National Flash Flood Program Development Plan FY 1979-84

Washington, D.C.
September 15, 1978

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

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Statement of the Problem and Impact

Flash floods now rank as the major killers and destroyers among weather-related disasters in the United States. Since 1968, the average annual death toll from flash floods has risen to about 200--more than double the rate of the 1960s and more than triple the rate of the 1940s. Property damage is now running at about $1 billion a year. Every State has been affected. The Federal Disaster Assistance Administration reports that about 85% of all Presidential declarations of major disasters currently are associated with floods and flash floods.

The U.S Water Resources Council predicts that damage from floods and flash floods will reach $3.5 billion annually by the year 2000 unless flood plain management is improved.

Growing realization of the severity of the flash flood problem already has stimulated calls by State and local officials and members of Congress for a greatly improved Federal/State/local thrust to solve the Nation's flash flood problem. The death toll and property damage from flash floods can be significantly reduced if the following actions are taken (paraphrased: American Meteorological Society, 1978).

- Increase regulation of the use of areas subject to flash flooding and certify and monitor the safety of dams;
- Expand the implementation and improve upon Local Flash Flood Warning Systems (LFFWS);
- Plan and carry out an extensive and continuous public awareness program, emphasize individual response to warnings;
- Improve the ability to monitor and detect flash flood conditions, by increased use of automated ground measurements, radar, weather satellites, and improved communication systems;

- Increase the capability (lead time and accuracy) to forecast the location and magnitude of rainfall;
- Improve the capability to forecast intense, small-scale phenomena; and
- Strengthen ties among meteorologists, hydrologists, engineers, social scientists, and action agencies in communities.

PURPOSE

The purpose of this Program Development Plan is to provide the basis for a coordinated nationwide Flash Flood Program.

NOAA Goals for Overall Program

The broad goals of the NOAA Flash Flood Program are to enable NOAA to help the Nation:

- Substantially reduce the annual loss of life from flash floods.
- Reduce property damage by 10% to 15%.
- Reduce disruption of commerce and human activities.

GENERAL INTERFACES

Federal

Several Federal and State agencies will be involved in the national flash flood forecast and warning program. Their actions will involve research, communication, data acquisition, construction, flood plain management, preparedness planning, education and response to natural disasters, and recovery operations.

The charter of the soon-to-be-created Federal Emergency Management Agency (FEMA) will consolidate several of the above functions, and NOAA will focus on the hydometeorological aspects of the program. Early in FY 1979 a working interface between NOAA's present and planned activities, and the entire spectrum of FEMA activities will be defined. In addition, strong coordination will be developed with the Department of Agriculture, Soil Conservation Service; Department of Defense, Corps of Engineers; and other Federal agencies.

NOAA/ARC/State/Local

The Appalachian Regional Commission (ARC) was established by Congress in 1965 to help the Region meet its problems by building a better economy and a better quality of life for its inhabitants. The Appalachian region contains 195,000 mi^2 in 13 States.

A basic element in the ARC charter is local participation in the Commission's development program. The implementation of the flash flood program in the early years relies heavily on ARC and the established ARC-State relationships to develop the detailed plans for implementation, and arrangements for local and State cost sharing.

The NOAA-ARC interaction in Appalachia will establish the pattern for later NOAA-State agreements as the program expands nationwide.

PRESENT NOAA FLASH FLOOD PROGRAM STRENGTHS

The flash flood warning process is composed of five primary elements.

- Data acquisition (sensing and communication)
- Data analysis/forecast preparation
- Forecast/warning dissemination
- Preparedness planning
- Public response

Over the past several years NOAA personnel have, within limited resources, made substantial progress on improving each element. Much remains to be done. A list of some recent NOAA accomplishments and some ongoing programs are:

- Over 650 LFFWS are in place.
- NOAA Weather Radio will reach 90% of the U.S. population within 2 years.
- A vastly improved NWS communication system, Automation of Field Operations and Services (AFOS), is being implemented and will be completely in place by late 1981.
- Hydrometeorological model* development is progressing, and rapid improvement in forecast accuracy is possible.

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*"Hydrometeorological model" is a generic term referring to a system of hydrologic and meteorological models and their interfaces.

- Efforts to classify synoptically flash flood storms have increased, and new techniques are in final stages of development.
- Use of data from radar, satellite, automated river and rainfall sensors, and manual reporting surface networks is effective.
- R&D effort on remote sensing sensors has been increased.
- Working relationships with many Federal/State/local agencies have been established.

AREAS FOR NOAA IMPROVEMENT

Despite considerable improvement in recent years, much work remains to be done. Principal areas are:

- Expand LFFWS coverage nationwide to save lives.
- Increase forecast and warning lead time to save property.
- Work with other agencies to increase public awareness/response.
- Improve communication and display systems.
- Improve forecast technology.
- Improve the integrated forecast and warning program.
- Pursue operational technology transfer, especially in observing and mesoscale analysis and prediction.
- Risk assessment to set priorities for action.

