available from the Internet web sites of the AUG and SAAS listed in Sections 11.11 and 11.12, respectively.

6.6.3 Emergency Maintenance

ALERT/IFLOWS gages are programmed to report twice a day. If gaged data are not being received as scheduled, initiate emergency maintenance to check suspected gage malfunctions. If there is a store-and-forward repeater in the LFWS and a large number of gages appear not to be reporting, the likely culprit is the repeater.

A spare parts inventory should be maintained. This is particularly important for the electronics packages of the gages and repeaters.

6.7 Backup System

The NWS advises some backup for the automated LFWS. To ensure the integrity of its local flood warning effort, the community should maintain an auxiliary power supply (uninterruptible power supply, generator) and a backup data collection capability (redundant radio paths, radios, and computer). Where such backup cannot be automated, it may be necessary to establish a network of observers to report at least rainfall and river stages when the automated system is not functioning. Although circumstances vary, many areas of the country have found computerized backup to be less expensive and more reliable than maintaining an auxiliary network of observers.

If the LFWS includes a forecast model on a computer and other backup is not available, a manual forecast procedure should be readily available. Numerous manual forecast procedures in the form of simple look-up tables have been used for years and serve as an effective backup process during critical flood situations. The last portion of Appendix B of this Handbook contains an example of a manual forecast procedure.

6.8 Transmitter Licenses

Many LFWSs transmit data via line-of-site radio signals. Transmission of these signals requires that licenses be obtained from the FCC through a process outlined in the subsections below. The FCC has set up specific procedures for obtaining licenses for the transmission of hydrologic data, which is the category that LFWS data come under. The FCC has reserved frequencies that are strictly for the transmission of hydrologic data. They are in the VHF band (169.425 to 171.925 MHZ) and in the UHF band (406.125 to 412.775 MHZ).

6.8.1 Coordination

For Federal agencies, application must be made to the Interdepartment Radio Advisory Committee (IRAC) through the Hydrologic Radio Frequency Coordination Group (HRFCG). The HRFCG of the Hydrology Subcommittee of IACWD reviews all applications for use of frequencies in the hydrologic bands, checks for possible impacts on already existing users of the frequencies, and recommends acceptance or rejection, based on its findings, to the IRAC and FCC. The IACWD committee has members from all Federal agencies that deal with water data.

For non-Federal agencies (e.g., counties, cities, etc.), application must be made to the FCC through the HRFCG. As part of the application, the non-Federal user must have a letter from a Federal agency verifying that agency is a cooperator in the hydrologic data collection system. All non-Federal users of these frequencies are secondary to Federal Government station users, and the hydrometeorological data being transmitted must be made freely available on request to government agencies.

The membership of the HRFCG includes representatives from the TVA and the Departments of Agriculture, Defense, Energy, Interior, and Commerce. The NWS representative serves as the permanent chairperson of the HRFCG.

6.8.2 Frequencies for Hydrologic Purposes

The HRFCG recommends to the IRAC and to the FCC the assignment of specific frequencies in the bands allocated for use jointly by Federal agencies and non-Federal users for transmission of hydrometeorological data for hydrologic purposes.

Specific frequencies allocated primarily for hydrologic purposes are (in MHZ):

169.425	170.225	171.025	171.825
169.4375	170.2375	171.0375	171.8375
169.450*	170.250	171.050	171.850
169.4625	170.2625	171.0625	171.8625
169.475	170.275	171.075*	171.875
169.4875	170.2875	171.0875	171.8875
169.500	170.300	171.100	171.900
169.5125	170.3125	171.1125	171.9125
169.525	170.325	171.125	171.925
406.125	409.675	412.625	412.725
406.175	409.725	412.675	412.775

* frequencies that are shared with the Department of the Treasury and are being phased out for hydrologic purposes

6.8.3 Application Process for Federal Agency

A. Applications by a Federal agency desiring use of hydrologic radio frequencies or in cooperation with a non-Federal user should be made through appropriate NWS channels to:

Hydrologic Radio Frequency Coordinator
Office of Hydrology (W/OH2), SSMC2
NOAA, National Weather Service
1325 East-West Highway
Silver Spring, MD 20910-3283

Applications by non-Federal users wishing to hold the license but having the NWS as the Federal Cooperator may be made directly by the non-Federal user to the above address. The approval process can be quite lengthy, usually taking 4-6 months. When establishing new stations, begin the process as soon as site coordinates have been accurately established.

Submit an original and nine copies of the application to the above address. The application consists of a memorandum describing the proposed plan of operation and the following information for each proposed station (see the example in Figure 6-1):

1. Location name;
2. Type of station (sensing, repeater, base station, etc.) [specify sensing type (precipitation, river stage, etc.) in the remarks column];
3. Location of gages, etc. (latitude and longitude to nearest second);
4. Frequency or frequencies required. Indicate transmitting (T) and receiving (R) frequencies;

5. Output power of transmitter in watts;
6. Antenna characteristics:
    a. antenna type (yagi, corner reflector, or collinear)
    b. orientation if directional (three-digit number in degrees from true north or nondirectional, as appropriate)
    c. gain in decibels (dB);
7. Height of antenna above ground (feet);
8. Gage site (ground) elevation (feet MSL);
9. Necessary band width of emission expressed in kilohertz using the letter K in lieu of the decimal (e.g., use 2K85 instead of 2.85 KHz);
10. Emission Classification Symbols (use "F2D");
11. Type of hydrologic data to be transmitted (precipitation, river stage, etc.);
12. Map showing location of transmitting and receiving stations and limits of operational area. A coordinate grid (latitude and longitude) should be shown on the map. When proposed stations are additions to or modifications of an existing network, the map should show the complete system that will exist after pending actions are completed.
13. Justify installation with an explanation of how the collected data will be used and why a radio is to be used in lieu of land lines.
14. Cooperating agencies, if any. (Non-Federal users must identify the cooperating Federal Government agency.)

B. The HRFCG Coordinator shall send a copy of the request to all group members for review and comment concerning the effect upon each of their agencies' operations and for an appraisal from each member as to the appropriateness of using the hydrologic frequency spectrum for the purpose intended. All requests for hydrologic frequencies are initially screened for two criteria:

    1. A Federal agency must sponsor the applicant, and the applicant must share the LFWS data with that agency free of charge, although the agency need not be on the HRFCG.
    2. The information transmitted must be of a hydrologic nature.

    The group members shall check the request against other current applications and records of existing installations. When the request has received clearance from all group members, the Coordinator shall advise the applicant on behalf of the Hydrology Subcommittee and so advise the IRAC or FCC that formal application may be made to the Frequency Assignment Subcommittee of IRAC or the FCC for frequency assignment. A copy of the Coordinator's clearance letter should be used by the applicant to indicate that coordination has been accomplished.

C. If, under B above, group members present objections to the applicant's proposal, the Coordinator shall recommend counter-proposals. If a counter-proposal is acceptable, the Coordinator shall then advise the applicant of required revisions to the original proposal in order to overcome the objections. If group members cannot reach agreement on a request, that particular case shall be referred to the full Hydrology Subcommittee for decision.

D. Applications to IRAC (or FCC) for frequency assignments shall be made within 3 months following Hydrology Subcommittee action; otherwise, requests must be resubmitted to obtain clearance.

E. Any modification of existing networks or individual stations (where the data supplied under A(1) through (11) are changed) shall be submitted in writing to the Coordinator with an original and nine copies. This submission shall clearly describe the revised system or network with modifications to the original system or network. According to the nature of the change, the Coordinator shall effect the necessary coordination with appropriate committee members.

F. When the authorized frequency assignment(s) are no longer needed by Federal agencies, termination of the operation(s) should be reported through individual agency channels to the IRAC Frequency Assignment Subcommittee in addition to notifying the HRFCG Coordinator.

6.8.4 Application Process for the Non-Federal Agency

A non-Federal user desiring frequency assignments shall submit a request that provides the information outlined in 6.8.3A. Such requests shall be processed in accordance with paragraphs 6.8.3B through E above. If the Committee recommends favorably, the HRFCG Coordinator shall advise the applicant, IRAC, and FCC that there is no objection to making a formal application to the FCC for license. A copy of the approval letter from the HRFCG should be attached to the FCC application as proof that coordination has been accomplished. If a license is granted, the responsibility for the applicant's adherence to all legal requirements of the license rests with the FCC. In the event of unfavorable action by the Committee, the applicant and the FCC shall be so notified. The application process can be quite lengthy, usually taking 6 months.

6.8.5 Status Reports

At each regular meeting of the Hydrology Subcommittee, the HRFCG Coordinator shall report, for the record, on the status of pending and completed coordinations. Every effort shall be made to expedite actions if the need is so stated in the original request.

6.8.6 License Renewal

Licenses are valid for a period of 5 years. The agency that holds the license is responsible for renewing the license before the expiration date. Renewal is accomplished by applying for radio frequency as if for the first time (Sections 6.8.3 or 6.8.4 above). When anticipating license renewals, applicants should initiate requests approximately 6 months before the license expiration date.

6.8.7 Responsibility of Licensee

The NWS processes all requests for hydrologic frequency assignments and is often the agency that holds the license. The agency that is assigned these authorizations is responsible for the transmissions that take place. If the transmissions cause interference with another project, whoever holds the license will be ordered by the FCC to rectify the situation.

6.8.8 Reference

U.S. Department of Commerce, *Manual of Regulations and Procedures for Federal Radio Frequency Management*, National Telecommunications and Information Administration.

December 4, 1996

NAME: Flood City LFWS

Map No	Station Name	Station Type	Latitude North DD MM SS	Longitude West DD MM SS	Frequency Receive (MHZ)	Frequency Transm (MHZ)	Transm Power Watts	Antenna Type	Antenna Orient (Deg)	Antenna Gain (db)	Height Above (ft)	Site Elev (ft)	Band Width (KHZ)	Emission Classi-fication	Remarks
1	NEWVILLE	Sensing	41,23,08	84,48,06		171.025	8	OMNI		3	13	815	8K00	F2D	P, S, T
2	DECATUR	Sensing	40,50,55	84 56 16		169.425	8	OMNI		3	13	790	8K00	F2D	P, S
3	ANTHONY BLVD	Sensing	41,05,02	85,06,47		169.425	8	OMNI		3	13	750	8K00	F2D	P, S
4	AUBURN	Sensing	41,20,40	85,03,31		171.025	8	OMNI		3	13	880	8K00	F2D	P
5	IRENE BYRON	Sensing	41,11,56	85,10,25		171.025	8	OMNI		3	13	850	8K00	F2D	P
6	SMITH FIELD	Sensing	41,08,41	85,09,24		171.025	8	OMNI		3	13	835	8K00	F2D	P
7	SPY RUN	Sensing	41,06,30	85,08,54		169.425	8	OMNI		3	13	810	8K00	F2D	P
8	ROCKFORD	Sensing	40,41,40	84,38,54		170.300	8	OMNI		3	13	805	8K00	F2D	P, S, T
9	SALEM	Sensing	40,41,48	84,51,07		170.300	8	OMNI		3	13	815	8K00	F2D	P
10	POE	Sensing	40,56,11	85,05,18		169.425	8	OMNI		3	13	790	8K00	F2D	P
11	MULDOON ST	Sensing	40,59,16	85,06,03		169.425	8	OMNI		3	13	830	8K00	F2D	S
12	GRABILL	Repeater	41,12,36	84,58,04	171.025	169.425	25	DIR	210	7	50	820	8K00	F2D	
13	DECATUR	Repeater	40,50,20	84,55,31	170.300	169.425	25	DIR	315	7	80	790	8K00	F2D	
	ROOTS SKI HA	Sensing	41,09,12	85,04,43		169.425	8	OMNI		3	13	795	8K00	F2D	P, S
14	FORT WAYNE	Receiver	41,00,10	85,12,41	169.425		110	OMNI		5	60	791	8K00	F2D	

Figure 6-1. *Example of station information for license application.*

CHAPTER 7

STANDARDS FOR AUTOMATED LOCAL FLOOD WARNING SYSTEMS

7.1 Overview

The primary purpose of LFWS standards is to ensure compatibility with NWS systems and operations. Any system meeting the standards specified in this chapter could effectively send data to NWS offices and receive products from NWS offices. In addition, these standards describe the sensor transmission system, the sensor communication protocols, and the data and product exchange formats of the "baseline" automated LFWS. The assumption is that private vendors are likely to market systems providing enhancements beyond this functional baseline, but NWS will not provide software with capabilities beyond the baseline. However, it is the intent of the NWS to structure the baseline software to facilitate the addition of applications to it by individual users. The NWS is free to enhance systems installed in its own offices as resources permit.

Although NWS standards for an automated LFWS establish technical requirements for compatibility with the NWS, they do not supersede regular policy channels for establishing NWS links to an automated LFWS under a properly ratified MOU. Meeting these standards is a necessary but not sufficient condition for exchange of information with the NWS.

7.1.1 Network-Configured System

Through congressional mandate, NWS developed and supported implementation of IFLOWS. The NWS initially developed cooperative agreements with selected Appalachian state emergency services agencies. Under these agreements, NWS (1) develops the system design, (2) provides equipment and software, (3) provides upgrades to software, (4) supports equipment replacement, and (5) provides continuing technical support. Since its initial implementation, IFLOWS technology has expanded into other areas. Each participating state operates and maintains the system within its boundaries. As a result of its continuing involvement in IFLOWS, NWS exercises a significant degree of configuration management authority, both hardware and software and both government and vendor supplied. This is critical to the ability of the NWS to effectively manage IFLOWS.

IFLOWS usually operates as a wide-area network with two-way communication capability (voice, data, and text). These NWS-developed systems include specific software loads that operate in a limited number of hardware environments. The IFLOWS software is available to others outside the IFLOWS program area.

7.1.2 Stand-Alone-Configured System Standards

Configurations of stand-alone, computer-based LFWSs, in particular ALERT systems, are funded, operated, and maintained by many cooperators. The original ALERT was developed in the NWS Western Region; Western Region has set standards for support of this suite of software. There are private vendor ALERT systems as well. The NWS may provide

NWS-developed software for a specific hardware configuration, or the cooperator may contract with private sources for this software. These LFWSs operate basically in a stand-alone configuration with one-way data collection per community or group of communities.

7.2 ALERT/IFLOWS Gage Formats

Message format for ALERT/IFLOWS observation platforms, as adopted by the AUG, is:

1. ALERT/IFLOWS data transmissions utilize a frequency shift which represents a "zero" with a 1920 Hz audio tone and a "one" with a 2133 Hz audio tone. These frequencies are not compatible with Bell 202 in isolating ALERT messages from the many interference sources that commonly utilize Bell-compatible message forms. This technique has not resulted in any discernible increase in manufacturing costs and helps to reduce the potential for decodable interference while maintaining a minimum message length.
2. ALERT/IFLOWS may use 300 or 1200 baud; however, 300 baud is recommended. Although 1200 baud has apparent advantages for automated data collection sites, these advantages may be illusory. The 1200-baud messages require better radio paths than are needed for 300-baud data recovery. Many remote sites now operating at 300 baud are at the margins of adequate data recovery and are not capable of operating at 1200 baud. The future requirement for "narrow banding" will alter radio transmission characteristics in a manner that will make the difficulties of using 1200 baud even more severe. These factors weigh against the use of 1200 baud in any area where data are needed from sites with marginal radio paths.
3. Each ALERT/IFLOWS message consists of 40 bits, representing four 8-bit characters, each preceded by a single start bit and followed by a single stop bit. The following table shows the order of transmission reading from **right to left**, then from **top to bottom.**

< -- Transmission Order < --

Stop	0	1	A_5	A_4	A_3	A_2	A_1	A_0	Start
Stop	0	1	A_{11}	A_{10}	A_9	A_8	A_7	A_6	Start
Stop	1	1	D_4	D_3	D_2	D_1	D_0	A_{12}	Start
Stop	1	1	D_{10}	D_9	D_8	D_7	D_6	D_5	Start

where:

A_i is the i^{th} bit of the reporting sensor address, where A_0 is the least significant bit and A_{12} the most significant.

D_i is the i^{th} bit of the reporting sensor data (accumulator) value, where D_0 is the least significant bit and D_{10} the most significant.

Start is the start bit for each character. It is always a space (0).

Stop is the stop bit for each character. It is always a mark (1).

This format provides an identifier range of 0 through 8191 and a data range of 0 through 2047. The bits identified with 1 or 0 are used to confirm that an incoming message is formatted in the ALERT/IFLOWS binary code.

4. No check sums or multiple transmissions are utilized in order to minimize interstation interference.
5. All sites shall transmit their principal sensor identifier and its current accumulator value at 12-hour intervals.

7.2.1 Enhanced IFLOWS Format for IFLOWS Gages

The Enhanced IFLOWS Format (EIF) is an alternative message format for IFLOWS observation platforms. EIF is fully compatible with ASCII and binary formats and can coexist on a single radio frequency with platforms that use these formats. Moreover, since EIF changes only the ***content*** of the message, implementation in microprocessor-controlled platforms should involve simple reprogramming. All other characteristics of reports, including message length, bit polarity, and frequency shift keying (FSK) tones used to encode mark and space states, remain unchanged.

