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

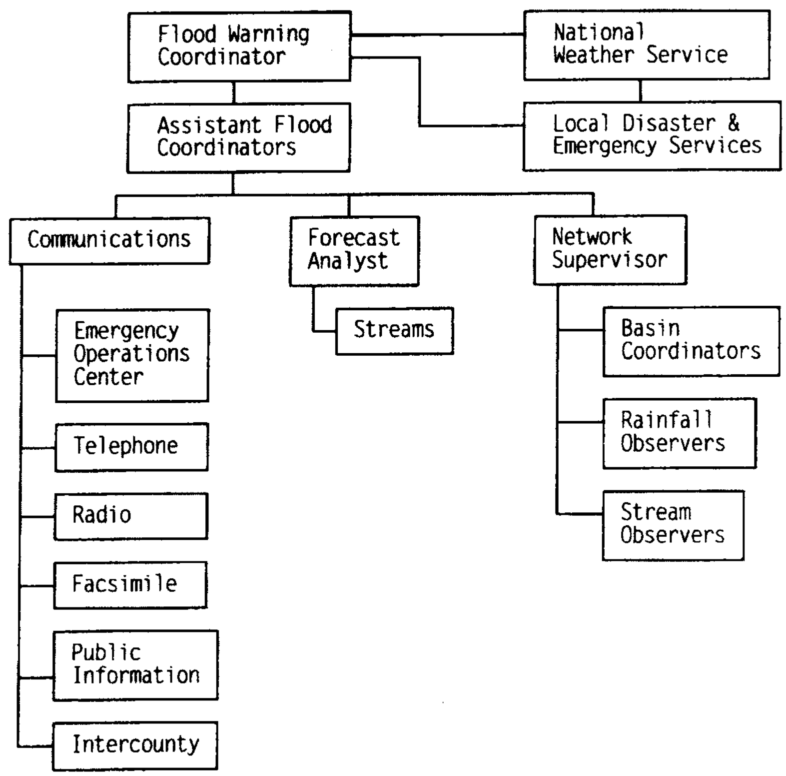

Figure 4-1. *Organization chart of a typical local flood warning unit.*

LOCAL FLASH FLOOD WARNING SYSTEM

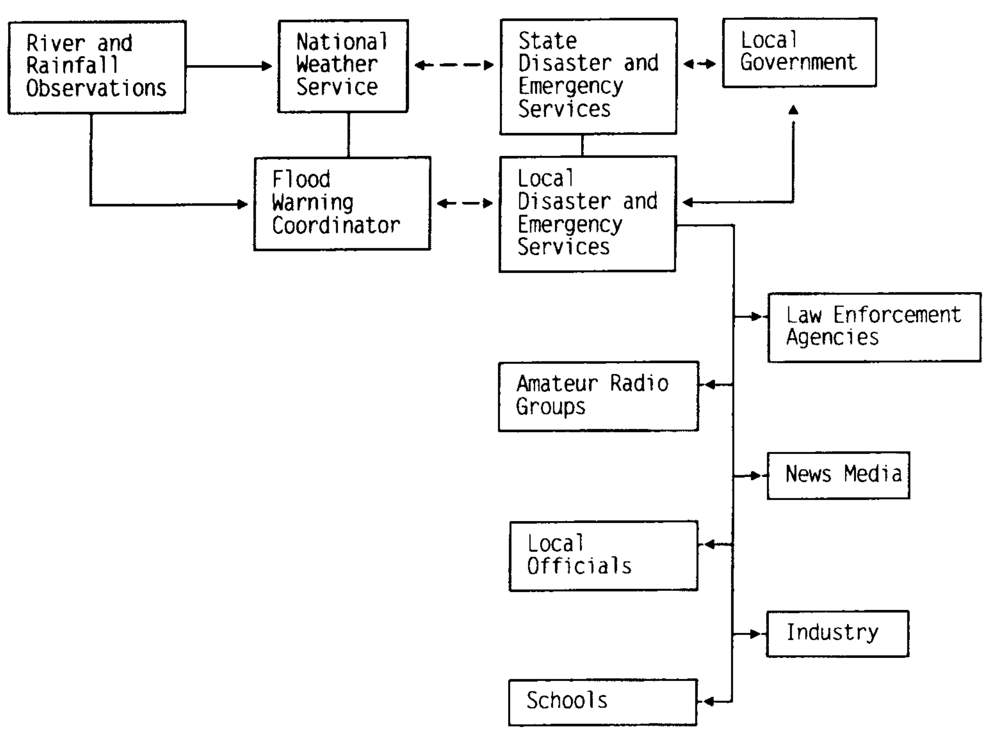

Figure 4-2. *Organization chart of a typical LFWS.*

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.

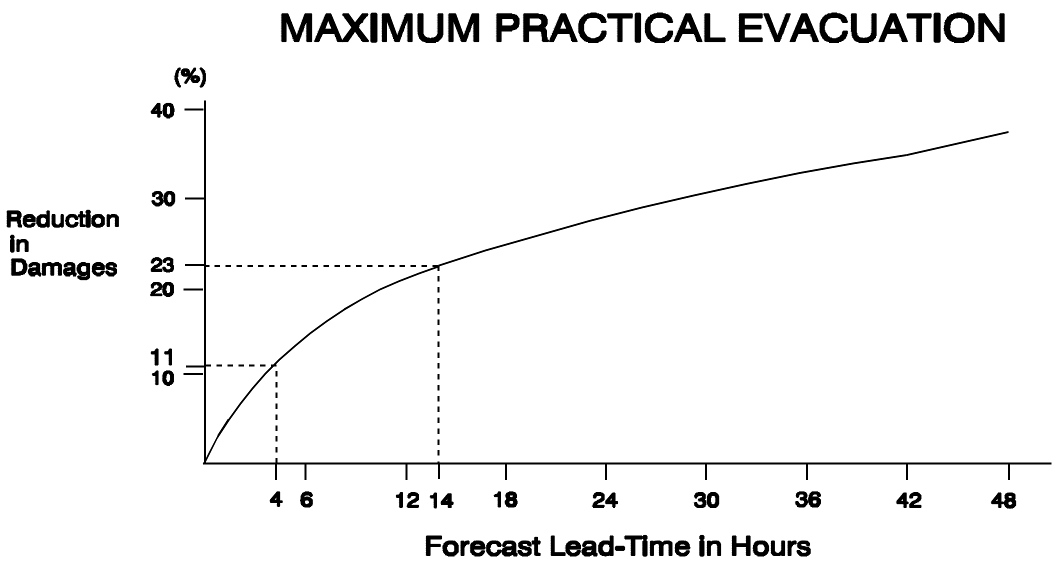

Figure 4-3. *Relationship of lead-time to damage loss.*

<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.