PLAN FOR IMPROVEMENT

Scope

The coordinated Federal-State-local response to the threat of flash floods has three primary thrusts: (1) improved forecast and warning programs supported by focused research and development, (2) local community involvement in terms of risk assessment, developing strategies to deal with flash flood situations, and planning, and (3) long-term measures to control the damage and loss of life from floods such as building dams and levees or relocation of people and businesses. Throughout, there will be varying levels of Federal involvement and responsibilities on the parts of NOAA, ARC, FEMA, Corps of Engineers, and other Federal agencies. Additionally, State and local programs will be essential to complement and supplement the Federal effort.

BASIC CONCEPTS

The plan envisions a modular concept of implementing regionalized programs in high-risk areas. These modules are to be supported by centralized facilities for forecasting heavy precipitation, mesoscale analysis and monitoring of weather as it develops, and alerting field offices to the potential of flash floods. The overall plan will provide mechanisms for evaluating new techniques and sensing technology that can then be incorporated into operational programs.

Implementation of the plan relies heavily on developing a prototype module to cover high-risk areas in Appalachia. The goals in operating this prototype are to test and evaluate techniques intended for nationwide application; develop procedures for linking centralized, regional, and local hydrometeorological services; and establish roles for Federal, State, and local agencies. A 12-county area at the intersection of Kentucky, West Virginia, and Virginia was selected as a nucleus for early implementation beginning in FY 1979. This start in FY 1979 will lay the foundation both for implementing the four-State segment of the Appalachian module beginning in FY 1980 and for establishing operating interfaces among NOAA, ARC, FEMA, and local agencies.

PROGRAM OBJECTIVES (FY 1979-84)

To carry out the program and attain the goals, four objectives have been adopted. The objectives are:

(1) Develop a management and implementation plan.

(2) Develop the basis for nationwide implementation, at the local level, of regionally coordinated flash flood programs.

(3) Develop the capability to provide centralized forecasting, monitoring, and alerting functions in support of the flash flood program.

(4) Provide technical support for field operations.

MAJOR DECISIONS

There are six top management decisions to be made in the 1979-84 time frame (table E.1). The first, in 1979, is to extend the four-State nucleus program throughout the Appalachian Region. In 1980 must come the decision on the kind of centralized facilities needed to support the Appalachian module including the creation of the prototype Hydrometeorological Mesoscale Analysis Support (HMAS) unit. In FY 1981 the focus will be on equipment and technology needed to support the module. The decision to start the second module will be made in FY 1982 and will depend on the results of early evaluation of the Appalachian prototype. Before the extension of the modules nationwide, the decision on the operational configuration of the HMAS will have to be made in FY 1983. The decisions on implementing modules nationwide and their configuration will be made in FY 1984 and beyond. Each of these represents decision points for program expansion and lends itself to thorough program review before budget action is taken. Table E.2 shows the proposed NOAA budget for the national flash flood program.

Table E.1--Major milestones

	1979	1980	1981	1982	1983	1984	1985	1986
Full Appalachian Module	▲		●					
Prototype Hydrometeorological Mesoscale Analysis Support (HMAS) unit		▲		●				
Equipment decisions			▲		●			
Start second module				▲		●		
Operational HMAS					▲		●	
Modular extension nationwide						▲		●

Key: ▲ = Decision year to begin budget process.
● = First budget year.

Table E.2.--Proposed NOAA budget for the national flash flood program

	Fiscal Year (thousands of dollars)				
	1980	1981	1982	1983	1984*
Objective #1 Develop the Management and Implementation Plan					
• Program Implementation Plan • Management team • Implementation decisions • Program evaluation		NO NEW RESOURCES REQUESTED			
Objective #2 Develop the basis for nationwide implementation at the local level of regionally coordinated Flash Flood Programs	4/1800[1]	8/4000	12/3300	12/3300	12/3300
• Equipment	0/1150	0/2200	0/600		
• Contract/grants	0/200	1/800	1/1200		
• Operations/maintenance/communications	4/450	7/1000	11/1500		
Objective #3 Develop centralized facilities and support	8/1200	13/1400	16/2100	16/2100	16/2100
• NHPU	5/300	6/300	6/300		
• NESS support NHPU	3/100	3/100	3/100		
• Interactive Flash Flood Analyzer (IFFA)	0/750	0/150	0/150		
• Hydrometeorological Mesoscale Analysis Support (HMAS)		3/600	6/1200		
• Training	0/50[2]	1/250	1/350		
Objective #4 Provide technical support for field operations	0/200[1]	4/1300	6/1300	6/1300	6/1300
A. Enhancement of sensing communication systems					
• RADAP FUNDED FY 78 (2/1900)					
• NWS/NESS design-test-evaluate		2/100	2/100		
• VAS techniques		0/350	0/350		
• Enhanced AFOS communication and display		0/350	0/350		
B. Development of hydrometeorological models and techniques	0/200	2/500	4/500		
TOTAL PROGRAM FUNDING LEVEL	12/3200	25/6700	34/6700	34/6700	34/6700