Each IFLOWS message consists of 40 bits, representing four 8-bit characters, each preceded by a single start bit and followed by a single stop bit. The following table shows the order of transmission reading from ***right to left***, then from ***top to bottom***.

< -- Transmission Order < --

Stop	1	1	A_5	A_4	A_3	A_2	A_1	A_0	Start
Stop	D_0	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	Start
Stop	D_8	D_7	D_6	D_5	D_4	D_3	D_2	D_1	Start
Stop	R_0	R_1	R_2	R_3	R_4	R_5	D_{10}	D_9	Start

where:

A_i is the i^{th} bit of the reporting sensor address, where A_0 is the least significant bit and A_{12} the most significant.

D_i is the i^{th} bit of the reporting sensor data (accumulator) value, where D_0 is the least significant bit and D_{10} the most significant.

R_i is the coefficient of the i^{th}-order term in the remainder polynomial (see below).

Start is the start bit for each character. It is always a space (0).

Stop is the stop bit for each character. It is always a mark (1).

Calculating The Remainder Polynomial

Ignoring start and stop bits (which serve only to frame characters and are discarded by receiver hardware), a gage report consists of 32 data bits transmitted serially. The first bit transmitted is A_0 and the last is R_0. Each bit may be considered the coefficient of a term in a 31^{st} order polynomial of some arbitrary variable x; A_0 is the coefficient of x^{31}, A_1 of x^{30}, and so forth, with R_0 the coefficient of x^0.

To create a message, store the sensor address and data in the A_i and D_i fields, respectively, and zero all R_i bits. Using modulo-2 arithmetic, divide the message polynomial by the EIF generator polynomial $x^6 + x^4 + x^3 + 1$ and add the remainder (a polynomial of order 5 or less) to the original message (the addition has the effect of setting R_i to the coefficient of x^i in the remainder polynomial). The resultant message is transmitted as outlined above.

When a receiver detects a message whose first byte has the form 11*xxxxxx*, it assumes the format is EIF. Treating the message as coefficients of a 31^{st} order polynomial of x and using modulo-2 arithmetic, the receiver divides it by the generator polynomial. If the remainder is not zero, the message suffered one or more errors during transmission and should be discarded. Otherwise, the message is presumed correct (although it may contain an undetected error) and is processed accordingly.

Undetected errors occur when the transmitted and received message polynomials differ by a polynomial (called the error polynomial) of which the generator polynomial is a factor. If all possible error polynomials were equally likely, the EIF would fail to detect one error in 64. However, some errors, such as one-bit and two-bit errors, are far more common than others. By choosing a generator polynomial carefully, one can improve the probability of detecting all (or most) common errors dramatically. The selected EIF generator $x^6 + x^4 + x^3 + 1$ detects all one-bit and two-bit errors, all errors affecting an odd number of bits, all burst errors of length 6 or less, 96.9 percent of seven-bit burst errors, and 98.4 percent of all other errors.

7.2.2 The ALERT Users Group Enhanced Format

The binary format that both the ALERT and IFLOWS systems used has an excellent range for sensor identification and data description. In addition, the message format is very well defined by start, stop, and format identifier bits; however, the binary format has no internal data-checking capability. In 1988, the Technical Review Committee of the AUG conducted a survey of over 40,000 ALERT messages. In this sampling, about 300 messages (approximately 0.7 percent of the decoded messages) had errors that might have been avoided by using a format with internal message-checking capability. The Committee, composed of ALERT users, equipment providers, hydrologists, meteorologists, equipment maintenance personnel, and software writers, suggested the application of an error-checking or enhanced format in an attempt to reduce the apparent error rate that had been associated with the binary format. In May of 1988, at the annual meeting of the AUG, an enhanced format recommended by the Technical Committee was approved as an alternate format for conjunctive use in the ALERT system. The enhanced format incorporated a cyclic redundancy check (CRC) for message checking and a battery-level indicator to guide field maintenance personnel. However, in order to avoid a decline in the system's throughput capability, the message was not altered. The bit structure of the enhanced format was organized so that it could operate concurrently with the earlier formats. Thus, if the new format proved successful, equipment that utilized earlier formats could be modified or replaced through attrition rather than requiring a simultaneous replacement of field equipment. The format selected as the AUG enhanced format is the following:

Character One

Bit Number	Significance			
1	Start Bit			
2	Sensor Identifier	0	or	1
3	Sensor Identifier	0	or	2
4	Sensor Identifier	0	or	4
5	Sensor Identifier	0	or	8
6	Sensor Identifier	0	or	16
7	Sensor Identifier	0	or	32
8	1 Format Identifier			
9	1 Format Identifier			
10	1 Stop Bit			

Character Two

Bit Number	Significance			
1	Start Bit			
2	Sensor Identifier	0	or	64
3	Sensor Identifier	0	or	128
4	Sensor Identifier	0	or	256
5	Sensor Identifier	0	or	512
6	Sensor Identifier	0	or	1024
7	Sensor Identifier	0	or	2048
8	Data Value	0	or	1
9	Data Value	0	or	2
10	Stop Bit			

Character Three

Bit Number	Significance			
1	Start Bit			
2	Data Value	0	or	4
3	Data Value	0	or	8
4	Data Value	0	or	16
5	Data Value	0	or	32
6	Data Value	0	or	64
7	Data Value	0	or	128
8	Data Value	0	or	256
9	Data Value	0	or	512
10	Stop Bit			

Character Four

Bit Number	Significance			
1	Start Bit			
2	Data Value	0	or	1024
3	Battery Level Bit			
4	CRC Bit			
5	CRC Bit			
6	CRC Bit			
7	CRC Bit			
8	CRC Bit			
9	CRC Bit			
10	Stop Bit			

Integrating a six-bit CRC within the enhanced format was intended to ensure that the station identifier and data value were received with virtually no possibility of error. Due to the complexity of the process, the technique for computing the CRC will not be included in this description. Using a battery-level indicator was intended to provide a method for identifying when the battery voltage at the sensor site had dropped to a level that was likely to require immediate field maintenance. These additions were accomplished by reducing the number of sensor identifiers to 4095 and the bits available for format identification from eight to two.

7.3 ALERT/IFLOWS Functional Capabilities

The radio-reporting rain gage (RRRG), the most common sensor platform found in the LFWS, is a device used to measure and report rainfall from remote locations. It is installed outdoors, unattended, and often in remote or unprotected areas where commercial power is generally unavailable. The RRRG is a hollow metal tube, 12 feet in height and 1 foot in diameter. Mounted inside the top of the tube is a screened funnel and an electromechanical tipping bucket. Side-mounted near the top of the tube is a radio-transmitting antenna. Inside the tube's underground footing is the RRRG electronics package: a battery-powered, microprocessor-controlled counter and a radio transmitter.

When 1 millimeter of rain fills the RRRG's hinged bucket through the top opening of the funnel, the bucket resets itself, spilling the water and tripping a switch. The switch causes the electronics package to generate a sensor address which ranges from 00 to 8191. A radio transmitter in the electronics package sends a four-byte message by audio tones. At 300 baud, the resulting radio report requires 133 milliseconds to convey its data message. The transmitter is turned on and brought up to its operating power level prior to transmitting the data report. If no relays are utilized in this system, about 70 milliseconds are required prior to transmitting the data message. The warm-up time must be extended by approxi-mately 50 milliseconds for each relay that is necessary to pass the message. Each remote data site reports its operational status by transmitting its principal sensor address and its current accumulator value twice per day.

In addition to reporting rainfall in ALERT/IFLOWS message format, various other environmental sensors (such as river stage, wind speed and direction, barometric pressure, temperature, relative humidity, water quality, and soil moisture) are marketed with this reporting format.

7.4 Selected ALERT/IFLOWS Technical Specifications

The sensor transmitter provides the capability of recognizing and encoding data from the sensors and then transmitting the resulting information in real time on appropriate radio frequencies. The transmitter must be self-powered and shaped to fit into the base of the rain gage support tube. The transmitter package must operate at unpowered, remote sites with a high level of reliability and the lowest possible maintenance requirements. In order to encourage the broadest possible involvement of many diverse organizations, the basic transmitter package must be as simple, reliable, and low priced as possible. At the same time, it must have the potential for cost-effective modifications that support the operation of a broad range of ancillary hydrometeorological sensors. In order to accomplish these objectives, the following specifications are necessary:

1. The sensor transmitter shall have a convenient means of setting a station ID that corresponds to the range of values appropriate to the transmission code in use. The number selected shall represent the input port used for the incremental precipitation sensor. Other incremental (digital) sensors shall utilize IDs that decrease from the precipitation sensor's ID. Analog sensors shall be identified in sequence by adding "1" to the previous sensor ID. If a precipitation gage is not attached to the transmitter, the station ID shall represent water level.
2. The sensor transmitter shall provide a means of varying the warm-up time prior to transmitting the data signal. Signal modulation would be capable of successful decoding at a base station with a lead-time of 100 milliseconds and through a relay system with proportionally longer lead-times. However, the warm-up time shall not exceed 600 milliseconds.
3. The sensor transmitter shall transmit check signals at approximately 12-hour intervals utilizing a single sensor as the principal station ID. This ID will be rainfall if the station is equipped with a rain gage.
4. The sensor transmitter shall use an FSK transmission form and be FCC type accepted (type certified to Part 90 and Part 2). VHF transmitters shall utilize a variable output power not to exceed 25 watts. Output levels shall be kept low to conserve battery life yet high enough to assure dependable transmission of data.
5. Transmissions shall be frequency controlled and consistent with FCC regulations through an operating range of -20 °C to +60 °C.
6. Transmitted messages shall conform to Logic 1 at 2133 Hz and Logic 0 at 1920 Hz.
7. The transmitter shall operate on those frequencies licensed for the transmission of hydrometeorological data.
8. To restrict extraneous transmissions of water levels in event-driven, digital, bidirectional water level sensors, the device shall be designed with the following features:

    a. A user-selectable lockout time to prevent consecutive transmissions occurring within a predefined time interval.

       Example: A rotary switch with positions 0 through 9 might use 9 to create a 1-hour (3600-second) lockout. Each decreasing switch position would cut the lockout time in half. Lockouts for switch positions 9 through 0 would create lockouts of 3600, 1800, 900, 450, 225, 112, 56, 28, 14, and 7 seconds, respectively.

b. The capability of varying the number of increments beyond a single increment that must occur to constitute an event and generate a transmission.

Example: 0 through 9 additional increments

c. An override that initiates a transmission during the lockout time if an indicated number of events should occur.

Example: If "5" is selected on an override switch, then five events occurring in the lockout time would override the timed lockout, and the fifth event would be transmitted.

9. The electronic package shall allow up to four digital (incremental) and eight analog sensors to operate with a common transmitter.

10. All analog sensors shall be read and transmitted on a user-determined time schedule controlled by an internal clock in the electronic package.

Example: The available choices might include: Event, 3, 7, 10, 15, 20, and 30 minutes, 1, 2, 3, 4, 5, 6, and 12 hours.

11. The ID assignments for transmitters configured for weather station use shall conform to the following schedule:

ID-3	Wind run and direction
ID-2	Optional event sensor
ID-1	Event river sensor
ID	1 millimeter event precipitation gage
ID + 1	Relative humidity
ID + 2	Temperature
ID + 3	Optional analog sensor
ID + 4	Atmospheric pressure

Additional ports shall be used for appropriate hydrometeorological sensors.

12. The transmitter features defined for water-level transmissions in item 8 shall also apply to wind run. However, the timed lockout shall have an override with no more than eight units of wind run.

CHAPTER 8

RESPONSE PLANNING GUIDANCE

8.0 Introduction

An effective flood warning system must include a response plan which shows that the community has procedures for ensuring effective evacuations and that actions are taken to reduce property damages. A response plan should cover the following elements:

- Warning Dissemination
- Evacuation and Rescue
- Damage Reduction
- Recovery
- Public Information
- Plan Implementation
- Plan Maintenance

The following sections have been abstracted and modified from the "Guide for Flood and Flash Flood Preparedness Planning[2]" dated May 1977. Some or all of the details in each section may be relevant to your local needs depending on the size and scope of your LFWS.

8.1 Warning Dissemination Element

Planning Objective: To disseminate warnings which are accurate, timely, and reliable.

1. Establish procedures for distributing warnings and advisories which:
   a. ensure prompt attention to information concerning flood threats;
   b. specify what types of warnings are issued for various possible conditions;
   c. ensure that product content is commensurate with the expected severity of the flood;
   d. ensure that the NWS warnings are disseminated to need-to-know individuals in a timely manner; and
   e. ensure that locally generated advisories are coordinated with NWS.
2. Establish procedures for disseminating information concerning potential flood threats to special need-to-know recipients which:
   a. identify special recipients who are to be notified under various possible conditions of flood threat;
   b. describe the means of communications to be used in alerting each special recipient; and

[2] Prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Disaster Preparedness Staff by H. James Owen, Consulting Engineer.

c. specify record keeping, acknowledgment, and other processes to assure notices are given and received.

3. Establish procedures for the dissemination of warnings to the general public which:
   a. are adequate to assure all affected persons receive warnings on a timely basis, notwithstanding telephone and power failures;
   b. provide for various levels of warning appropriate to the immediacy and seriousness of the flood threat;
   c. specify the conditions under which each means of warning dissemination will be used;
   d. describe the process by which parties responsible for each means of dissemination are instructed to begin distributing warnings; and
   e. take into consideration the time of day, day of week, or seasonal factors affecting the need for or means of warning dissemination.

8.2 Evacuation and Rescue Element

Planning Objectives: To prevent the loss of life due to flooding or to flood-related causes.

A. Evacuation Area Identification Task

1. Identify areas that will be inundated at each potential level of flooding due to:
   a. overbank flows; and
   b. entry of floodwaters through sewers, drainage channels, or other means of access.
2. Identify areas which will be inundated due to internal drainage or ponding unrelated to flood height in streams.
3. Identify areas requiring evacuation for reasons other than inundation including:
   a. loss of access or escape routes;
   b. loss of curtailment of utility or other emergency services; and
   c. site-specific problems.

B. Evacuation Procedures Development Task

1. Select evacuation destinations for each area to be evacuated which are:
   a. safe from flooding and other related hazards;
   b. easily identified to the public;
   c. within time and distance commensurate with the warning time; and
   d. suitable for use for the expected duration of flooding.
2. Identify best available evacuation routes which are:
   a. safe from early flooding due to urban drainage or other impediments;
   b. passable in all weather; and
   c. adequate to handle expected traffic.
3. Establish priorities for evacuation which take into account:
   a. time of flooding with respect to other areas;
   b. severity of flooding; and

c. loss of escape routes.

4. Establish procedures for carrying out evacuation which are consistent with the warning time available including:
    a. ensuring that the affected public is advised of the need to evacuate, safe destinations, routes, and time available for evacuation;
    b. providing general assistance in transportation and in preparing homes and businesses for evacuation;
    c. providing special assistance to those having unusual evacuation needs;
    d. assuring evacuation is complete;
    e. establishing traffic controls to prevent accidental entry into dangerous areas, identifying evacuation routes, and facilitating evacuation traffic; and
    f. establishing surveillance over the evacuation area to ensure safety of the area.

C. Reception Center Operations Task

1. Estimate the duration, damage, and population affected in the case of a severe flood and determine reception center requirements including:
    a. number of evacuated persons likely to require emergency overnight housing;
    b. number of meals to be served;
    c. type and extent of medical or other care that may be required;
    d. required services, equipment, and supplies for operation; and
    e. required personnel for operation.
2. Select reception centers which:
    a. are safe under conditions of severe flooding;
    b. have or can be provided with necessary equipment and services;
    c. provide sufficient space for required activities;
    d. are available on short notice for the required duration; and
    e. are readily identifiable to the public and accessible from all areas.
3. Establish procedures for the operation of reception centers including:
    a. basis on which reception center operations will be activated and terminated;
    b. source and means of providing necessary supplies, equipment, and services;
    c. allocation of space for reception center functions; and
    d. provision of temporary assistance and information on long-term recovery aid.

D. Emergency Action Task

1. Evaluate the areas subject to flooding or isolation during flood events with respect to the types of emergency activities which may be required including:
    a. emergency evacuation of persons from dangerous areas;
    b. emergency provision of medical attention, fire control, or other assistance;

    c. emergency operation or curtailment of power, water, gas, and other services;
    d. control or containment of toxics, explosive gases, and other dangerous commodities; and
    e. search for survivors.
2. Determine requirements for conducting emergency actions including:
    a. personnel;
    b. transportation;
    c. heavy-duty equipment (e.g., boats, trucks, earthmovers, and others); and
    d. portable hand tools and other equipment.
3. Establish procedures for carrying out emergency actions including:
    a. organization of rescue squads;
    b. placement of personnel and equipment for conducting emergency activities;
    c. coordination arrangements for identifying needs for assistance and responding to calls; and
    d. maintenance of communications.

8.3 Damage Reduction Element

Planning Objectives: To reduce public and private property damages from flooding or flood-related causes.