[1]The FY 1980 budget submission shows these two items combined under "the Four-State" Flash Flood Program.
[2]The FY 1980 budget submission shows this item under the National Heavy Precipitation Unit.
*FY 1984 resources do not include nationwide implementation of modules.

1.0 INTRODUCTION

1.1 Statement of the Problem and Impact

Flash floods now rank as the major killers and destroyers among weather-related disasters in the United States. Since 1968, the average annual death toll from flash floods has risen to about 200--more than double the rate of the 1960s and more than triple the rate of the 1940s. Property damage is now running at about $1 billion a year. Every State has been affected. The Federal Disaster Assistance Administration reports that about 85% of all Presidential declarations of major diasters currently are associated with floods and flash floods.

The U.S Water Resources Council predicts that damage from floods and flash floods will reach $3.5 billion annually by the year 2000 unless flood plain management is improved.

The increase in deaths and destruction from flash floods results partly from the spread of urban development and partly from increased population mobility. In cities, removal of vegetation increases the flow rates of small streams. Bridges, culverts, and buildings are often constructed in a manner that impedes the flow of water. In the countryside, increased use of mountainous areas and narrow canyons for recreation is exposing growing numbers of unwary visitors to flash floods. The list of danger spots is growing. By latest count, more than 15,000 U.S. communities and recreational areas were identified by the Flood Insurance Administration as flash flood prone and are spread through all but a few of the Nation's 3,143 counties. Some 3,000 of these flood-prone areas are high risk in terms of potential deaths and property damage.

The following is a partial list of tragedies in the past decade which highlight the need for an improved National Flash Flood Forecast and Warning Program.

- August 1969, James River Basin, Va.--153 dead and millions of dollars in property damage as dying Hurricane Camille dumped more than 30 in of rain in less than 8 h.
- February 1972, Buffalo Creek, W. Va.--118 killed and hundreds of homes washed away as a dam made of coal mine waste gave way after heavy rains.

- June 1972, Rapid City, S. Dak.--236 dead and $100 million in property damage after a large, slow-moving thunderstorm unleashed torrents of rain on the slopes of the Black Hills.
- June 1972, northeastern United States--120 killed and more than $2 billion in property damage as the remnants of Hurricane Agnes produced widespread and destructive flooding and flash flooding in Virginia, West Virginia, Maryland, Pennsylvania, and New York.
- July 1976, Big Thompson Canyon, Colo.--139 drowned and millions in property damage after a thunderstorm deluged the western third of the canyon with 12 in of rain in less than 3 h.
- July 1977, Johnstown, Pa.--76 dead and more than $200 million in property damage when up to 12 in of rain fell on a seven-county area in 9 h during violent thunderstorms.
- September 1977, Kansas City, Mo.--25 killed and $90 million in property damage when thunderstorm rains turned "gentle" Brush Creek, which flows through the heart of the city, into a raging torrent.
- November 1977, Taccoa, Ga.--40 dead, half of them children, when heavy rains ruptured an earthen dam and demolished a mobile home community in the valley below.

Growing realization of the severity of the flash flood problem already has stimulated calls by State and local officials and members of Congress for a greatly improved Federal/State/local thrust to solve the Nation's flash flood problem. The death toll and property damage from flash floods can be significantly reduced if the following actions are taken (paraphrased: American Meteorological Society, 1978).

- Increase regulation of the use of areas subject to flash flooding and certify and monitor the safety of dams;
- Expand the implementation and improve upon Local Flash Flood Warning Systems (LFFWS);
- Plan and carry out an extensive and continuous public awareness program, emphasize individual response to warnings;

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- Increase the capability (lead time and accuracy) to forecast the location and magnitude of rainfall;
- Improve the capability to forecast intense, small-scale phenomena; and
- Strengthen ties among meteorologists, hydrologists, engineers, social scientists, and action agencies in communities.

1.2 Purpose

The purpose of this Program Development Plan is to provide the basis for a coordinated Nationwide Flash Flood Program.

1.3 NOAA Goals for Overall Program

The broad goals of the NOAA flash flood program are to enable NOAA to help the Nation:

- Substantially reduce the annual loss of life from flash floods.
- Reduce property damage by 10% to 15%.
- Reduce disruption of commerce and human activities.

1.4 General Interfaces

1.4.1 Federal

Several Federal and State agencies will be involved in the national flash flood forecast and warning program. Their actions will involve research, communication, data acquisition, construction, flood plain management, preparedness planning, education and response to natural disasters, and recovery operations.

The charter of the soon-to-be-created Federal Emergency Management Agency (FEMA) will consolidate several of the above functions, and NOAA will focus on the hydrometeorological aspects of the program. Early in FY 1979 a working interface between NOAA's present and planned activities, and the entire spectrum of FEMA activities will be defined. In addition, strong coordination will be developed with the Department of Agriculture, Soil Conservation Service, Department of Defense; Corps of Engineers; and other Federal agencies.

1.4.2 NOAA/ARC/State/Local

The Appalachian Regional Commission (ARC) was established by Congress in 1965 to assist the Region to meets its problems by building a better economy and a better quality of life for its inhabitants. The Appalachian region contains 195,000 mi^2 in 13 States (fig. 1).

ARC is composed of the Governors of the 13 States and a Federal cochairman who is appointed by the President. A State's cochairman is elected from among the Governors; the position is rotated among the States. The executive director of the Commission is appointed by and reports to the Governors and the Federal Cochairman; he heads a staff of about 125 persons.

A basic element in the ARC charter is local participation in the Commission's development program. To assist local planning and to ensure that ARC funds are used to serve local communities, the Commission, through its member States, works with multicounty planning and development agencies, known as local development districts (LDDs). Each LDD has a board, consisting of elected officials, public representatives of several counties, and a professional staff to plan and carry out programs.

The flash flood program in the early years will rely heavily on ARC and the established ARC-State relationships to develop detailed plans for implementation, and arrangements for local and State cost sharing.

The NOAA-ARC interaction in Appalachia will establish the pattern for later NOAA-State agreements as the program expands nationwide.

2.0 PRESENT PROGRAM

2.1 Present Program - NOAA

A comprehensive description (including an extensive reference list) of NOAA's present flash flood program can be found in Mogil, Monro, and Groper (1978). The following material has been abstracted from this paper.