A. Flood-Fighting Task

1. Identify needed flood-fighting actions to reduce overflow, seepage, and other types of flooding as well as erosion due to floodwaters including:
    a. assuring floodgates or sewer outlets are closed;
    b. temporary heightening of levees or floodwalls;
    c. securing of openings in levees and other embankments;
    d. containing overflows through manholes and other openings in the sewer system;
    e. pumping of internal drainage waters; and
    f. control of erosion at bridges, levees, building foundations, and roadway embankments.
2. Establish flood-fighting procedures to control overflow, seepage, or other types of flooding with respect to:
    a. locations where each action is to be carried out;
    b. maintaining surveillance to determine the need for personnel, equipment, and further actions;
    c. priority for accomplishment; and
    d. extent of action required for various flood heights.
3. Establish procedures for the evacuation or temporary removal and relocation of automobiles, furniture, valuables, clothes, business and personal records, machinery, and other movable property to reduce damage including:

a. identification of types of action required at various locations and expected flood heights;
b. arrangements for the provision of labor and transportation assistance; and
c. identification of safe locations for storage of property.

B. Utility Management Task

1. Establish procedures for the curtailment of utility services to flooded areas including:
   a. need for curtailment by area or individual property for each flood height;
   b. means for accomplishing curtailment (i.e., homeowner, utility staff, or other); and
   c. preparations to be made by property owner (within allowable time) prior to evacuation to minimize damage and facilitate the eventual return of services.
2. Establish utility operation procedures to be used immediately prior to and during floods to:
   a. minimize losses and risks caused by damaged utility systems;
   b. reduce damage done to utility equipment, supplies, and operational capabilities; and
   c. maintain necessary utility services to vital community facilities.

C. Traffic Control Task

1. Identify needs for traffic control prior to, during, and immediately after floods including:
   a. preventing accidental travel in areas which are or will be flooded;
   b. establishing evacuation routes and speeding evacuation traffic;
   c. facilitating access to evacuation areas for transportation, rescue, and other essential traffic;
   d. preventing use of damaged roadways and bridges; and
   e. controlling access to damaged areas.
2. Establish procedures for traffic control which:
   a. identify areas to be controlled at each expected flood height;
   b. specify locations where traffic control is to be established;
   c. identify detours or types of control to be effected;
   d. specify placement of personnel, barricades, and signs to effect necessary control and means of enforcement; and
   e. restrict access to flood-damaged areas to residents and other authorized persons.

D. Maintenance of Vital Services Task

1. Identify police, fire, medical, and other vital community services and facilities with respect to:
   a. location;
   b. vulnerability to interference by inundation, loss of access, or communications;
   c. interdependencies on other services and facilities including utilities;
   d. temporary floodproofing or other actions required to prevent the loss of service or function; and
   e. the need for and means of providing auxiliary power, heat, water, sewage disposal, and other services necessary for continued operation of vital facilities.
2. Establish operational procedures for police, fire, utility repair, rescue, medical, and other services prior to and during floods including:
   a. placement of equipment and personnel to prevent loss of access due to flooding of roads and underpasses or failure of bridges;
   b. means of relaying calls for assistance and coordinating responses; and
   c. alternate routes for entering areas where traffic is controlled and avoiding evacuation routes.
3. Establish procedures for evacuation or protection of important records and documents located in areas subject to flooding including those relating to:
   a. vital statistics;
   b. tax and payroll information;
   c. court records;
   d. utility records;
   e. property ownership; and
   f. business records.

8.4 Recovery Element

Planning Objectives: To initiate and carry out post-flood actions to maintain public health, return community services to normal at the earliest possible time, provide aid, and assist in recovery operations.

A. Maintenance of Public Health Task

1. Establish procedures for handling of the dead including:
   a. morgue location and method of operation;
   b. handling of personal effects; and
   c. identification and release of bodies.
2. Establish procedures for actions to preserve public health including:
   a. provision of emergency medical services and care for injured persons;
   b. procedure for locating missing persons and providing information to friends and relations;
   c. collection and destruction of contaminated foodstuffs;

d. disinfection of private water supply sources and systems;
e. inoculations and other preventive medical care;
f. disease control; and
g. control of insects, rodents, and other pests.

B. Return of Services Task

1. Establish procedures for actions to resume provision of utility services including:
   a. preparations to be made by property owners;
   b. system preparations including decontamination of water supplies;
   c. sequence for returning services; and
   d. priority for resuming services.
2. Establish procedures for returning to normal traffic patterns including:
   a. evaluation of road and bridge safety;
   b. debris clearance; and
   c. priority for providing access.

C. Rehabilitation and Repair Task

1. Establish procedures for post-flood cleanup including:
   a. clearing, collecting, and disposing of debris and discarded goods;
   b. street washing;
   c. pumping basements; and
   d. returning material previously relocated for safekeeping.
2. Establish procedures for management of damaged structures including:
   a. procedures for identification and evaluation of damage; and
   b. demolition or temporary repair of hazardous buildings.
3. Identify the sources and programs for recovery assistance and the means of obtaining each including:
   a. volunteer organizations;
   b. mutual aid agreements;
   c. state assistance; and
   d. Federal assistance.
4. Establish procedures for mobilizing assistance from each available source including:
   a. conditions under which requests for assistance will be made;
   b. channels to be followed in requesting assistance; and
   c. preparation of necessary requests, disaster declarations, or other documentation required as a condition of assistance.

8.5 Public Information Element

Planning Objectives: To develop community awareness and understanding of the flood hazard and to prepare for the accurate and timely provision of information during flood emergencies.

A. Community Education Task

1. Prepare the materials for and carry out a continuing public information program, including letters to residents in evacuation areas to increase community awareness of floods and evacuation area residents' knowledge with respect to:
   a. the source, nature, frequency, and potential severity of floods;
   b. the community's system for flood recognition and dissemination of warnings to the public;
   c. the meaning of various types of warning announcements, siren signals, and/or evacuation notices;
   d. the areas likely to be inundated or evacuated at each level of expected flooding;
   e. procedures for evacuation including preparations for evacuation, routes, safe destinations, and identification of reception centers;
   f. actions which can be taken by property owners to reduce damages, including moving furniture and valuables, curtailing electrical power and gas service, and temporary floodproofing;
   g. means of requesting identification as a special warning recipient or receiving special assistance in evacuation; and
   h. safety and remedial actions to be taken when returning to flood-damaged buildings.
2. Prepare and carry out a continuing program to provide technical information to those wishing to employ temporary floodproofing measures or needing to develop more detailed subplans for warning dissemination, evacuation, and damage reduction including:
   a. identification of areas where the depth and velocity of expected flooding and opportunities for egress enable the use of temporary floodproofing measures;
   b. procedures for temporary floodproofing;
   c. relation between forecast flood heights and on-site depths; and
   d. guidelines and criteria for warning dissemination and evacuation plans for hotels, motels, hospitals, and/or other facilities requiring more detailed arrangements.

B. Emergency Information Task

1. Identify the types of emergency information to be conveyed to the public in the period prior to, during, and immediately following a flood including:
   a. early watches, warnings, and evacuation notices, worded appropriately to obtain maximum public response;
   b. information on actions to be taken, location of safe areas and areas to be avoided, location of reception centers, and ways of obtaining emergency assistance;
   c. actions being taken or to be taken to deal with the flood;
   d. calls for labor, equipment, or other types of assistance needed for evacuation, damage reduction, and/or recovery activities; and

e. information concerning sources and availability of recovery assistance.

2. Identify the means and procedures to be used in communicating each type of information with respect to:
    a. form and content of each type of message;
    b. handling of flood warnings and other related messages;
    c. source and verification of messages; and
    d. interfacing of communications equipment.
3. Prepare warning announcements for use in various potential circumstances and expected flood heights which:
    a. provide specific information and instructions;
    b. reference an authoritative and familiar source; and
    c. ensure an immediate and adequate response to warning messages by the public and responsible officials by considering the various factors governing warning confirmation and warning belief.

8.6 Plan Implementation Element

Planning Objectives: To develop the administrative arrangements necessary for effective implementation of the flood preparedness plan.

A. Resource Identification Task

1. Identify type and amount of resources required for implementing the plan including:
    a. technical, administrative, and other personnel;
    b. equipment and supplies; and
    c. facilities.
2. Identify the sources of personnel, equipment, supplies, and facilities for implementing the plan including:
    a. community resources;
    b. private resources;
    c. assistance through mutual aid agreements; and
    d. Federal and/or state assistance.

B. Responsibility Allocation Task

1. Evaluate each aspect of plan implementation with respect to:
    a. actions requiring detailed and specific assignments of responsibility; and
    b. actions suitable for assignment on an organizational basis.
2. Assign responsibility for implementation of each aspect of the plan including:
    a. instructions as to how, when, and by whom implementation is to be assured;
    b. requirements for any necessary subplans or supplemental procedures; and
    c. establishment of a chain of command to ensure plan implementation will proceed in the absence or incapacity of key personnel.

C. Coordination Task

1. Establish procedures for coordination of local governmental actions through an emergency operations center, if available, or other mechanisms including:
   a. identification of responsibilities to be assigned to the center;
   b. operational procedures for staffing and operation of the center to carry out the assigned responsibilities; and
   c. procedures for activation and termination of the center.
2. Establish necessary arrangements, including mutual aid agreements, for use of facilities, equipment, personnel, and services necessary for implementation of the plan including:
   a. location of river and rainfall gages, participation of observers, and receipt of information from upstream areas;
   b. land rights for flood fighting and other purposes;
   c. use of reception centers, hospitals, and areas for property storage;
   d. use of vehicles for evacuation or movement of property;
   e. participation of volunteer organizations; and
   f. provision of necessary supplies, materials, construction equipment, and other items.
3. Establish procedures to coordinate the local plan fully with state and other local plans for emergency operations including:
   a. integration with regional or statewide flood warning systems and communication networks, state flood disaster plans, and other local natural disaster plans;
   b. coordination of evacuation plans with those for flood control, particularly where closure of floodgates in levees or floodwalls may affect escape routes; and
   c. coordination with the NWS with respect to use of all available information and issuance of warnings.
4. Establish procedures to guide and coordinate more detailed site-specific planning for warning dissemination, evacuation, and damage reduction in public and private buildings including:
   a. process for identifying locations where such plans are necessary;
   b. minimum elements and appropriate level of detail to be included in planning; and
   c. provision of technical assistance in planning.

8.7 Plan Maintenance Element

Planning Objectives: To update, extend, and improve the flood response plan and to ensure readiness for executing the plan.

A. Plan Updating Task

1. Establish procedures and schedules for plan contents subject to rapid obsolescence including:
    a. addresses, telephone numbers, and names of key participants;
    b. assignments of responsibility;
    c. changes in flood potential;
    d. areas requiring evacuation;
    e. availability of facilities for reception centers;
    f. evacuation routes and priorities;
    g. flood-fighting requirements;
    h. utility extensions or system modifications; and
    i. traffic control requirements.
2. Establish procedures for updating of plan contents based on specific events such as:
    a. construction of or modification in the operation of upstream water control structures which affect the height, severity, or time of flooding;
    b. natural or unplanned events which modify the flood potential; and
    c. construction or modification in the operation of facilities in or downstream of the community which increases the height, severity, or duration of floods.

B. Plan Improvement Task

1. Describe needed and planned extensions of the warning system and response plan including:
    a. coverage of additional area; and
    b. incorporation of elements, tasks, and subtasks omitted from the initial plan.
2. Describe needed and planned refinements to the warning system and response plan including:
    a. provision of additional observers, gages, and flash flood alarms to improve the flood recognition system;
    b. more detailed identification of areas to be evacuated;
    c. strengthening of communications involved in all aspects of the plan; and
    d. development of additional subplans for various affected organizations and locations.
3. Establish procedures for the critical evaluation of performance in real and simulated implementation of the plan including:
    a. process for initiation, organization, and conduct of the evaluation; and
    b. process for modification of the plan based on findings of the evaluation.

C. Plan Practice Task

1. Establish procedures and schedules for testing those aspects of the flood warning system and response plan which are susceptible to periodic use such as:
   a. procedures for communication with observer networks, the NWS, and other Federal offices, special warning recipients, organizations, and officials responsible for warning dissemination and plan execution, and others as may be appropriate;
   b. communications equipment including sirens, radio transmitters and receivers, flash flood alarm circuits, and others, with particular attention to battery-powered equipment;
   c. auxiliary sources of electrical power and other services;
   d. procedures for activating the emergency operations center, sending and receiving observer reports, handling messages, preparing forecasts, disseminating warnings, placing equipment and personnel for evacuation and rescue, protecting vital facilities, and other steps in execution of the plan;
   e. availability and operational status of equipment for evacuation, rescue, and damage-reduction activities; and
   f. availability and procedures to use key maps, lists, and other important plan documentation.
2. Establish procedures and schedules for periodic simulation of those aspects of the warning system and response plan not susceptible to direct testing such as:
   a. decisions to issue warnings or direct evacuation;
   b. evacuation;
   c. implementation of traffic control procedures;
   d. activation of reception centers;
   e. curtailment of utility services; and
   f. procedures for rescue, handling of injuries and casualties, and public health measures.

CHAPTER 9

FEDERAL INSURANCE ADMINISTRATION
COMMUNITY RATING SYSTEM

9.0 Introduction

In order to be covered by a flood insurance policy, a property must be located in a community that participates in the National Flood Insurance Program (NFIP). To qualify its residents to participate in the NFIP, a community must adopt and enforce a floodplain management ordinance to regulate proposed development in flood hazard areas. The objective of the ordinance is to ensure that such development will not aggravate existing flooding conditions and that new buildings will be protected from future flood damage. To date, nearly 18,000 communities in the United States participate.

Until recently, the NFIP did little to recognize or encourage community activities to (1) reduce flood damages to existing buildings, (2) manage development in areas not mapped by the NFIP, (3) protect new buildings beyond the minimum NFIP protection level, (4) help insurance agents obtain flood data, or (5) help people obtain flood insurance. Because these activities can have a great impact on the insurance premium base, flood damages, flood insurance claims, and Federal disaster assistance payments, the Federal Insurance Administration (FIA), which is part of FEMA, implemented the Community Rating System (CRS) on October 1, 1990.

The CRS rewards those communities, through lower insurance rates, that are doing more than the minimum NFIP requirements to prevent or reduce flood losses. The system should also provide an incentive for communities to initiate new flood protection activities. Community application for CRS classification is voluntary. Any community in full compliance with the rules and regulations of the NFIP may apply for a CRS classification. The applicant community submits documentation that it is implementing one or more of the activities recognized in the CRS schedule.

The CRS schedule identifies creditable activities, organized under four categories: public information, mapping and regulations, flood damage reduction, and flood preparedness. The CRS schedule assigns points based on how well an activity affects the basic goals of the CRS. Some of the creditable activities may be implemented by the state or a regional district rather than at the local level. In some cases, any community in those states or districts could receive credit points if the community applies for a CRS classification and if the state or district program is in fact being implemented in the community.

The regional FEMA office and the state NFIP coordinator review and comment on the community's application. The FIA verifies the information and also the community's implementation of the activities and sets the credit that will be granted. The FIA notifies the community, the state, the insurance companies, and other appropriate parties. The community's activities and performance are reviewed periodically. If it is not properly or fully implementing the credited activities, its credit points and possibly its CRS classification will be revised. A community may add or drop creditable activities each year. Credit criteria for each activity may also change as more experience is gained in implementing, observing, and measuring the activities.

It is important to note that reduction in flood insurance rates is only one of the rewards communities receive from undertaking the activities credited under the CRS. Others include increased public safety, reduction of damages to property and public infrastructure, avoidance of economic disruption and losses, reduction of human suffering, and protection of the environment.

9.1 Local Flood Warning Systems

Although the NWS maintains a high interest in any attempt to reduce flood damages, its principal involvement in the CRS is described in Section 610, Flood Warning Program, in FEMA's *National Flood Insurance Program Community Rating System [NFIP CRS] Coordinator's Manual*, October 1990. These FEMA guidelines state that the NWS certifies the automated LFWS to enable the individual community to receive credit under the CRS and to reduce their flood insurance premiums.

The NWS is an advocate of the automated LFWS as evidenced primarily by its efforts in the ALERT networks and the IFLOWS. The NWS works in concert with local communities to implement the automated LFWS to obtain data and information to augment its basic mission of issuing flood/flash flood watches, warnings, and forecasts. Normally, the NWS works with a community in the development of an automated LFWS under an MOU. The MOU serves as certification to FEMA/FIA that the NWS is aware of the automated LFWS.

There may be instances when there is no MOU between the NWS and a community which operates an LFWS, but the NWS is aware of the existence of the system. In this instance, the certification wording provided to FEMA/FIA would be: "Although the NWS does not have an MOU with the entity, we are aware that such a system does exist." Naturally, more information can be conveyed if the NWS is familiar with the system but simply does not have an MOU with the community. If the NWS is not aware of the existence of an automated LFWS, it cannot certify the system.