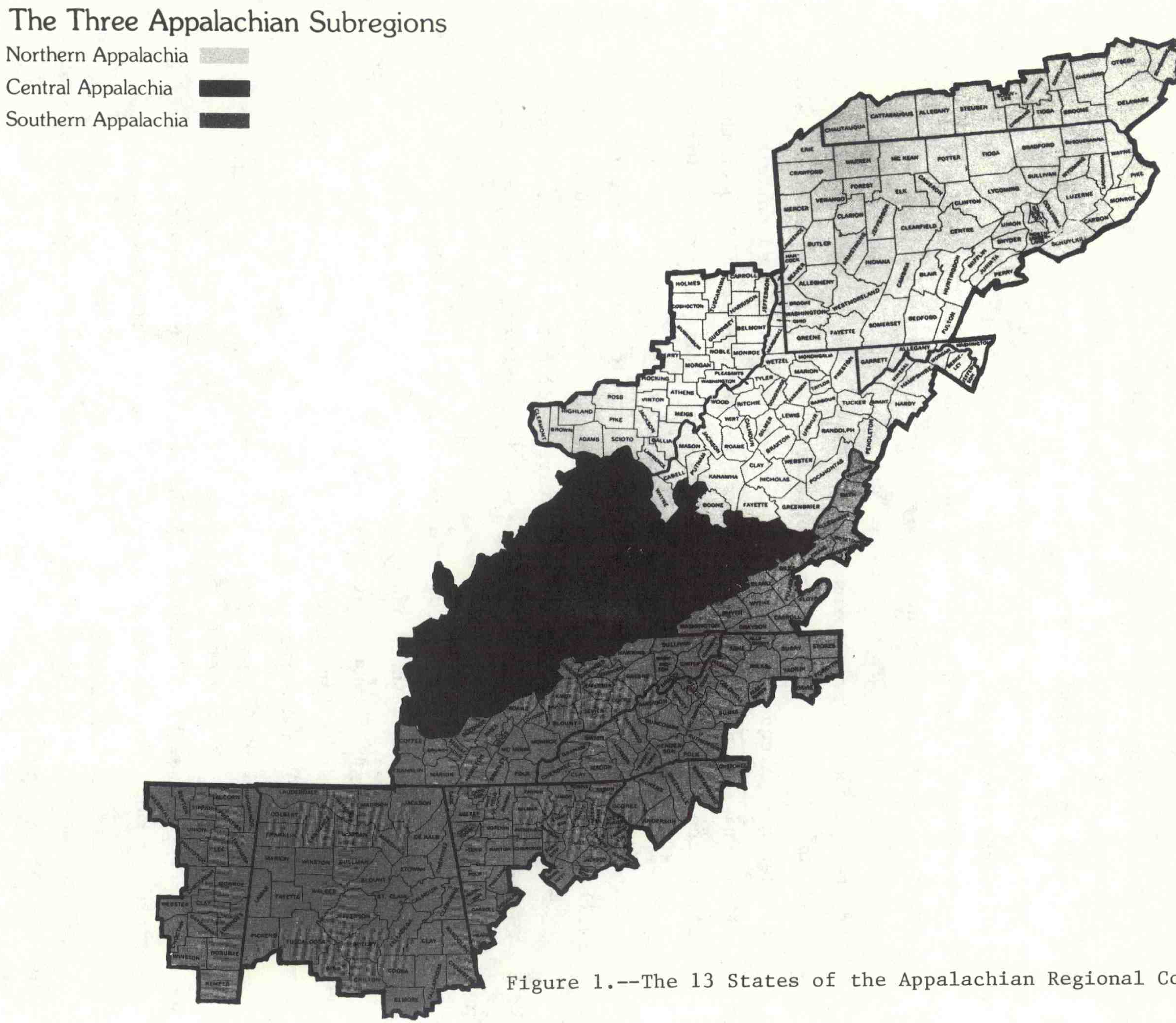

Figure 1.--The 13 States of the Appalachian Regional Commission.

• Flash flood watch/warning* program

The basic forecast program begins at the National Meteorological Center (NMC) in Camp Springs, Md. Here, computers process meteorological observations and produce maps of observed and forecast weather systems. The Quantitative Precipitation Branch (QPB) of NMC issues rainfall forecasts at scheduled times as well as in special situations. These indicate areas in which rainfall amounts are expected to equal or exceed specified forecast values. The NMC QPB has been recently restructuring its program to give additional support to the flash flood program. Fewer fixed-issuance time, fixed-forecast period products will be issued; instead, QPB will issue "outlooks" such as those issued by the National Severe Storms Forecast Center (Kansas City, Mo.) and will monitor weather situations more closely and coordinate with field offices more frequently. This information is transmitted on teletypewriter and facsimile for use by River Forecast Centers (RFCs) in their river flood prediction program and by Weather Service Forecast Offices (WSFOs) for use in operational forecast programs.

This guidance, based largely on synoptic scale analyses, and forecasts, will not specify localized excessive convective rainfall amounts. This is a highly specialized task and requires hydrometeorological mesoscale analysis. It has, however, been useful in specifying synoptic scale rainfall patterns and amounts.

Currently, the flash flood warning program consists of:

1) flash flood watches and warnings;
2) local flash flood warning systems;
3) stream stage forecasts;
4) flash flood alarm systems (FFAS); and
5) combination of the above.

RFCs prepare stream stage forecasts and hydrologic flash flood guidance for use by WSFOs. The flash flood guidance is based in part on drainage basic configuration and past rainfall. RFCs also examine

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*Watch means flash flooding is possible. Warning means flash flooding is imminent or in progress.

their areas for high-risk points and develop local flash flood forecast procedures and recommend applicable flash flood warning systems to local communities.

WSFOs are responsible for issuing flash flood watches. Flash flood watches are usually valid for periods of 12 h or less and may affect all or part of a WSFO forecast area. Coordination among WSFOs is necessary to ensure watch continuity across State borders.

To be most effective, watches should be issued prior to the onset of heavy rainfall. There are some general guidelines for predicting thunderstorm rainfall potential based on a diagnosis of synoptic scale data. There are also guidelines for predicting extratropical storm rainfall. These guidelines are inadequate for predicting the extreme rainfall that causes flash floods.

Local NWS offices issue warnings only when flash flooding is observed and reported or when flash flood producing rainfall is indicated by radar, automated rain gages, or by rainfall observers. Flash flood warnings are usually issued for periods of less than 4 h. They may be valid for a single drainage basin, although more commonly they are issued for several counties.

WSFOs and WSOs also issue statements about thunderstorm rainfall that may cause urban drainage flooding and/or small stream flooding. Radar can be especially useful because it gives an areal perspective and can be used to estimate quickly accumulated rainfall. For example, the following techniques can be used:

- Subjective radar scope evaluation
- Manually digitized radar (MDR)
- Radar digitizer and processor (RADAP).

All of the above requires the use of a Z-R (radar reflectivity-rainfall rate) relationship. However, because of the many assumptions used in deriving such a relationship, there has been considerable variation among researchers as to what the relationship should be. In some parts of the United States (for example, in the High Plains from eastern Colorado to the Dakotas) the presence of hail and/or the evaporation of precipitation as it falls through low-level drier air can make it difficult to rely on any present Z-R relationship to give accurate rainfall amounts.

Satellite data may also be used for estimating rainfall amounts. Both the National Environmental Satellite Service (NESS) and the National Hurricane and Experimental Meteorology Laboratory (NHEML) have developed techniques for estimating rainfall amounts from satellite imagery. Provisional procedures have been published by NESS for these estimates, based on a study of convective rainfall events over the central United States for one summer season; several NWS offices are now evaluating these procedures.

- Local flash flood warning system

The NWS watch/warning program is as accurate as the available data and the meteorological/hydrologic state-of-the-art permit. However, a locally operated community warning system (LFFWS) is a most effective means of preventing loss of life and reducing property damage from flash flooding. This system has high community involvement; it can activate itself when required by localized weather conditions that NWS/NESS may not be aware of, and is responsive to NWS watches and warnings. Recent surveys following major flash flood disasters have clearly shown that where there is good cooperation among Federal, State, and local agencies, LFFWSs work to save lives and reduce property damage. There are over 650 LFFWSs now in place nationwide.

The design of such systems depends upon site specific problems (e.g., geography, population in the flood plain, flood control structures, and warning time) and resources available for program implementation and maintenance. The systems can range from the simple to the sophisticated. Some equipment and communication options of the local flash flood warning system are given below:

1) Equipment:

plastic rain gage
staff river gage
recording river gage
tipping bucket rain gage
automated river alarms and stage reporting stations
automated rainfall reporting stations

2) Communication System - from cooperative observer to local flash flood coordinator:

telephone

ham radio

CB radio

police, fire, and other emergency radio

3) Communication System - from automated equipment to local flash flood coordinator

telephone

hardwire

line of sight radio (VHF)

satellite relay radio (UHF)

The essential elements of such a local program are:

1) volunteer rainfall and stream gage observers;
2) a reliable and rapid local communication system with emergency backup;
3) a local flash flood warning coordinator and alternate;
4) forecast procedures developed by NWS hydrologists;
5) a warning dissemination plan; and
6) an adequate preparedness plan (including public education).

Often, inexpensive rainfall gages and staff gages for river data will be sufficient. However, automated precipitation gages and stream level sensors are essential to give additional warning time to communities and complement networks of cooperative observers. Event-reporting instrumentation is useful, too.

NWS assists communities in establishing their flash flood warning program. NWS will survey the area, recommend appropriate equipment and network design, and provide some of the necessary equipment. NWS has also purchased and installed 66 Flash Flood Alarm Systems (FFASs) as part of a demonstration program. During the major flooding and flash flooding that occurred in eastern Kentucky, western Virginia, and West Virgnia between 2 and 5 April 1977, four FFASs provided invaluable notification of critical river levels to officials in the communities.

FFAS is only one of several devices now available for automated river level sensing. Automated precipitation sensors have also been developed. This type of equipment is a valuable complement to existing volunteer observer networks, especially in remote watershed areas where coop observers are very scarce. Cost of such automated equipment ranges from about $200 to over $3,000 per site, depending on sophistication and installation difficulty.

A critical element in local programs is the stream level forecast procedure. Using an index of antecedent soil moisture conditions and rainfall amounts, NWS hydrologists prepare simplified procedures for predicting stream levels. Hydrologic staffs at RFCs routinely furnish the index to communities that have local flash flood warning programs. The forecast procedure usually includes a set of tables and/or graphs. These are used by the community's flash flood warning coordinator to predict potential flooding levels.

The success of the local warning program depends on a rapid and reliable local communications sytem. A redundant configuration is recommended, because the typical overhead telephone lines are often destroyed early in the storm.

- Dissemination

NOAA relies upon many systems to disseminate watches, warnings, and statements. These include commercial radio and television, cable television, NOAA Weather Wire Service (teletypewriter), NOAA Weather Radio, hotline telephones, and the national press wire services.

The NOAA Weather Radio is an extremely important vehicle for disseminating critical weather information. This is an NWS-operated VHF-FM system with three special frequencies (162,400, 162.475, and 162.550MH_z), having an effective range of 65km. In March 1978 there were approximately 170 stations in operation; by 1980 NWS expects to have more than 330 stations in operation that will be within listening range of 90% of the U.S population.

The NOAA Weather Wire Service is a teletypewriter system devoted exclusively to weather information. Commercial radio and television, police, some local civil defense offices, and others subscribe to this service.

Commercial radio and television and cable television represent other important vehicles for warning dissemination. They receive NWS watches and warnings from the NOAA Weather Wire Service, NOAA Weather Radio, and national press wire services, or by telephone and are urged to rebroadcast the information immediately. About 2 years ago, the NWS, the Federal Communications Commission, the Defense Civil Preparedness Agency (DCPA), and the National Industrial Advisory Committee (which represents the broadcast industry) began a joint effort to develop State and local disaster warning dissemination procedures for the Emergency Broadcast System (EBS). Once operational area plans are implemented, NWS offices will be able to relay short-fuse warnings rapidly to many broadcast stations by simply calling one station.