FEMA guidelines imply that only automated LFWSs should receive credit under Section 610, Flood Warning Program. However, there are manual flood warning systems that have existed for many years in communities with an adequate response plan, and FEMA/FIA may give credit for these systems, though possibly not as much as a community would receive for an automated LFWS. The procedure applicable for certification of an automated LFWS should be similar for a manual LFWS.

A viable flood warning system consists of two parts: (1) a flood warning dissemination system and (2) a corresponding recognition/response plan. As described in FEMA's *NFIP/CRS Coordinator's Manual*, the certification role of the NWS in flood warning systems does not differentiate between the flood threat recognition portion and the response plan. In many instances, the NWS is not aware of the details of a response plan. The review of the response portion of an automated LFWS should be delegated to specialized consultants or to FEMA/FIA directly for certification.

The NWS is involved in the initial certification process, not the CRS evaluation. The NWS is only required to certify that an automated LFWS exists. Since the NWS cannot forecast for all specific structures in a community or for the numerous small creeks and drainage within a given community, any flood impact information requested by either FEMA or the community for specific structures within a community generally cannot be provided by NWS. Similarly, any request from the community that the NWS establish new forecast points in its area is also subject to limited available NWS resources.

Section 610 of FEMA's *NFIP/CRS Coordinator's Manual* requires that there be a minimum of 30 minutes warning time to obtain credit for an LFWS. While there are numerous events when a 30-minute warning time can be obtained easily, the NWS cannot assure the 30-minute lead-time under all conditions. Therefore, the 30-minute lead-time requirement for certification by NWS can be overlooked for some cases of riverine flooding as long as the community has some organized type of flood threat recognition system which allows them to take action without necessarily relying on the NWS. This flood threat recognition system could include such things as operating an automated LFWS, employing a private weather forecasting service, contributing toward the funding of a regional flood threat recognition system, or collecting local data for use by the NWS in making flood forecasts for the area.

CHAPTER 10

SOFTWARE

10.0 Introduction

This chapter contains descriptions of software for LFWSs available from the NWS. For each software package a brief summary of the required operating environment, basic functionality, and availability is presented.

10.1 ALERT Software

ALERT software operates on the QNX-multitasking operating system for microcomputers. The recommended minimum configuration is an IBM-compatible 486 (or Pentium) with a minimum of 4 megabytes of memory and a 500-megabyte or larger hard disk. The ALERT software receives and handles all sensor data and provides a multitude of applications. Using a menu of options, the user performs routines to initialize sensor databases, tabularize data from sensor groups in easy-to-read formats, and display data graphically or numerically. In addition, databases can be edited manually and archived. Warning routines can be used to sound an alarm whenever the parameter of a specified sensor exceeds a predefined value or designated rate of change.

The ALERT software has the capability to exchange text messages between the local base station and an NWS field office via a dial-up connection. In addition, there is the option to use a stream forecasting procedure called the Sacramento-Soil Moisture Accounting Model. This model produces hydrologic forecasts describing a variety of river conditions that could result from current and/or future rainfall amounts. Use of this option requires a great deal of resident hydrologic expertise. It also requires a substantial historical local database to calibrate the model to adequately represent the local rainfall-runoff process.

Distribution

Executable code and associated user guide material may be obtained at a nominal fee (reproduction cost) from the following address:

Chief, Hydrologic Services Division
NOAA/NWS Western Region
125 South State Street, Room 1210
Salt Lake City, UT 84138

Technical Support

The Chief, Hydrologic Services Division, NWS Western Region, is responsible for the distribution of NWS ALERT software to Western Region field offices, their cooperators, and other NWS regional offices. The Hydrologic Services Division Chief of any NWS region may support and distribute NWS ALERT software beyond that mentioned above as resources permit and as specified in the MOU with a cooperator.

10.2 IFLOWS Software

IFLOWS software usually operates as a wide-area network with two-way communication capability carrying voice, data, and text messages. IFLOWS runs on any IBM-compatible personal computer operating under MS-DOS. The recommended minimum configuration is a 486 microprocessor with 4 megabytes of memory and a 120-megabyte (or larger) hard drive.

The IFLOWS software consists of two major software categories: real-time software and application programs. The real-time software performs the following tasks:

1. Acquires, verifies, stores, and distributes sensor data;
2. Accepts, stores, and distributes text products such as NWS watches, warnings, and forecasts;
3. Measures local computer system and network performance and stores and distributes their measurement data;
4. Triggers audible alarms on receipt of critical messages or when observed conditions exceed user-defined thresholds;
5. Transmits data to and receives data from other IFLOWS computer systems within a local network; and
6. Exchanges information among independent IFLOWS network via communication "bridges."

The IFLOWS applications include options to tabularize data from sensors in easy-to-read formats and display data graphically or numerically, to create and display text messages, to display site status information, etc. In addition, there are various maintenance applications that maintain the IFLOWS database.

Distribution

The IFLOWS Operational Development and Experimental Facility, maintained by the Virginia Department of Emergency Services, distributes the IFLOWS software to participating state/county IFLOWS cooperators. Included is the executable code and associated user guide material. For purposes of IFLOWS software distribution and associated technical support, an IFLOWS cooperator is defined as follows: One who has agreed, generally through a memorandum of agreement, to assist the NWS in providing an effective flood and flash flood forecast and warning service to the public through participation in the IFLOWS Program.

The NWS IFLOWS Operations Manager (NWS Eastern Region) is responsible for the distribution of software and associated support material to NWS field offices.

The IFLOWS Program Office (NWS Office of Hydrology) is responsible for handling requests for IFLOWS software from those not directly cooperating in the IFLOWS Program. These requests may be forwarded to the address below:

NWS Office of Hydrology
W/OH2 - IFLOWS Program Office
SSMC2, 8th Floor
1325 East-West Highway
Silver Spring, MD 20910-3283

Those not directly cooperating in the IFLOWS Program may obtain the IFLOWS executable code for their exclusive use and only for the stated purpose in the letter of request. The IFLOWS Program Office will make arrangements to copy and ship the code and documentation to the requestor for a nominal (reproduction) fee.

Portions of the IFLOWS software are copyrighted. Therefore, this code cannot be reproduced (except for personal backup copies) nor distributed further to any other party.

Technical Support

The NWS can provide or arrange limited amounts of resources to render technical assistance in using the software to IFLOWS cooperators. All operational participants in the IFLOWS Program are expected to develop a level of understanding of the software to deal with its day-to-day operation. The NWS will support training of its IFLOWS focal points and cooperator's primary focal points as new versions of software are released.

Operational problems, in general, should initially be directed to (1) the state IFLOWS Program Manager (by state cooperators) or (2) the NWS Implementation Manager (by NWS personnel). Operational difficulties that are time critical may be directed to the software developer.

Since the NWS has limited resources to provide technical assistance in using the software, those not directly cooperating in the IFLOWS Program will need to make arrangements with outside sources for assistance.

PC/IFLOWS Software License Agreement

Following is text from the "License Agreement for PC/IFLOWS Software."

License Agreement for PC/IFLOWS Software

1. Grant of License

The Office of Hydrology, National Weather Service, grants you, the end user, the right to copy PC/IFLOWS SOFTWARE onto a single computer system and the right for you and others to use that copy of the SOFTWARE on that single computer.

You may not transfer, lease, rent, sell, or sublicense the SOFTWARE to any person or entity. You may not reverse engineer, decompile, disassemble, or create derivative works from the SOFTWARE.

2. Ownership and Copyright Notice

The SOFTWARE is and remains the property of the United States Government or its suppliers and is protected by United States copyright laws and international treaty provisions. Therefore, you must treat the SOFTWARE like any other copyrighted material, such as a book or musical recording, except that you may make copies of the SOFTWARE solely for backup or archival purposes **provided** that all such copies carry the same copyright and other notices that appear on the original.

You may copy any written materials provided with the SOFTWARE, such as the PC/IFLOWS User Reference Guide, to whatever extent necessary for your effective use of the SOFTWARE.

3. Limitation of Liability

The National Weather Service and its suppliers have endeavored to ensure that the SOFTWARE is reliable and performs substantially in accordance with the accompanying written materials. The National Weather Service and its suppliers, however, disclaim all warranties, expressed or implied, including but not limited to implied warranties of merchantability and fitness for a particular purpose.

In no event shall the National Weather Service or its suppliers be liable for any damages whatsoever, including, without limitation, damages for loss of business profits, business interruption, or other pecuniary loss arising out of the use of or inability to use the SOFTWARE.

4. Technical Assistance

The National Weather Service has limited resources to provide technical assistance in using the SOFTWARE. The level of support and the first echelon contact for assistance is, in part, dependent on the status of the end user. If you experience problems with the SOFTWARE or need assistance, follow the appropriate instruction below:

a. NWS IFLOWS COOPERATOR - Contact the State IFLOWS Program Manager or his/her designated assistant for your state. If your state does not have a State Program Manager or you do not know who the State Program Manager is, contact the NWS IFLOWS Operations Manager at the NWS Eastern Region (516/244-0112).
b. NWS PERSONNEL - Contact your Implementation Manager or his/her designated assistant.
c. OTHER USERS - You will need to make arrangements with outside sources.

10.3 ADVIS[3] Flash Flood Hydrologic Forecast Model

ADVIS is a simplified version of the hydrologic forecast models used in many of the NWS RFCs and will be replaced with more advanced hydrologic models once they are ready to be supported by NWS. ADVIS output includes the following:

1. Plots a forecast hydrograph showing the crest stage; categorical forecasts can be produced for small, ungaged streams;
2. Displays response plans; and
3. Displays significant high crests and their dates.

Input includes the following:

1. Incremental rainfall as observed and/or forecast amounts;
2. Soil moisture expressed as flash flood guidance or index;
3. A beginning river stage; and
4. Upstream reservoir releases as needed.

A separate program provides all management functions to maintain static parameters such as flood stages, rating curves, and unitgraphs.

<u>Distribution</u>

ADVIS, in executable code for an IBM-compatible personal computer operating under MS-DOS, may be obtained from the following address:

NWS Office of Hydrology
W/OH1 - Hydrologic Research Laboratory
SSMC2, 8th Floor
1325 East-West Highway
Silver Spring, MD 20910-3283

There is only a limited level of user documentation available for ADVIS.

<u>Technical Support</u>

Technical support is only available as specified under the MOU between the NWS and a cooperator.

10.4 Other Software

Information and the availability for other ALERT-type software may be obtained from the AUG (Section 11.11) and SAAS (Section 11.12).

[3] ADVIS is the computer program title for the Flash Flood Hydrologic Forecast Model.

CHAPTER 11

ROLES AND ACTIVITIES OF PARTICIPANTS

11.0 Introduction

A number of Federal and state agencies have instituted programs for helping communities identify and solve local flood problems. Successful LFWSs depend on mutual support among all levels of government and the private sector. Accurate and timely weather and river forecast and warning systems are vital to the safety and well-being of the Nation. The interpretation of NWS forecast, warning, and guidance products on a scale that helps to assure appropriate response along the tens of thousands of streams which threaten our population can be most effectively accomplished with the cooperation of local interests. The combination of Federal and local resources in a cooperative program that maximizes responsible flood warning capabilities is necessary for accomplishing a primary goal of the NWS.

The roles of the various Federal and state agencies, associations, and user groups in developing flood warning and response systems are broadly described in the following pages. The intent is to provide a guide to local communities seeking assistance in evaluating the need for local flood warning and response systems and developing appropriate local programs. The following information has been, in part, summarized from "Guidelines on Community Local Flood Warning and Response Systems," Hydrology Subcommittee of the Federal Interagency Advisory Committees on Water Data, August 1985.

11.1 U.S. Army Corps of Engineers

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

The USACE may undertake investigations of water and related land resources plans under specific authorizations by the Congress or, for smaller studies, under general continuing authorities. Continuing authorities permit the USACE to undertake investigations and construction of small projects for flood control, navigation, beach erosion control, clearing, and emergency bank protection. Other legislation empowers the USACE to undertake investigations for modifying existing projects or their operation; or for cooperative assistance to states in the preparation of comprehensive plans for water resources development, utilization, and conservation.

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

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

The USACE's Floodplain Management Services Program can provide technical assistance and planning guidance upon request to both Federal and non-Federal entities in identifying the magnitude and extent of the flood hazard and in planning for the wise use of floodplains. This assistance and guidance can include the development of LFWSs. Under the Planning Assistance to States Program, the USACE can provide Corps expertise in preparation of comprehensive plans for development, utilization, and conservation of water and related resources. Studies performed under this Program can include planning for LFWSs.

11.2 U.S. Bureau of Reclamation

The USBR, an agency of the U.S. Department of the Interior, operates in the Nation's 17 western states. Technical assistance can be obtained from a flood hydrologist at each of the USBR's seven regional offices.

The mission of the USBR is to manage, develop, and protect water and related resources in an environmentally and economically sound manner. The USBR's functions and services include providing municipal and industrial water supplies, hydroelectric power generation, irrigation water for agriculture, water quality improvement, flood control, river navigation, river regulation and control, fish and wildlife endorsement, and outdoor recreation. The USBR must also safeguard the investment of approximately $16 billion in water project infrastructure and research on water-related design, construction, materials, atmospheric management, and wind and solar power. The USBR's interest in the automated LFWS is focused primarily on its dam safety program. A national MOU between NOAA and USBR highlights the need to fully coordinate an automated LFWS.

11.3 Natural Resources Conservation Service

The NRCS, an agency of the U.S. Department of Agriculture, recognizes the use of flood warning systems along with other nonstructural and structural measures as a means of reducing flood damages. The NRCS can provide both financial and technical assistance in the development and installation of LFWSs.

In watersheds that are less than 250,000 acres in size, the NRCS can pay up to 80 percent of the installation costs for a flood warning system. Flood warning systems must be economically justified to be eligible for cost-share assistance. Normally, the NRCS cooperates with the NWS in the development and installation of the systems. Cost sharing may be provided for the installation of rain and/or stream gages, radio relay equipment, a computer or analysis system, and a warning system. After the system is operational, the local sponsors must operate and maintain it. The NRCS makes a major effort to interview floodplain residents to help them understand how a flood warning can reduce their specific flood losses. They may participate in pilot projects to demonstrate new technology or gain acceptance of innovative approaches using special funds available under the Resource Conservation Act. For more information, guidance, or technical assistance, contact your state's conservationist.

11.4 U.S. Geological Survey

The Water Resources Division of the USGS has the mission to provide the hydrologic information and understanding needed to best use and manage the Nation's water resources for the benefit of its people. To accomplish this, the Division assesses the Nation's water resources in terms of the quality, quantity, and usage and develops the information and hydrologic understanding necessary to predict the consequences of alternative plans and policies for developing and using water resources. Much of this work is done through cooperation with and funding from Federal, state, and local agencies. The USGS operates nationally over 7,000 continuous-recording gaging stations and numerous precipitation gages. Many LFWSs have taken advantage of these gages, incorporating them into their systems at little or no cost.

Where the USGS has interest in the hydrologic data being collected by the LFWS, they may be willing to operate and maintain the gages on a repay basis. In some instances, the USGS may even be able to bear one-half the costs of the operation and maintenance. The USGS involvement in LFWS is occurring in many locations, including the island of Puerto Rico; Clark County (Las Vegas), Nevada; and Somerset County, New Jersey.

The USGS maintains Water Resources Division District (state) offices in or near almost every state capital. The appropriate procedure for investigating the possibility of receiving assistance for an LFWS from one of these offices would be to contact the District Chief.

11.5 National Weather Service

The mission of the NWS is to provide weather and flood warnings, public forecasts, and advisories for all of the United States, its territories, adjacent waters, and ocean areas, primarily for the protection of life and property. The NWS provides its data and products to private meteorologists to utilize in their specialized services. Hence, the NWS issues warnings and forecasts of severe weather, floods, hurricanes, and tsunami events that adversely affect life and property. Also, the NWS collects, exchanges, and distributes meteorologic, hydrologic, climatic, and oceanographic data and information on a national and international basis. The NWS is the official voice when issuing warnings for weather and flood-threatening situations.

Additionally, the NWS issues weather, river, and water resources forecasts and related guidance materials used to form a common national hydrometeorological information base for the general public, private sector, aviation, marine, forestry, agricultural, navigation, power interests, land and water resources management agencies, and emergency managers at all levels of government.

The NWS WFOs provide general weather information, warnings, advisories, and aviation and public forecasts to the general public and to special user groups in their service areas. The WFOs also collect hydrometeorological data that are relayed to the supporting RFC(s). The RFCs are staffed with professional hydrologists who are responsible for quality control of input data, execution of computerized hydrologic models, interactive analysis of the model output, and distribution of river, navigation, and flood forecasts to WFOs. WFOs then use the RFC products to issue a variety of hydrologic forecast and warning products for the local area. These RFC forecasts can usually be achieved only for the larger river basins with crest times greater than 6 hours. For communities located on small, flashy streams with crest times of less than 6 hours, the NWS provides flash flood watches and warnings and works with state and local government agencies to establish local flood warning and response systems.