NWS also uses several civil defense and law enforcement communications systems in its warning program. The most important of these is the National Warning System (NAWAS), a multipoint inter- and intrastate telephone hotline system funded by DCPA. This system connects State and area warning points, local municipalities, and many NWS offices. There are also a few statewide microwave emergency communications systems in operation (e.g., KEWS-Kentucky Emergency Warnings System). In addition, amateur radio and CB groups can be used to disseminate warning information as well as gather storm reports.

An improved NOAA communications system called AFOS (Automation of Field Operations and Services) is scheduled for nationwide implementation beginning this year. This system will provide NOAA Offices with high-speed data handling and display capabilities by means of on-site minicomputers linked together in a nationwide network. Weather information will be displayed on TV-like screens instead of on paper, and warning messages will be received by adjacent weather offices in seconds rather than in minutes. The AFOS system will have forecast applications as well.

2.2 Present NOAA Program Strengths

The flash flood warning process is composed of five primary elements:

- Data acquisition (sensing and communication)
- Data analysis/forecast preparation
- Forecast/warning dissemination
- Preparedness planning
- Public response.

Over the past several years NOAA personnel have, within limited resources, made substantial progress on improving each element. Much remains to be done. A list of some recent NOAA accomplishments and some ongoing programs are:

- Over 650 LFFWSs are in place.
- NOAA Weather Radio will reach 90% of the U.S. population within 2 years.
- A vastly improved NWS communication system, Automation of Field Operations and Services (AFOS), is being implemented and will be completely in place by late 1981.
- Hydrometeorological model* development is progressing, and rapid improvement in forecast accuracy is possible.
- Efforts to classify synoptically flash flood storms have increased, and new techniques are in final stages of development.
- Use of data from radar, satellite, automated river and rainfall sensors, and manual reporting surface networks is expanding.
- R&D effort on remote sensing has been increased.
- Working relationships with many Federal/State/local agencies have been established.

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2.3 Areas for NOAA Improvement

Despite considerable improvement in recent years, much work remains to be done. Principal areas are:

- Expand LFFWS coverage nationwide to save lives.
- Increase forecast/warning lead time to save property.
- Work with other agencies to increase public awareness/response.
- Improve communication and display systems.
- Improve forecast technology.
- Improve the integrated forecast and warning program.
- Pursue operational technology transfer, especially in observing and in mesoscale analysis and prediction.
- Risk assessment to set priorities for action.

3.0 PLAN FOR IMPROVEMENT

3.1 Scope

The coordinated Federal-State-local response to the threat of flash floods has three primary thrusts: (1) improved forecast and warning programs supported by focused research and development; (2) local community involvement in terms of risk assessment, developing strategies to deal with flash flood situations, and planning; and (3) long-term measures to control the damage and loss of life such as by building dams and levees or relocation of people and jobs. Throughout, there will be varying levels of Federal involvement and responsibilities on the parts of NOAA, ARC, FEMA, Corps of Engineers, and other Federal agencies. Additionally, State and local programs will be essential to complement and supplement the Federal effort.

The NOAA Program Development Plan deals with the hydrometeorological portion of the flash flood threat. It envisions strong Federal-State-local community involvement both to deal with and plan for flash floods together with a directed effort to apply new technology and forecast techniques.

3.2 Basic Concepts

The plan is based on a modular concept of implementing regionalized programs in high-risk areas. These modules are to be supported by centralized facilities for forecasting heavy precipitation, mesoscale analysis and monitoring of weather as it develops, and alerting field offices to the potential of flash floods. The overall plan provides mechanisms for evaluating new forecast techniques and remote sensing technology that can then be incorporated into operational programs.

Implementation of the plan begins by developing a prototype module to cover high-risk areas in Appalachia. Goals in operating this module are to test and evaluate techniques intended for possible nationwide application; to develop procedures for linking centralized, regional, and local hydrometeorological services; and to establish roles for Federal, State, and local agencies. A 12-county area at the intersection of Kentucky, West Virginia, and Virginia was selected as a nucleus site for early implementation beginning in FY 1979. This start will lay the foundation both for implementation of the four-State segment of the Appalachian module beginning in FY 1980 and for establishment of operating interfaces among NOAA, ARC, FEMA, and local agencies.

Major management decisions are anticipated in FY 1979 to extend the four-State nucleus program throughout the Appalachian Region, in FY 1980 on the nature of the prototype Hydrometeorological Mesoscale Analysis Support (HMAS) required, in FY 1982 on the start of a second module, in FY 1983 on the nature of the operational HMAS unit, and in FY 1984 on the nationwide implementation of the modular concept.