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

11.6 Tennessee Valley Authority

The TVA has a broad duty of planning for the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and its adjoining territory for the general, social, and economic welfare of the Nation. In 1953, the TVA's approach was broadened to permit the use of flood damage reduction measures that encouraged locally based planning and the wise use of floodplain lands. The TVA has used many approaches ranging from the publication of local flood reports that detail the nature and extent of the problem to providing assistance on locally administered relocation projects in towns where housing has been badly damaged by unusually large floods to flood damage abatement as part of broader community redevelopment projects. Since the 1960s, the TVA has been involved with coordinating flood warning systems and has been participating in IFLOWS since 1980. The TVA has been working with the City of Gatlinburg, Tennessee, on an automated LFWS with an extremely complex response plan. This complexity of the response plan is necessary because Gatlinburg serves as the gateway to the Great Smokey Mountains National Park and is a major tourist area.

Communities in the Tennessee River watershed may contact TVA for information and assistance.

11.7 Federal Emergency Management Agency

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

FEMA supports state and local governments in a wide range of disaster planning, preparedness, mitigation, response, and recovery efforts. As necessary, FEMA provides funding, technical assistance, services, supplies, equipment, and direct Federal support to fulfill state and local government emergency management responsibilities. Additional services and products that FEMA may fund include:

- an inventory of properties and structures in flood-prone areas;
- a statewide flood hazard mitigation plan developed in a predisaster context;
- public awareness media presentations on flood hazards; and
- handbooks or other technical assistance on a variety of flood hazard topics, which may include LFWSs.

FEMA also administers the NFIP, which provides insurance coverage to property owners in communities with flood hazards in exchange for community agreement to adopt floodplain management measures to protect lives and reduce property losses. See Chapter 9 of this Handbook for a description of the CRS, which is a part of the NFIP. Technical assistance is provided to communities in both floodplain management and postdisaster hazard mitigation activities, such as encouragement of new construction away from flood-prone areas. At present, over 18,935 communities participate in the NFIP and nearly 3 million insurance policies are in effect. FEMA has published detailed floodplain mapping for about 95 percent of the communities and approximate floodplain delineations for most of the remainder. A detailed NFIP study and backup materials are also available.

There are 10 FEMA Regional Offices. Each office is headed by a regional Director who reports to the FEMA Director and is responsible for all FEMA programs in the region. For additional information and assistance, contact your Regional Office.

11.8 National Park Service

The Department of Interior's National Park Service (NPS) is made up of 334 units covering some 79 million acres. These park units are of such historic or natural significance that they justify special recognition and protection by the Congress; Congress continually adds new park units to the system. Many of these units are subject to flooding from rivers, lakes, oceans, and tsunamis. Flooding problems are sometimes aggravated by improper development within floodplains, by dam failures, and by unanticipated rises at reservoirs.

To minimize losses, the NPS has implemented policies on floodplains and dam safety in accordance with Executive Orders. As part of these policies, both manual and automated local flood warning and response systems are being installed. With technical review assistance from the USBR, parks are installing flood warning systems on their high dams and dams with significant hazard potential as part of required emergency action plans. Several of these warning systems have been installed with the assistance of the NWS and the USACE.

Contact the NPS for additional information about the use of local flood warning and response systems on floodplains or at dam locations within the NPS area of responsibility.

11.9 State Agencies

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

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

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

11.10 Association of State Floodplain Managers

The cornerstone of the Association of State Floodplain Managers (ASFPM) is its membership. Membership is comprised of Federal, state, and local water resources agencies along with consultants, the private sector, and universities. The ASFPM supports comprehensive nonstructural and structural management of the Nation's watersheds and floodplains and their related land and water resources. The ASFPM provides members from all geographical areas a unified voice that is heard at the national level, thereby fostering ways to reduce flood losses and promote wise floodplain management in the Nation.

An automated LFWS committee promotes the opportunity to educate members and the public at large with in-depth knowledge of the automated LFWS at its national conferences. The ASFPM has experienced substantial growth in the past decade and is expected to continue its growth in the future, presenting an ideal vehicle for experts in the automated LFWS to communicate with their counterparts.

11.11 ALERT Users Group

The AUG is a nonprofit corporation representing organizations, agencies, corporations, and individuals interested in furthering the capabilities of real-time environmental warning systems through the application and improvement of ALERT technologies. Membership extends throughout the United States as well as worldwide. The organization primarily supports the interests of the California and Nevada representatives but actively supports many other western states as well. The AUG maintains a close liaison with the SAAS to develop common policies and objectives. They also encourage the development of regional ALERT systems and support groups and strive to improve the effective interaction of those organizations that can benefit from real-time hydrologic systems.

ALERT users have common interests in promoting adequate data networks to meet their needs in the noninterfering use of those networks and in the effectiveness and cost of ALERT hardware, software, and services in their areas of interest. They share information and concerns about the establishment, management, and use of those systems.

The AUG holds an annual conference with a structured agenda that includes talks, discussions, workshops, and demonstrations. In addition, quarterly business meetings are held. The AUG publishes a quarterly newsletter, *ALERT Transmission*, with SAAS, to maintain effective communications among members and others interested in automated LFWSs. For further information, contact the AUG (see Chapter 12 for address).

Internet. The AUG has a Web Page on the World Wide Web at the following address:

http://nimbo.wrh.noaa.gov/Alert/

11.12 Southwestern Association of ALERT Systems

SAAS covers the States of Arizona, Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas. This nonprofit corporation began in 1987 and is the second largest ALERT user group. SAAS was formed to improve the performance and utilization of real-time environmental monitoring systems for the ultimate purpose of protecting public health, safety, and welfare. Specifically, SAAS promotes public awareness of ALERT system use and applications; exchanges information, methods, procedures, and solutions; and encourages preparedness planning. It also promotes sharing of real-time data with other government agencies, encourages suppliers to develop needed solutions, and cooperates with agencies and organizations of similar purpose. SAAS holds an annual conference in the fall where suppliers, ALERT operators, and government agencies exchange information. For further information, contact SAAS (see Chapter 12 for address).

Internet. The SAAS has established a Web Page on the World Wide Web at the following address:

http://www.io.com/ rooke/alert/saas

11.13 National Hydrologic Warning Council

The National Hydrologic Warning Council was established in 1993 by the nonprofit AUG and SAAS to enhance cooperation between the two organizations on national issues that impact local flood warning programs. The initial organizational meeting was held in Baltimore in May 1995.

Internet. The National Hydrologic Warning Council has a Web Page on the World Wide Web at the following address:

http://www.io.com/ rooke/alert/nhwc

11.14 IFLOWS Management

The IFLOWS was created by congressional mandate in 1980. The NWS has developed cooperative agreements between the NWS and selected Appalachian state emergency service agencies. Under these agreements, the NWS designs and develops the system, provides equipment, software, and software upgrades, supports equipment replacement, and provides continuing technical support. The participating states operate and maintain the system. IFLOWS technology, including software, is available to others outside the IFLOWS program area.

CHAPTER 12

SELECTED REFERENCES AND ADDRESSES

12.0 Introduction

This section lists references on automated LFWSs and response planning. Selected addresses from the list of participants in Chapter 11 are also presented.

12.1 References

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

National Weather Service, Office of Hydrology. August 1993. *Integrated Flood Observing and Warning System Management Guide*. Department of Commerce, NOAA, Silver Spring, Maryland.

__________, Eastern Region. 1988. Unpublished Technical Memorandum on ALERT Systems. Department of Commerce, NOAA, Northeast River Forecast Center, Taunton, Massachusetts.

__________, Western Region. October 1982. *Automated Local Evaluation in Real Time—A Cooperative Flood Warning System for Your Community*. Department of Commerce, NOAA, Silver Spring, Maryland.

Owen, H. James. 1977. *Guide for Flood and Flash Flood Preparedness Planning*. Prepared for Department of Commerce, NOAA, National Weather Service, Silver Spring, Maryland.

__________. 1979. *Information for Local Officials on Flood Warning Systems*. Prepared for Department of Commerce, NOAA, National Weather Service, Silver Spring, Maryland.

U.S. Bureau of Reclamation. 1995. *Emergency Planning and Exercise Guidelines*. Department of the Interior, Denver, Colorado.

12.2 Addresses

ALERT Users Group
10852 Douglass Road
Anaheim, CA 92806

Southwestern Association of
ALERT Systems
6922 Old Katy Drive
Houston, TX 77024

Executive Director
Association of State
Floodplain Managers
Wisconsin Dept. of Natural Resources
P. O. Box 7921
Madison, WI 53707

NWS Office of Hydrology
W/OH2 - IFLOWS Program Office
SSMC2, 8th Floor
1325 East-West Highway
Silver Spring, MD 20910-3283

NOAA/NWS Office of Hydrology
W/OH2 - Hydrologic Operations Division
SSMC2, Rm 8176
1325 East-West Highway
Silver Spring, MD 20910-3283

Office of the Federal Coordinator
for Meteorology
8455 Colesville Road, Ste 1500
Silver Spring, MD 20910

U.S. Army Corps of Engineers
CECW-PF, 7214-C Pulaski Bldg.
20 Massachusetts Avenue NW
Washington, DC 20314-1000

Technical Service Center
Flood Hydrology Grp, Mail Code D-8530
U.S. Bureau of Reclamation
P.O. Box 25007
Denver, CO 80225

Sr. Technical Advisor, FEMA
Federal Center Plaza
500 C Street SW, Room 418
Washington, DC 20472

Land Surface Hydrology Program
NASA HQ - Mail Code YS
300 E Street SW
Washington, DC 20546

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Mail Stop T-10L1
Washington, DC 20555

Program Manager, Operations Engnr
Tennessee Valley Authority
WT-10B
Knoxville, TN 37901

USDA Natural Resources
Conservation Service
Rm 6137, South Bldg.
14th & Independence Ave. SW
Washington, DC 20250

USGS Water Resources Division
Department of the Interior
Mail Stop 417
Reston, VA 22092

National Hydrologic Warning Council
10852 Douglass Road
Anaheim, CA 92806

APPENDIX A

SAMPLE MEMORANDUMS OF UNDERSTANDING FOR

LOCAL FLOOD WARNING SYSTEMS (LFWS)

Automated Local Flood Warning System

This sample Memorandum of Understanding for an automated Local Flood Warning System contains the core responsibilities of both the Cooperator and the National Weather Service (NWS). Additional responsibilities, such as those related to the Cooperator donating or loaning base station equipment to the NWS, must be included as described under Weather Service Operations Manual Chapter E-40.

Manual LFWS

This sample Memorandum of Understanding for a manual Local Flood Warning System contains the core responsibilities of both the Cooperator and the NWS. Additional responsibilities must be included as described under Weather Service Operations Manual Chapter E-40.

MEMORANDUM OF UNDERSTANDING

FOR AN

AUTOMATED LOCAL FLOOD WARNING SYSTEM

This Memorandum of Understanding (MOU) between the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) and ____ (Cooperator) is undertaken for the development and operation of an automated Local Flood Warning System (LFWS).

1. Authority

The NWS undertakes this MOU pursuant to its authority in 15 U.S.C. Section 313 and 7 U.S.C. Section 450b in order to carry out its functions relating to flood warnings.

2. Nature of Agreement

The Cooperator and the NWS agree to a program for the installation and operation of an automated LFWS for __________________________ (community, area, or basin).

3. Responsibilities of the Cooperator

A. Ensure development and operation of an emergency response plan prior to or concurrent with execution of this MOU that includes:

- coordination with the NWS and
- dissemination of warnings to the public.

B. With Cooperator or third-party funds, pay for capital cost of equipment and all installation costs.

C. With Cooperator or third-party funds, pay for the capital cost of major equipment replacement.

D. Install, operate, maintain, and assume recurring costs of the automated LFWS including:

- emergency operations center (utilities, physical space);
- equipment used to support the Cooperator's program including radio reporting rain gages, flash flood alarms, base station including the radio equipment, repeaters, staff gages;
- communications and utility costs to support the Cooperator activities; and
- equipment in NWS office.

E. Designate, by name or position, who shall act for the Cooperator as the local representative.

F. Review annually with the NWS this MOU and the response plan. Update as necessary.

G. Conduct an annual drill, in coordination with the NWS, to test the system.

H. Ensure continuous operation of the system in order to provide the necessary database.

I. Monitor the system and immediately notify the NWS of system malfunctions.

J. Relay NWS flash flood/flood watches, warnings, and statements to the public.

K. Establish a continuously operating (or as required) emergency operations center for the purpose of:

- operating the base station (data receiver and computer) where applicable;
- receiving and recording all reports of rainfall and flood conditions;
- promptly relaying or making available all such reports to the designated Cooperator's representative;
- serving as the official distribution point for all warnings and statements issued by or for the designated Cooperator's Flood Warning Coordinator. When emergency conditions and lack of time prevent warnings from being issued by the NWS, the designated local official(s) shall be prepared to issue appropriate warnings;
- ensuring that, in addition to general public distribution, flood warnings or statements reach warning action points as listed in the Cooperator's response plan;
- relaying river and rainfall reports, flood data, and warnings to the designated NWS office as soon as practicable after local requirements have been satisfied. The standards and formats for this information relay are described in ______________________(attachment).

4. <u>Responsibilities of the National Weather Service</u>

A. Assist in selection of equipment appropriate to the automated LFWS.

B. Provide assistance in rain and river gage site location.

C. Sponsor, where applicable, radio licenses required for the system on behalf of the Cooperator. (The Cooperator shall be the licensee of record.)

D. Utilize data from the automated LFWS and provide hydrometeorological forecast and warning service for the area served by the automated LFWS.

E. Provide appropriate warning distribution over NOAA Weather Wire Service and/or other NOAA product dissemination systems.

F. Where feasible and appropriate, transmit to the Cooperator, in the most convenient manner, suitable and mutually agreed upon NWS hydrometeorological products.

G. Provide training for the Cooperator's flash flood coordinators and local authorities (including network observers). The scope of the training covers:

- the NWS flood/flash flood watch/warning program,
- local flood warning programs,
- operation and maintenance procedures for communications and hydrologic instrumentation,
- the need for emergency response planning,
- how to establish and maintain observer networks, and
- periodic drills to test the system.

H. Conduct an annual drill, in coordination with the Cooperator, to test the system.

5. <u>Title to Equipment</u>

Title to equipment purchased under this MOU shall remain vested with the purchaser.

6. <u>Amendments and Modifications</u>

This MOU may be amended or modified by mutual agreement of the NWS and the Cooperator. Additional responsibilities by either party are listed on an Addendum attached hereto and made a part hereof.

7. Termination

This MOU may be terminated by either party upon sixty (60) days written notice to the other party, notice to begin with date of mailing. All equipment shall be returned within sixty (60) days to the purchasing party of such equipment. Equipment shall be returned in the condition it was at the time of termination.

8. Effective Date

This MOU becomes effective on the date of the last signature shown below upon execution by the parties hereto.

Cooperator	National Weather Service
BY: ______________________________	BY: _____________________________________
TITLE: ___________________________	TITLE: Regional Director
DATE: ____________________________	DATE: ___________________________________

MEMORANDUM OF UNDERSTANDING

FOR A

MANUAL LOCAL FLOOD WARNING SYSTEM

This Memorandum of Understanding (MOU) between the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) and ____ (Cooperator) is undertaken for the development and operation of a manual Local Flood Warning System (LFWS).

1. Authority

The NWS undertakes this MOU pursuant to its authority in 15 U.S.C. Section 313 and 7 U.S.C. Section 450b in order to carry out its functions relating to flood warnings.

2. Nature of Agreement

The Cooperator and the NWS agree to a program for the installation and operation of a manual LFWS for _________________________ (community, area, or basin).

3. Responsibilities of the Cooperator

A. Ensure development and operation of an emergency response plan prior to or concurrent with the execution of this MOU that includes:

- coordination with the NWS and
- dissemination of warnings to the public.

B. Arrange for volunteer network observers.

C. Install, operate, and maintain the manual LFWS including:

- emergency operations center and
- equipment used to support the Cooperator's program including staff gages and plastic rain gages.

D. Designate, by name or position, who shall act for the Cooperator as the local representative.

E. Review annually with the NWS this MOU and the response plan. Update as necessary.

F. Conduct an annual drill, in coordination with the NWS, to test the system.

G. Monitor the manual LFWS and immediately notify the NWS of any significant program problems.

H. Relay NWS flash flood/flood watches, warnings, and statements to the public.

I. Establish an emergency operations center for the purpose of:

- receiving and recording all reports of rainfall and flood conditions;
- promptly relaying or making available all such reports to the designated Cooperator's representative;
- serving as the official distribution point for all warnings and statements issued by or for the designated Cooperator's Flood Warning Coordinator. When emergency conditions and lack of time prevent warnings being issued by the NWS, the designated local official(s) shall be prepared to issue appropriate warnings;
- ensuring that, in addition to general public distribution, flood warnings or statements reach warning action points as listed in the Cooperator's response plan;
- relaying river and rainfall reports, flood data, and warnings to the ____________________________ ________ NWS office as soon as practicable after local requirements have been satisfied.

4. <u>Responsibilities of the National Weather Service</u>

A. Assist in selection of equipment appropriate to the manual LFWS.

B. Provide assistance in rain and river gage site location.

C. Develop a self-help forecasting procedure as data become available for specific drainage basins and provide a copy to the Cooperator officials along with instructions for its use.

D. Utilize data from the manual LFWS and provide hydrometeorological forecast and warning service for the area served by the manual LFWS.

E. Provide appropriate warning distribution over NOAA Weather Wire Service and/or other NOAA product dissemination systems.

F. Provide training for the Cooperator's flash flood coordinators and local authorities (including network observers). The scope of the training covers:

- the NWS flood/flash flood watch/warning program,
- local flood warning programs,
- the need for emergency response planning,
- how to establish and maintain observer networks, and
- periodic drills to test the system.

G. Conduct an annual drill, in coordination with the Cooperator, to test the system.

5. Amendments and Modifications

This MOU may be amended or modified by mutual agreement of the NWS and the Cooperator. Additional responsibilities by either party are listed on an Addendum attached hereto and made a part hereof.

6. Termination

This MOU may be terminated by either party upon sixty (60) days written notice to the other party, notice to begin with date of mailing.

7. Effective Date

This MOU becomes effective on the date of the last signature shown below upon execution by the parties hereto.

Cooperator	National Weather Service
BY: ______________________________	BY: ____________________________________
TITLE: __________________________	TITLE: Regional Director
DATE: ___________________________	DATE: __________________________________

APPENDIX B

FLASH FLOOD MANUAL

OF

LOCAL FLOOD FORECAST PROCEDURES

Appendix B is the Flash Flood Manual which contains forecast procedures or backup forecast procedures prepared for the county/community by the National Weather Service (NWS). This sample manual does not explicitly reference automated hydrometeorological sensors or personal computer base stations. It is based on the assumption that rain gages and stream gages are read by local observers and computations are manually performed. The extension of this manual to cover automated warning systems, however, should be straightforward. Chapters B-1 through B-4 of this Flash Flood Manual contain general information and instructions that pertain to all counties/communities. Chapter B-5 describes the flood problem(s) for a particular county/community and includes the forecast procedure(s) (table) developed for the county/community.

Chapter B-5 in this Appendix is an example for a fictitious community called Lake County. Chapters B-1 through B-4 are designed to be a part of an operational document for flood forecasting and can be separated or copied from this Handbook. Chapter B-5, containing actual forecast procedures for the specific county/community, would then complete an operational Flash Flood Manual.

FLASH FLOOD MANUAL

FOR THE

COUNTY/COMMUNITY OF

____

APPENDIX B
FLASH FLOOD MANUAL
TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

Note: Pages in Chapter 5 are included as necessary.

FLASH FLOOD MANUAL

CHAPTER B-1 - INTRODUCTION

This Flash Flood Manual is intended for use by Federal, state, and local offices. It consists of two major parts: the basic manual in Chapters 1, 2, 3, and 4; and the county/community-specific manual in Chapter 5. All pages in Chapter 5 would include the county/community name as part of the page identifier. An office that maintains manuals for several counties would have the basic manual (Chapters 1-4) plus a Chapter 5 for **each** county/community that it represents. Page identifiers on Flood Advisory Tables include both county and station name. More than one Flood Advisory Table may be included in Chapter 5 for a particular county/community.

1.1 Purpose

The purpose of this Flash Flood Manual is to establish NWS guidelines and procedures under which a county/community can forecast flash floods, thus enabling advance warnings to those communities located along small tributary streams.

1.2 Plan

A "Flood Warning Unit" will be organized consisting of a flood warning coordinator, communications support, gage network supervisor, rainfall and stream observers, and other support staff. This unit will work closely with Disaster Services Agency/Office of Emergency Services/Disaster and Emergency Services to ensure that advisories and warnings will produce effective and timely community action.

1.3 Organization

Community cooperation is the foundation of the Flood Warning Unit. Rain gages will be installed at specified sites (coordinated with problem areas) around the Local Flood Warning System (LFWS) area. The daily reading and maintenance of these gages will be the responsibility of local observers. Rainfall amounts will be reported by these observers to a designated local Flash Flood Coordinator, and this Coordinator will use the amounts to calculate the average precipitation over the area. Utilizing a procedure developed by the NWS River Forecast Center (RFC) to determine the threat for flash flooding, the Flash Flood Coordinator will notify the Disaster Services Agency Director if the potential of flash flooding exists or if flooding is imminent. The Coordinator must relay this same information to the NWS office having flood warning responsibility for the county. The structure of the LFWS is shown graphically in Figure 1, Section 1.4 below.

The responsibilities and relationship between the NWS and the local government for the LFWS is specified in a mutual agreement between the participating agencies. Several meetings between the local government and the NWS will be required to define the roles and responsibilities of each. The mutual agreement (Memorandum of Understanding) begins on page 5-20 of this Manual.

1.4 Structure

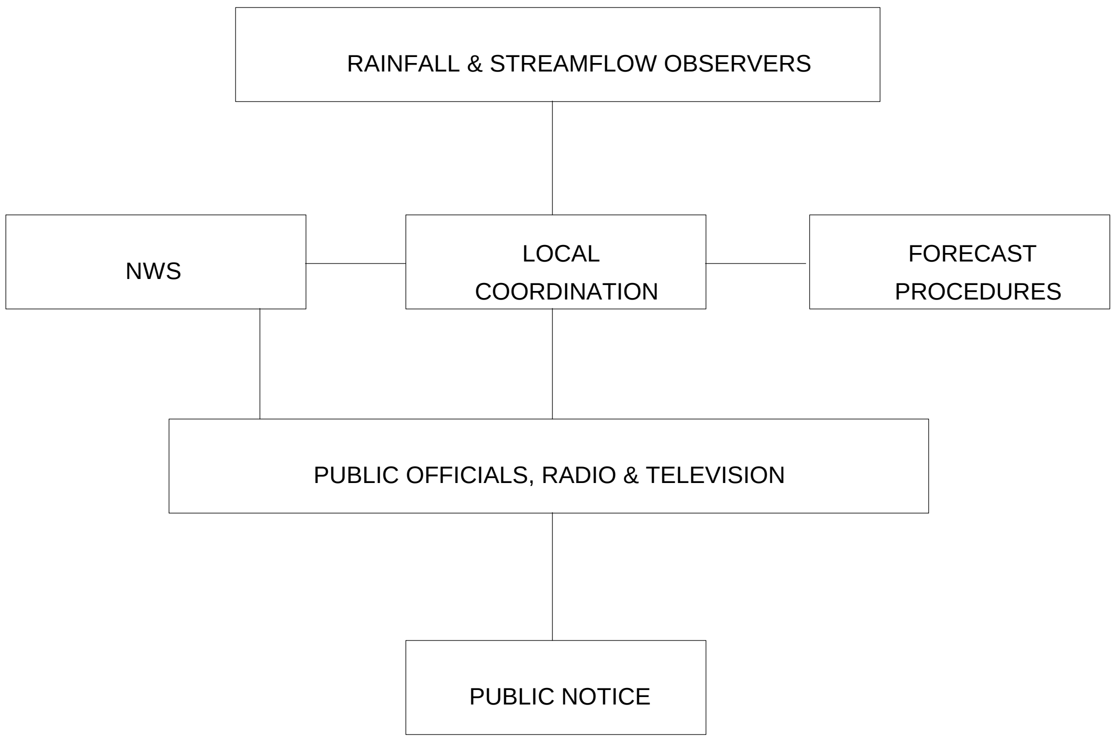

Figure 1. *Structure of typical flood warning system.*

1.5 Feedback

Cooperation at all levels of the program is the key to success of any flood warning system. The work of the local observer should go beyond reporting rainfall. If possible, observations should also include storm characteristics, stream response to rainfall, the time flooding begins and ends, time of flood crest, etc. The Flash Flood Coordinator should always be checking the effectiveness of the flood procedure which may have been developed by the NWS. The effectiveness of the procedure may relate to location, time of year, or storm characteristics. Close coordination with the Disaster and Emergency Services Agency will help refine community response to the warning system.

The importance of feedback to the NWS cannot be overstated. Through this feedback, present procedures can be maintained to better handle flash flood problems of the individual communities within the county.

FLASH FLOOD MANUAL

CHAPTER B-2 - HYDROLOGIC FORECASTING

2.1 Hydrologic Factors

In the application of the self-help hydrologic forecast procedures for floods and flash floods, the following information is needed:

1. The amount of water available for runoff. (This includes snowmelt as well as rainfall and is usually referred to as the average basin rainfall.)

2. A method of determining the amount of runoff produced. [The Advisory Table (or categorical procedure) relates rainfall to runoff for a location with the use of the current advisory rainfall (or flood guidance) and the runoff procedure.]

3. The length of time of rainfall which produces runoff (duration of significant rainfall).

4. The amount of water in the stream prior to a runoff-producing event.

5. Reservoir release changes from upstream reservoirs.

Items 1, 3, and 4 have to be measured or observed at the site. Item 2 has been incorporated into the forecast procedure and requires getting into the correct column in the Advisory Table. The advisory rainfall furnished to the user identifies the column to use. This value is updated and sent daily by the NWS RFC to the Weather Forecast Office (WFO). The WFO forwards the advisory rainfall to the Flood Warning Unit. Each forecast procedure has been developed specifically for the location stated thereon and should not be applied to any other site. This includes even localities situated on the same stream since hydrologic characteristics and gage datums are rarely identical at different locations. Item 5 is available from the agency who controls the upstream reservoir.

2.1.1 Determining the Amount of Rain

This is by far the most important factor needed in making a forecast and, of course, can come only from your precipitation network, including volunteer and automated gages. Therefore, it is your responsibility to see that all instructions for measuring and reporting precipitation are clearly understood and followed. Note that the word "precipitation" is used rather than "rainfall" because your network should also keep you informed of the amount of snow present, not only its depth but, of even greater importance, the amount of water in the snow. In hydrology, this is known as the "water content" of the snowpack and refers to the amount of water the snow will yield upon melting. The rate of the snow depth to the water equivalent of the same depth is generally 10:1. As the snow packs down, the density increases to two or three times this amount. In using the procedure when rain falls and snow is present on the ground, the water content of the snow should be added to the rainfall (see section 5.9); and the total is used in making the forecast. This assumes that all the snow will either be washed down or melted with the rain. This is usually what happens; but, in those cases where this does not

The precipitation value used is the average for the entire basin not just the amount measured at a single station. The reason for this will soon become obvious with use, and you will probably

on the accuracy of any report that appears exceptionally low or exceptionally high. Also, it is a good idea to inquire as to the state of the present weather and the prospects for additional

of certain situations is to use future rain in forecasting rivers.

2.1.2

Quite often a moderate rainfall of 2 inches in January can cause a significant river rise, perhaps even a flood; yet, this same amount of rain in July may have little or no effect. The

different seasons of the year. The production of runoff is a complex natural process and is affected by many factors, the principal ones being the type of soil, its recent moisture history,

and seasonal rainfall patterns. The relationship of these factors to runoff productivity has been built into your procedures with the overall effect expressed in a number. This number is the

flooding at your location. The advisory rainfall designates the proper column to use in the Advisory Table.

Determining Runoff Duration

In order to better understand the mechanism involved in the rise and fall of a stream, consider

that water is running out at the bottom, the water level will not rise as long as the inflow does not exceed the outflow. However, if the inflow is increased so it exceeds the outflow, the

rate of rise increases. Decrease the rate of inflow below the rate of outflow and the water level falls. The principles illustrated here apply equally well in the rise and fall of a river. As the

(the rain slackens), the rate of rise decreases. If the rate of inflow decreases below the outflow rate, the river will fall even though the rain still continues. Now you can understand why the

This will also explain why there may be more than one crest since the river can start rising again after cresting if the rate of inflow again exceeds the rate of outflow, i.e., the rainfall

Define duration as the length of time from the beginning of runoff until the end of heavy rain. A good estimate will usually be satisfactory. The start of runoff can be obtained by noting when the river starts to rise. Duration is important because of its effect on the crest, both its height and time of occurrence. The relationship is inverse, i.e., as the duration increases, the length of time to crest after the end of heavy rain decreases. In cases of prolonged rainfall, the crest will be close to the end of heavy rain; and warning time may be zero. It is for this reason that we cannot always wait until the rain is measured before making a forecast. Accordingly, under certain conditions, the only practical way to provide warning time is to prepare forecasts ahead of or before the end of the rain event. Wording of the forecast should clearly indicate that rainfall has not yet occurred but may be likely or it has not yet ended. The forecast is worded, "The crest will be…feet if we get one inch of additional rain and…feet if we get two inches of additional rain."

2.1.4 Stream Level Before the Runoff Event

A typical stream that is prone to flash floods rises and falls within a short time of a runoff-producing event. Therefore, most of the time, the stream level is very low, and the amount of water in the stream is insignificant in comparison to the amount of water in the stream during a flood. However, some streams respond slower to runoff-producing events and may have a significant amount of water when another runoff-producing event occurs. In this situation, the current level of the stream must be included in a crest forecast. The reason for this is that all advisory rainfall and flood guidance assume the streams are at a low or insignificant flow. We refer to these low flows as base flows.

2.1.5 Adjustment for Upstream Reservoir Releases

If a reservoir is located upstream of your location, your crest forecast must be adjusted to reflect changes in releases from the reservoir. It is important to note that we said changes in releases. The current reservoir release is represented by the current stream level. Adjustment of your crest forecast for the current stream level was explained in Section 2.1.4 above.

Frequently, reservoir releases will be greatly reduced during or after a runoff-producing event to lessen the severity of flooding downstream. At times, such action can eliminate downstream flooding. If there are any reservoirs in your system, your crest forecast must be adjusted to reflect any changes in upstream reservoir releases. The amount of the adjustment is the difference between the release prior to runoff and the release at the time of the expected crest. The time of the expected crest is specified in your Advisory Table. The reservoir release at the expected time of crest will be available from the agency that operates the reservoir. Timing of the reservoir releases is critical to your crest forecast as you will learn from a few events. A good working relationship with the agency responsible for operation of the reservoir would be beneficial. If no changes in releases are planned after a runoff-producing event, you do not adjust your crest forecast.

2.2

The following information is needed to make a crest forecast using a Flood Advisory Table or a Categorical Procedure:

Average basin rainfall for the area of concern. (This is the amount of water available for runoff and includes snowmelt as well as rainfall.)

Advisory rainfall or flood guidance for the area. (This is available from the NWS. These values are an indicator of soil moisture and are derived from a history of storms

the RFC.)

3.

4. Base flow. This is the amount of water in the stream before the rain occurred.

Reservoir release changes. (If a reservoir is located upstream, any changes in releases must be considered to obtain a crest forecast.)

Flash Flood Watches, Warnings, and Internal Affairs

1.

NWS office any time you feel a watch may be necessary.

2.

3. Based on your reports of heavy rain and/or flooding relayed to the NWS office

precipitation estimates, the NWS will issue a FLASH FLOOD WARNING for your county (see example #1 below). However, if you cannot contact the NWS, time is

local WARNING (see example #2 below). Every effort should be made to notify the NWS as soon as possible after the warning is issued.

Example #1:

SAMPLE FLASH FLOOD WARNING ISSUED BY
NATIONAL WEATHER SERVICE

The National Weather Service has issued a Flash Flood Warning effective until 5 p.m., Sunday, for ____________________________ County, ______________(state).

A Flash Flood Warning means flooding is imminent. Take necessary precautions as required.

Heavy rains have been falling over much of the county with gage reports and radar precipitation estimates indicating almost four inches in western parts of the county…radar indicates additional heavy thunderstorms southwest of the county and more heavy rains are likely this afternoon…

This additional rainfall will produce local flooding.

Persons near areas that are prone to flooding should be on the alert for fast-rising waters.

* *

Example #2

SAMPLE FLASH FLOOD WARNING ISSUED BY
LOCAL DISASTER AND EMERGENCY SERVICES AGENCY

________________________ Disaster and Emergency Services Agency has issued a Flash Flood Warning for _________________________ County until 5 p.m. this afternoon. Heavy rains over the area through 3 p.m. this afternoon have caused rises on the small streams and creeks throughout the county. Unless the rain ends shortly, significant flooding of small streams and creeks is likely. All interests along rivers and streams in the area should take immediate life-saving action and keep alert for later statements on the FLOOD SITUATION.

FLASH FLOOD MANUAL

CHAPTER B-3 - SMALL STREAM FORECASTS

3.1 Description of Categorical Forecasts

The categorical forecasts of flooding used in this manual can be interpreted by the following terminology :

Degree of Flooding	General Description
Minor	Near flood stage—only minimal damage expected.
Moderate	Secondary roads blocked—transfer to higher elevations necessary to save property. Some evacuations may be required.
Major	Extensive inundation and damage—many primary roads and bridges closed. Many people may be evacuated.

The amount of runoff needed to cause these “levels” of flooding are incorporated in the small stream forecast procedures.

3.2 Sample Categorical Forecast Procedure

GENERALIZED FORECAST PROCEDURE FOR UNGAGED STREAMS

CATEGORY	RUNOFF INCHES	AVERAGE BASIN RAINFALL (INCHES) FOR TIME DURATION OF GUIDANCE USED											
MINOR	0.25	0.5	0.6	0.7	0.8	1.1	1.2	1.4	1.8	2.2	2.6	3.1	3.6
GUIDANCE	0.50	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	4.5
	0.75	1.1	1.3	1.5	1.8	2.1	2.4	2.6	3.1	3.6	4.1	4.5	5.0
	1.00	1.4	1.6	1.8	2.1	2.5	2.8	3.0	3.5	4.0	4.5	5.0	5.5
MODERATE	1.25	1.7	1.9	2.1	2.4	2.8	3.1	3.3	3.8	4.4	4.9	5.3	5.8
	1.50	1.9	2.1	2.4	2.7	3.1	3.3	3.6	4.1	4.7	5.2	5.6	6.1
	1.75	2.2	2.4	2.6	3.0	3.4	3.6	3.9	4.4	5.0	5.5	5.9	6.4
----------	2.00----	2.4	2.7	2.9	3.3	3.7	3.9	4.2	4.8	5.3	5.8	6.3	6.7
	2.25	2.7	2.9	3.2	3.5	4.0	4.2	4.5	5.0	5.6	6.1	6.5	7.0
	2.50	3.0	3.2	3.5	3.8	4.2	4.5	4.8	5.3	5.9	6.3	6.8	7.2
MAJOR	2.75	3.2	3.5	3.7	4.1	4.5	4.8	5.1	5.6	6.1	6.6	7.1	7.5
	3.00	3.5	3.7	4.0	4.4	4.8	5.1	5.4	5.9	6.4	6.9	7.4	7.8
	3.25	3.7	4.0	4.3	4.6	5.1	5.4	5.6	6.2	6.7	7.2	7.6	8.0
	3.50	4.0	4.3	4.5	4.9	5.4	5.7	5.9	6.5	7.0	7.4	7.9	8.3
	3.75	4.3	4.5	4.8	5.2	5.6	5.9	6.2	6.8	7.2	7.7	8.1	8.6
	4.00	4.5	4.8	5.1	5.5	5.9	6.2	6.5	7.0	7.5	8.0	8.4	8.8
	4.25	4.8	5.0	5.3	5.7	6.2	6.5	6.7	7.3	7.8	8.2	8.7	9.1
	4.50	5.0	5.3	5.6	6.0	6.4	6.7	7.0	7.5	8.0	8.5	8.9	9.3
	4.75	5.3	5.6	5.8	6.2	6.7	7.0	7.2	7.8	8.3	8.7	9.2	9.6
	5.00	5.6	5.8	6.1	6.5	6.9	7.2	7.5	8.0	8.5	9.0	9.4	9.8
	5.25	5.8	6.1	6.3	6.7	7.2	7.5	7.7	8.3	8.8	9.2	9.7	10.1
	5.50	6.1	6.3	6.6	7.0	7.5	7.7	8.0	8.6	9.0	9.5	9.9	10.3

3.3 Instructions for Use of Categorical Forecast Procedure

Follow steps 1 through 5 under section 4.1, "Instructions for Using the Advisory Table."

3.4 Examples of Categorical Forecasts

EXAMPLE #1 **Rainfall Tabulation**

Guidance from NWS for 9/15
1 Hour: 1.0
3 Hour: 1.2
6 Hour: 1.5
12 Hour: 2.0

Date/Time LOCATION	9/15 7 AM				REMARKS
#1	3.10				Heavy rainfall occurring over about 4 hours
#2	2.88				
#3	3.24				
#4	2.95				
#5	3.01				
Total Rainfall	15.18				
Average (/5)	3.04				
Guidance (NWS)	1.2				Use 3-hour guidance
Degree of Flooding	Major				

EXAMPLE #2 **Rainfall Tabulation**

Guidance from NWS for 10/15
1 Hour: 1.1
3 Hour: 1.3
6 Hour: 1.6
12 Hour: 2.0

Date/Time LOCATION	10/15 10 PM				REMARKS
#1	2.16				Heavy rainfall occurring over about 5 hours
#2	2.42				
#3	1.89				
#4	1.97				
#5	2.07				
Total Rainfall	10.51				
Average (/5)	2.10				
Guidance (NWS)	1.6				Use 6-hour guidance
Degree of Flooding	Moderate				

CHAPTER B-4 - SITE-SPECIFIC (HEADWATER) FORECASTS

4.1 Instructions for Using the Advisory Table

Steps to follow when using the Advisory Table in Section 4.2 to arrive at a crest forecast (or categorical forecast):

1. Obtain the flood guidance (a measure of soil moisture conditions) from the NWS office which has guidance responsibility for your community.

2. Determine the observed rainfall for the basin and the duration of rain (hours). When several rain gages are located in or near the basin, average these values to obtain the average basin rainfall, which becomes the observed rainfall to use in the Advisory Table (categorical procedure).

3. Select guidance corresponding to the proper duration of continuous rain or nearest duration if between two values. For instance, if the observed rainfall duration was 5 hours, use guidance for 6 hours. If the duration was 4 hours, use guidance for 3 hours instead of for 6 hours.

4. Enter the table at the line labeled flood stage, "FS," (or guidance) and move to the right to the guidance value selected in Step 3. You may need to estimate between columns if the guidance does not match a column. Move up or down in this column until the observed basin rainfall is found. You may need to estimate between rows.

5. Move to the left along the same row containing the observed basin rainfall to the column labeled "Discharge" for a gaged stream. This value is the discharge or flow you can expect from the rainfall just observed. (For an ungaged stream, using the table in Section B-3.2, move to the column labeled "Category" and extract the categorical forecast. End of categorical procedure.)

6. If this is a gaged stream and you have been reading the river gage, you have an idea of the discharge which, in low water conditions, is referred to as base flow; otherwise, go to Step 9. Enter the far left column labeled "Stage Feet" and move down to the river gage reading. Then move right to the next column and read the discharge. This is the base flow.

7. Obtain releases from any reservoirs upstream of gage location. Determine the increment of change in releases. (Increment of change will be zero if releases are the same as previous value.) ONLY THE INCREMENT OF CHANGE IS USED TO SUM THE TOTAL FLOW/DISCHARGE. Reservoir release values are given in cubic feet per second (cfs).

8. Add the discharge from Step 5 to the base flow in Step 6 and the increment of change in reservoir releases in Step 7. This new summed value becomes the total discharge of

the expected crest in cubic feet per second.

9. Enter the column labeled "Discharge" (second column from the left) and find the discharge of the expected crest. Move to the left to the stage column and read the stage to the nearest foot or one-half foot. This is the crest stage. Refer to the notes above the table to determine when the crest will occur.

4.2 Sample of Flood Advisory Table

EXAMPLE FLOOD ADVISORY TABLE ANYTOWN MUDDY R

FLOOD STAGE 6.0 FT FLOOD OF RECORD 11.70 FT 01/22/59
DRAINAGE AREA 175 SQ MI GAGE DATUM 610.30 FT MSL

CREST ABOUT 10 HOURS AFTER HEAVY RAIN ENDS.

EXAMPLE

MAXIMUM HEIGHT 12.9 FT ON 3/04/48 BACKWATER FROM ICE.

STAGE FEET	DISCHARGE 1000 CFS	AVERAGE BASIN RAINFALL (INCHES) FOR TIME DURATION OF GUIDANCE USED												
3.0	0.4	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.9	1.2	1.4	1.7	2.1	2.6
3.5	0.6	0.1	0.3	0.4	0.4	0.5	0.6	0.7	1.0	1.4	1.7	1.9	2.5	2.9
4.0	0.8	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.2	1.6	1.9	2.3	2.8	3.4
4.5	1.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.4	1.9	2.3	2.7	3.3	3.8
5.0	1.6	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.7	2.2	2.7	3.2	3.7	4.2
5.5	2.2	0.6	0.7	0.9	1.1	1.4	1.5	1.6	2.1	2.5	3.0	3.5	4.1	4.6
FS 6.0	2.9	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.0
6.5	3.6	0.9	1.2	1.4	1.6	1.8	2.0	2.3	2.8	3.3	3.8	4.3	4.8	5.3
7.0	4.3	1.1	1.4	1.6	1.8	2.0	2.2	2.4	3.0	3.5	4.1	4.6	5.1	5.6
7.5	5.3	1.4	1.6	1.8	2.0	2.3	2.5	2.7	3.3	3.8	4.4	4.9	5.4	5.9
8.0	6.4	1.6	1.9	2.1	2.3	2.6	2.8	3.1	3.6	4.2	4.7	5.2	5.8	6.3
8.5	7.4	1.9	2.2	2.4	2.6	2.9	3.1	3.4	4.0	4.5	5.0	5.5	6.1	6.6
9.0	8.5	2.2	2.5	2.7	2.9	3.2	3.4	3.7	4.3	4.8	5.4	5.9	6.4	6.9
9.5	9.7	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.7	5.2	5.7	6.2	6.8	7.2
10.0	11.0	2.8	3.1	3.4	3.6	3.9	4.2	4.4	5.0	5.6	6.1	6.6	7.1	7.6
10.5	12.5	3.2	3.5	3.8	4.0	4.3	4.6	4.9	5.5	6.1	6.6	7.0	7.6	8.0
11.0	14.2	3.6	4.0	4.2	4.5	4.7	5.0	5.3	6.0	6.5	7.0	7.5	8.0	8.4
11.5	16.0	4.1	4.5	4.7	5.0	5.2	5.5	5.8	6.5	7.0	7.5	8.0	8.5	8.9
12.0	18.0	4.6	5.0	5.2	5.5	5.8	6.1	6.3	7.0	7.5	8.0	8.5	9.0	9.4

3 HR UNITGRAPH PEAK ORDINATE = 3900.CFS FLOOD STAGE R.O. = 0.75

4.3 Examples on Use of Advisory Tables

<u>Example</u>

Guidance from NWS for:

Example 1	3 hr: 1.2 6 hr: 1.6 12 hr: 2.0	Excessive Rainfall Duration is 3 hours; therefore, use the 3-hour guidance value.
Example 2	3 hr: 2.1 6 hr: 3.0 12 hr: 3.8	Excessive Rainfall Duration is 5 hours; therefore, use the 6-hour guidance value.
Example 3	3 hr: 2.0 6 hr: 3.0 12 hr: 4.5	Excessive Rainfall Duration is 10 hours; therefore, use the 12-hour guidance value.

For Anytown, Muddy River
Example

	#1	#2	#3
DATA:			
Guidance	1.2	3.0	4.5
River Stage	4.0	3.5	3.0
Observed Rainfall Data:			
Gage 1	2.21	2.75	3.05
Gage 2	2.34	3.08	2.98
Gage 3	2.57	2.88	3.24
Gage 4	2.41	2.94	3.12
Total Rainfall	9.53	11.64	12.39
Average	2.38	2.91	3.10
Flow/discharge from rainfall	7400	2800	1000
Flow/discharge from base flow	800	600	400
Releases from reservoir (increment of change)	500	-1000	0
Total flow/discharge	8700	2400	1400
FORECAST:			
Crest Stage in Table	9.1 ft	5.6 ft	4.8 ft
Crest Stage Issued	NEAR 9.5 FT	NEAR 6 FT	NEAR 5 FT

FLASH FLOOD MANUAL

CHAPTER B-5 - LAKE COUNTY (SAMPLE)

HYDROLOGIC FORECAST PROCEDURES

This chapter is structured to discuss the following topics as they relate to the sample flash flood locality called Lake County:

5.1 Problem Streams

5.2 Area Description

5.3 Past Floods

5.4 Instructions for Flash Flood Coordinator

5.5 Support Agencies and Flash Flood Warning Staff Members
- 5.5.1 Support Agencies
- 5.5.2 Flash Flood Warning Staff Members

5.6 Flash Flood Warning List

5.7 Map of Streams and Observer Locations

5.8 Rain and Stream Gage Network Observers

5.9 Instructions for Rainfall Observers
- 5.9.1 WS Form E-16

5.10 Small Stream Forecasts
- 5.10.1 Categorical Forecast Procedure
- 5.10.2 Categorical Forecast Worksheet
- 5.10.3 Storm Record for Categorical Forecasts

5.11 Site-Specific Forecasts
- 5.11.1 Flood Advisory Table
- 5.11.2 Advisory Table Forecast Worksheet
- 5.11.3 Storm Record for Advisory Table Forecasts

5.12 Memorandum of Understanding

Note: Pages in this section are included as necessary.

5.1 Problem Streams

Heavy rainfall can cause any small stream to overflow its banks. Some streams and creeks in the county are more flood prone than others due to topographic features and continuing development along the streams. The following list summarizes the problem streams in the county:

Name of Stream	Flood Problem Location
Brush Creek	In Maple City between Main and Broadway
Black River	In Maple City along Knoll Avenue and Lee Avenue east of Lake Drive

5.2 Area Description

Lake County has an average annual precipitation of approximately 40 inches. Monthly precipitation is distributed fairly evenly during the year; May and June are the wettest months; October is the driest month.

Flash floods can occur during any season but are more prevalent during prolonged periods of rain with a large, sudden burst of heavy rain usually associated with thunderstorms. The average number of thunderstorms is about 20 per year. Maximum temperatures average in the mid-30s °F in January to near 80 °F in July. Minimum temperatures average in the low 20s °F in January to the mid-60s °F in July. Average winter season snowfall is about 15 inches with greater amounts at higher elevations. Flash floods from a combination of snowmelt and rainfall can pose a problem during this season.

5.3 Past Floods

DATE	CREST	REMARKS	DATE	CREST	REMARKS

5.4 Instructions for the Flash Flood Coordinator

The Flash Flood Coordinator is the focal point for the flood warning system. Preplanned action is required to make the flood warning system operate successfully to achieve its goal—reducing the loss of lives and personal property due to the destructiveness of floods and flash floods.

Specific tasks of the Flash Flood Coordinator are as follows:

1. Using the flash flood procedure to analyze all storm events to determine the potential for flash flooding.

2. Contacting the NWS if the flash flood procedure indicates flooding or if flooding has been reported. The NWS will issue the flash flood warning. If time is critical, the Flash Flood Coordinator should issue a warning through designated county officials THEN contact the NWS.

3. Keeping the Disaster Emergency Services Director and the NWS informed on all pertinent weather and flash flood information.

4. Maintaining contact with local observers to verify flooding, to obtain data, and/or to inform observers of recent developments.

5. Recruiting, organizing, and training volunteer rainfall and stream gage observers.

At the end of each month, the rainfall observers are instructed to mail two copies of the observation form to the Flash Flood Coordinator (WS Form E-16, "RECORD OF RAINFALL REPORTER" may be used and copies obtained from the NWS, see section 5.9.1, or a locally prepared form). One copy is retained in county files; the other copy is for NWS files. When all observers have sent their observation forms in to their county, the Coordinator must forward one copy from each observer to the following address:

____

____

____

____

____

5.5 Support Agencies and Flash Flood Warning Staff Members

The County is responsible for maintaining an up-to-date list of contact persons from their support agencies as well as all staff members.

5.5.1 Support Agencies

	Name	Title/Agency	Telephone No.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

5.5.2 Flash Flood Warning Staff Members

	Name	Title/Agency	Telephone No.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

5.6 Flash Flood Warning List

The County is responsible for maintaining an up-to-date list of contact persons in the event a flash flood warning is issued.

	Name	Agency	Telephone No.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			
21.			
22.			
23.			
24.			

5.7 Map of Streams and Observer Locations

[Reserved for map]

5.8 Rain and Stream Gage Network Observers

The placement of any rain gage is dependent on the size and shape of the drainage basin, local topography, accessibility of the gage, and the availability of a responsible observer.

	Name of Creek	Name of Observer	Location/Address	Telephone No.
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				

5.9 Instructions for Rainfall Observers

Introduction

The rainfall observers' responsibilities are to read, record, and report the amount of precipitation that falls in their areas. Prompt reports are extremely important to the effectiveness of the Flood Warning System.

Observations

A **daily** observation should be taken (usually about 7 a.m.). Empty the rain gage at this time. Special observations are taken during periods of heavy rainfall. See items 2 and 3 below in "WHEN" to report by telephone or radio.

If snow has fallen, the snow should be melted to obtain the water equivalent as described on the next page.

Recording the Observation

Enter all observations in the appropriate columns on the recording form. Total snow depth on the ground should be recorded in the remarks column, if necessary.

Report by Telephone or Radio

WHEN:

1. At 7 a.m., if *x* inch (or more) of rain was observed during the winter months (November-April) or *y* inch (or more) during the summer months (May-October). The amount “x” and “y” amount of rain should be defined by the local flash flood coordinator in coordination with the NWS.

2. At any other time if less than the reporting amount in item 1 above was observed at 7 a.m. but the rain continues and the total storm rainfall (7 a.m. plus additional rainfall) equals or exceeds the reporting amount in item 1.

3. At any time each additional amount (equal to the reporting amount in item 1 above) accumulates as the rain continues.

4. Occurrence of any of the following SEVERE weather:

   A. Tornado or funnel cloud;
   B. Damaging winds that uproot trees and/or damage buildings;
   C. Hail (dime-size or larger);
   D. Flooding that begins to cover roads or causes evacuation; and
   E. Freezing rain.

WHAT:

1. Your name and location or station.

2. Amount of rain in your gage at last observation.

3. Amount of rain in your gage at the last 7 a.m. observation if not reported previously. **REMEMBER--EMPTY GAGE ONLY AT 7 a.m.**

4. Type of SEVERE weather (if any).

TO:

Flood Coordinator: ______________________________

or Assistant 1: ______________________________

or Assistant 2: ______________________________

or, as a last resort, the National Weather Service at the following location:

____

____

____

Wintertime Operation

During low temperatures when freezing will occur, remove the funnel and center measuring tube. (The tube breaks easily when water freezes inside it.) Place them in a safe and convenient location because the measuring tube will still be needed. Frozen precipitation caught by the outer tube must be melted and poured into the measuring tube to measure the water content of the frozen precipitation. This can be done by two different methods:

1. Place the outer tube with the frozen precipitation in it near a source of heat—NOT ON IT—and let stand until the frozen precipitation has melted. Then pour the liquid into the measuring tube and read the amount.

2. Fill the center measuring tube with warm water to the 0.50-inch line. Pour this on the frozen precipitation in the outer tube. Place the funnel on the measuring tube and carefully pour the liquid in the outer tube back into the measuring tube. Read the amount and subtract 0.50 inch from it to obtain the water content of the frozen precipitation.

Water Equivalent (Liquid Content) of Snow on the Ground

This is the amount of water in the snow and/or ice on the ground. It becomes very important when above-freezing temperature is expected along with rain.

Press the outer tube of the rain gage top down into a level area of snow. Slip a thin piece of material, such as aluminum, beneath the mouth of the outer tube to hold the sample in as you withdraw the outer tube from the snow. Cut and remove the samples in layers when the depth of snow to be sampled is deeper than the outer tube. Make the cut where the sample will represent the average snowfall and where the snow cover seems least affected by drifting. (Obtain several samples to get a more representative liquid content.)

Melt and measure the samples as described above for wintertime operation. Record the water content on the record form and include the content in the 7 a.m. report.

Gage Exposure

Mount the rain gage in a convenient location. Ideally, the gage should be mounted on a sturdy post in an open area away from buildings or trees. The top of the gage should extend about 6 inches above the top of the post; the gage should be level.

Operation of the Rain Gage

The funnel catches the rain and delivers it to the measuring tube. The measuring tube in the 4-inch diameter (11-inch depth) plastic gage will hold 1 inch of rain. Rainfalls of less than 1 inch can be read directly on the measuring tube to the nearest 0.01 inch. Rainfalls exceeding 1 inch will overflow the measuring tube and collect in the outer tube. To measure, empty the measuring tube containing the first inch. Place the funnel into the empty measuring tube and carefully pour the contents of the outer tube into the measuring tube. Repeat the pouring and emptying until the outer tube is empty. Be sure you add 1 inch each time you empty a full measuring tube. It is a good idea to measure heavy rainfalls twice to ensure accuracy. Just use an empty can or pan to pour the water into, then measure again.

5.9.1 WS Form E-16

WS FORM E-16
(12-72)
PRES. BY WSOM E-41

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMIN
NATIONAL WEATHER SERVICE

RECORD OF RAINFALL REPORTER

STATION

RIVER DRAINAGE

TYPE OF RAINGAGE

MONTH | YEAR | TIME OF OBSERVATION

DATE	PRECIPITATION				REMARKS (Special observations, etc.) E
	BEGAN A	ENDED B	24-HOUR AMOUNT C	CHARACTER D	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					

NOTE: Send this form to Supervising Office monthly.

SUPERVISING OFFICE

REPORTER

WS FORM E-16 (12-72)

☆ U.S. Government Printing Office: 1979—668-127

Record of Rainfall Reporter

Station - Name of your town and state.

River Drainage - Stream for which warnings are issued based on your rainfall reports. If no particular stream, leave blank.

Month, Year - Be sure to enter these.

Time of Observation - Time you usually take daily reading.

Type of Rain Gage - Most are plastic 11" Clear-Vue.

Began, Ended - The time precipitation began and ended is *not required* and is difficult to keep track of. If you do know the times, especially of heavy rainfall, you may enter them here or in remarks.

24-Hour Amount - The amount of precipitation that fell in the 24-hour period ending with your observation time. For example, the entry at 8 a.m. on the 6th would cover the 24 hours from 8 a.m. on the 5th to 8 a.m. on the 6th. In the winter, any snow, sleet, etc., must be melted and figured in with any rain that fell. Enter precipitation in inches and hundredths of an inch (e.g., 0.07, 0.26, 1.09, 2.67). Use the following:

0 - No precipitation in the last 24 hours.

T - Trace—it rained but there was too little to measure, less than 0.01 inch.

M - Missing—you could not read the gage that day.

MAKE AN ENTRY EVERY DAY.

Character - *Not required*. If you wish, enter rain, snow, hail, etc.

Remarks - Special readings and those called to the Flood Coordinator are important. Unusual or severe weather and flooding should be reported.

Supervising Office - Your county.

Reporter - Your name.

KEEP A COPY OF YOUR RECORDS AND AT THE END OF EACH MONTH SEND THE REQUIRED NUMBER OF COPIES TO YOUR COORDINATOR.

5.10 Small Stream Forecasts

5.10.1 Categorical Forecast Procedure

GENERALIZED FORECAST PROCEDURE FOR SMALL STREAMS

CATEGORY	RUNOFF INCHES	AVERAGE BASIN RAINFALL (INCHES) FOR TIME DURATION OF GUIDANCE USED											
MINOR	0.25	0.4	0.5	0.6	0.7	0.8	1.0	1.4	1.8	2.1	2.5	3.1	3.6
	0.50	0.7	0.9	1.1	1.3	1.4	1.5	1.9	2.4	2.9	3.4	4.0	4.5
GUIDANCE	0.75	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	1.00	1.3	1.5	1.7	1.9	2.1	2.4	2.9	3.4	3.9	4.4	5.0	5.5
	1.25	1.5	1.7	2.0	2.1	2.4	2.6	3.2	3.7	4.2	4.8	5.3	5.8
MODERATE	1.50	1.8	2.0	2.2	2.4	2.7	2.9	3.5	4.1	4.6	5.1	5.6	6.1
	1.75	2.0	2.3	2.5	2.7	3.0	3.2	3.8	4.4	4.9	5.4	5.9	6.4
	2.00	2.3	2.5	2.8	3.0	3.3	3.5	4.1	4.7	5.2	5.7	6.2	6.7
	2.25	2.5	2.8	3.0	3.2	3.5	3.8	4.4	5.0	5.5	6.0	6.5	7.0
	2.50	2.8	3.1	3.3	3.5	3.8	4.1	4.7	5.3	5.7	6.3	6.8	7.2
MAJOR	2.75	3.1	3.3	3.6	3.8	4.1	4.4	5.0	5.5	6.0	6.5	7.1	7.5
	3.00	3.3	3.6	3.8	4.1	4.4	4.7	5.3	5.8	6.3	6.8	7.3	7.8
	3.25	3.6	3.8	4.1	4.3	4.6	4.9	5.6	6.1	6.6	7.1	7.6	8.0
	3.50	3.8	4.1	4.4	4.6	4.9	5.2	5.8	6.4	6.9	7.3	7.9	8.3
	3.75	4.1	4.4	4.6	4.9	5.2	5.5	6.1	6.7	7.1	7.6	8.1	8.6
	4.00	4.3	4.6	4.9	5.1	5.5	5.7	6.4	7.0	7.4	7.9	8.4	8.8
	4.25	4.6	4.9	5.2	5.4	5.7	6.0	6.6	7.2	7.7	8.1	8.6	9.1
	4.50	4.9	5.1	5.4	5.6	6.0	6.3	6.9	7.5	7.9	8.4	8.9	9.3
	4.75	5.1	5.4	5.7	5.9	6.2	6.5	7.1	7.7	8.2	8.6	9.1	9.6
	5.00	5.4	5.7	5.9	6.2	6.5	6.8	7.4	8.0	8.4	8.9	9.4	9.8
	5.25	5.7	5.9	6.2	6.4	6.7	7.0	7.7	8.2	8.7	9.1	9.6	10.1
	5.50	5.9	6.2	6.4	6.7	7.0	7.3	7.9	8.5	8.9	9.4	9.9	10.3

5.10.2 Categorical Forecast Worksheet

	Date/Time				
Location					**Remarks**
#1					
#2					
#3					
#4					
#5					
#6					
#7					
#8					
#9					
#10					
#11					
#12					
TOTAL RAINFALL					
AVERAGE BASIN RAINFALL					
GUIDANCE (NWS)					
DEGREE OF FLOOD					

Average basin rainfall = Total Rainfall/# observations

5.10.3 Storm Record for Categorical Forecasts

Date	Location/Creek	Guidance	Basin Average Rainfall	Degree of Flood

5.11 Site-Specific Forecasts

5.11.1 Flood Advisory Table

MAPLE CITY BRUSH CR

FLOOD STAGE 13.0 FT FLOOD OF RECORD 24.54 FT 08/13/80

DRAINAGE AREA 406 SQ MI GAGE DATUM 772.34 FT MSL

CREST ABOUT 10 HOURS AFTER HEAVY RAIN ENDS

STAGE FEET	DISCHARGE 1000 CFS	AVERAGE BASIN RAINFALL (INCHES) FOR TIME DURATION OF GUIDANCE USED												
2.0	0.1	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.7	0.9	1.1	1.3	1.6
3.0	0.2	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.7	1.0	1.2	1.5	1.8	2.2
4.0	0.4	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.3	1.5	1.8	2.3	2.8
5.0	0.7	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.1	1.5	1.8	2.1	2.7	3.2
6.0	0.9	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.3	1.7	2.1	2.5	3.0	3.5
7.0	1.1	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.5	1.9	2.3	2.8	3.3	3.9
8.0	1.3	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.6	2.1	2.6	3.0	3.6	4.1
9.0	1.6	0.5	0.6	0.8	0.9	1.1	1.3	1.4	1.8	2.2	2.7	3.2	3.8	4.3
10.0	1.9	0.5	0.7	0.9	1.1	1.3	1.4	1.6	2.0	2.4	2.9	3.4	4.0	4.5
11.0	2.1	0.6	0.8	1.0	1.2	1.4	1.6	1.7	2.1	2.6	3.1	3.6	4.2	4.7
12.0	2.4	0.7	0.9	1.1	1.3	1.5	1.7	1.8	2.3	2.8	3.3	3.8	4.3	4.8
FS13.0	2.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.0
14.0	3.0	0.9	1.2	1.3	1.5	1.7	1.9	2.2	2.7	3.2	3.7	4.2	4.7	5.2
15.0	3.4	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.8	3.3	3.9	4.4	4.9	5.4
16.0	3.8	1.1	1.3	1.5	1.7	1.9	2.2	2.4	3.0	3.5	4.0	4.5	5.0	5.6
17.0	4.2	1.2	1.5	1.6	1.8	2.1	2.3	2.5	3.1	3.6	4.1	4.7	5.2	5.7
18.0	4.9	1.4	1.7	1.9	2.1	2.3	2.5	2.8	3.3	3.9	4.4	4.9	5.4	6.0
19.0	5.7	1.6	1.9	2.1	2.3	2.5	2.8	3.0	3.6	4.2	4.7	5.2	5.7	6.2
20.0	6.6	1.9	2.1	2.3	2.6	2.8	3.1	3.3	3.9	4.5	5.0	5.5	6.0	6.5
21.0	7.5	2.2	2.4	2.6	2.9	3.1	3.4	3.6	4.2	4.8	5.3	5.8	6.3	6.9
22.0	8.6	2.4	2.7	2.9	3.2	3.4	3.7	4.0	4.6	5.1	5.6	6.2	6.7	7.2
23.0	9.7	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.9	5.5	6.0	6.5	7.0	7.5
24.0	11.6	3.3	3.6	3.8	4.1	4.4	4.6	4.9	5.6	6.1	6.6	7.1	7.6	8.1
25.0	13.9	4.0	4.3	4.5	4.8	5.1	5.4	5.6	6.3	6.9	7.3	7.8	8.3	8.8
26.0	15.6	4.5	4.8	5.0	5.3	5.6	5.9	6.1	6.8	7.4	7.8	8.3	8.8	9.3

3 HR UNITGRAPH PEAK ORDINATE = 3500.CFS FLOOD STAGE R.O. = 0.77

xxRFC 9/91

5.11.2 Advisory Table Forecast Worksheet

WORKSHEET FOR: Maple City, Brush Cr (SAMPLE)

	Date/Time					
Guidance (from NWS)						
River Stage						
Observed Rainfall:						
Gage 1						
Gage 2						
Gage 3						
Gage 4						
Gage 5						
Gage 6						
Gage 7						
Gage 8						
Gage 9						
Gage 10						
Gage 11						
Total Rainfall						
Average Basin Rainfall						
Flow/Discharge from Rainfall						
Flow/Discharge from Base Flow						
Incremental Changes Reservoir						
Total flow/Discharge						

FORECAST:

Crest Stage in Table						
Crest Stage Issued						
Time of Crest Stage						

5.11.3 Storm Record for Advisory Table Forecasts

STATION: Maple City, Brush Cr (SAMPLE)

DATE	GUIDANCE	BASIN AVERAGE RAINFALL	FORECAST CREST STAGE	ACTUAL CREST STAGE	REMARKS

5.12 Memorandum of Understanding

A completed sample of the Memorandum of Understanding follows and completes Chapter 5 of this Appendix (see also samples in Appendix A). This sample Memorandum of Understanding contains the core responsibilities of both the Cooperator and NWS. Additional responsibilities must be included as described in Weather Service Operations Manual Chapter E-40.

SAMPLE
MEMORANDUM OF UNDERSTANDING
FOR A
MANUAL LOCAL FLOOD WARNING SYSTEM

This Memorandum of Understanding (MOU) between the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) and Lake County (Cooperator) is undertaken for the development and operation of a manual Local Flood Warning System (LFWS).

1. Authority

The NWS undertakes this MOU pursuant to its authority in 15 U.S.C. Section 313 and 7 U.S.C. Section 450b in order to carry out its functions relating to flood warnings.

2. Nature of Agreement

The Cooperator and the NWS agree to a program for the installation and operation of a manual LFWS for Lake County (community, area, or basin).

3. Responsibilities of the Cooperator

A. Ensure development and operation of an emergency response plan prior to or concurrent with the execution of this MOU that includes:

- coordination with the NWS and
- dissemination of warnings to the public.

B. Arrange for volunteer network observers.

C. Install, operate, and maintain the manual LFWS including:

- emergency operations center and
- equipment used to support the Cooperator's program including staff gages and plastic rain gages.

D. Designate, by name or position, who shall act for the Cooperator as the local representative.

E. Review annually with the NWS this MOU and the response plan. Update as necessary.

F. Conduct an annual drill, in coordination with the NWS, to test the system.

G. Monitor the manual LFWS and immediately notify the NWS of any significant program problems.

H. Relay NWS flash flood/flood watches, warnings, and statements to the public.

I. Establish an emergency operations center for the purpose of:

- receiving and recording all reports of rainfall and flood conditions;
- promptly relaying or making available all such reports to the designated Cooperator's representative;
- serving as the official distribution point for all warnings and statements issued by or for the designated Cooperator's Flood Warning Coordinator. When emergency conditions and lack of time prevent warnings being issued by the NWS, the designated local official(s) shall be prepared to issue appropriate warnings;
- ensuring that, in addition to general public distribution, flood warnings or statements reach warning action points as listed in the Cooperator's response plan;
- relaying river and rainfall reports, flood data, and warnings to the WFO Lake City NWS office as soon as practicable after local requirements have been satisfied.

4. Responsibilities of the National Weather Service

A. Assist in selection of equipment appropriate to the manual LFWS.

B. Provide assistance in rain and river gage site location.

C. Develop a self-help forecasting procedure as data become available for specific drainage basins and provide a copy to the Cooperator officials along with instructions for its use.

D. Utilize data from the manual LFWS and provide hydrometeorological forecast and warning service for the area served by the manual LFWS.

E. Provide appropriate warning distribution over NOAA Weather Wire Service and/or other NOAA product dissemination systems.

F. Provide training for the Cooperator's flash flood coordinators and local authorities (including network observers). The scope of the training covers:

- the NWS flood/flash flood watch/warning program,
- local flood warning programs,
- the need for emergency response planning,
- how to establish and maintain observer networks, and
- periodic drills to test the system.

G. Conduct an annual drill, in coordination with the Cooperator, to test the system.

5. Amendments and Modifications

This MOU may be amended or modified by mutual agreement of the NWS and the Cooperator. Additional responsibilities by either party are listed on an Addendum attached hereto and made a part hereof.

6. Termination

This MOU may be terminated by either party upon sixty (60) days written notice to the other party, notice to begin with date of mailing.

7. Effective Date

This MOU becomes effective on the date of the last signature shown below upon execution by the parties hereto.

Cooperator	National Weather Service
BY: Jane Brown	BY: Joseph Smith
TITLE: Mayor, Lake County	TITLE: Regional Director
DATE: May 3, 1996	DATE: May 10, 1996