3.3 Technological Considerations

The Program Development Plan (PDP) provides the general guidelines for developing both the national program to be in place by 1984 and the regional modules; one module (Appalachia) will be in place and fully operational by 1983. The remaining (8-10) modules will be implemented beginning in 1984. Each module to be implemented represents a decision point for program expansion and lends itself to thorough program review before budget decisions are made.

Many considerations entered into developing the concept of a national plan with regional modules. Technological considerations were: (1) the flash flood threat, and hence the response, is different for the widely differing time and space scales encountered on a national basis; (2) large area techniques for observing and prediction need to be devised to meet local needs; and (3) a significant effort is needed to provide technical support to field offices, especially in mesoscale analysis and prediction, which is heavily influenced by the effects of regional and local terrain.

3.3.1 Scale Considerations in Structuring the Program

A critical need is to match the action unit and its capabilities with the time and space scale of the flash flood threat. A tropical storm moving inland is vastly different than severe convective storms embedded in a fast moving squall line. The former develops slowly and affects wide areas, and heavy rain may last for a day or more. The convective activity, on the other hand, may develop, create the localized flash flood, and dissipate in an hour or two. The area of concern and reaction time differ widely for these two situations and dictates the equipment, data, and skills needed at the action unit to do the job.

The scale of the hydrometeorological problem for flash floods is presented in table 3.3.1. Note that each action unit is responsible for a different type of notification and scale. Alerts allow the system to avoid the "cry wolf" problem by restricting the audience to specialists who can understand the confidence to be placed in different information on hazard potential. The area of concern for alerts is generally large, and their primary purpose is to direct the attention of NWS and NESS offices as early as possible to areas of potential flash floods.

On the opposite end, the current status is monitored closely, using mostly observations as a basis for short-fuse warnings by NWS field offices and local community officials. This information must be communicated directly from the observer to the user with minimal time delay, potential for confusion, or communications breakdown by man or machine. This is where LFFWSs play a most important life saving role.

Table 3.3.1--Scales apropriate to the hydrometeorological service problem for flash floods

Name	Averaging times, sizes	Peak intensity sizes	Duration* of concern	Key action units	Notification responsibility
large, L	6 h, $(160\ km)^2$	$(40\ km)^2$	$\pm$ 24 h	NMC, NHPU	alert (internal)
medium, M	3 h, $(80\ km)^2$	$(20\ km)^2$	$\pm$ 12 h	WSFO, HMAS RFC, SFSS	watch (forecast)
small, S	1 h, $(40\ km)^2$	$(5\ km)^2$	$\pm$ 3 h	WSFO, HMAS, or WSO, WSMO, and community (LFFWS)	warning
cumulus, C	15 min, $(10\ km)^2$	$(1\ km)^2$	$\pm$ 1 h	WSMO, LFFWS	emergency information

*Periods are before and after the onset of heavy precipitation.

3.3.2 Centralized Techniques and Support

Flash flood warnings are directed primarily toward saving lives. The extent to which property can be saved and unnecessary precautions avoided is tied to the lead time, accuracy, and reliability of forecasts. Since flood damage is reaching $1.5 billion annually, much can be gained from systematic improvements in centralized forecasting skills for large areas based on better observations, analysis, and knowledge of flash flood impacts. Improvements in each of these areas are underway, and have had an impact on the PDP.

Mesoscale analysis is the foundation of forecasting flash flood situations. These analyses must include satellite and radar imagery in time lapse as well as large-scale analyses of images, surface observations, and rawinsonde and improved satellite sounder data. Interactive graphics, large computer memories, and powerful computer processing units are expensive, and data volumes are too large for complete mesoscale analysis to be done at each field office. A Hydrometeorological Mesoscale Analysis Support (HMAS) unit will be used to distill and format the data so they can be transmitted to local stations equipped with AFOS and a modest amount of image sequencing equipment.

Cumulus convection has been examined extensively in recent years by researchers using computer models. Promising techniques need to be tested in flash flood events and in similar situations that did not result in heavy rains so that reliable models can be found or developed for operational use. These models will place heavy demands on computing resources and skill must be demonstrated before operational implementation.

The TIROS Operational Vertical Sounder (TOVS) will be avilable with the launch of TIROS-N and NOAA-A late in 1978. These data must be examined for possible application in the flash flood program, for example, in defining the moisture fields for initialization of the NWP computer models. AFOS and high-resolution image sequencing equipment will provide field offices with much more powerful tools and more effective data bases. In conjunction with the analysis support unit and increased surface observations from cooperative observers, these efforts will provide the basis for substantially improved mesoscale analysis and prediction of flash flood producing storms.

3.3.3 Technical Support to Field Operations

New technology, automation, and new forecast techniques are necessary to provide a reliable, cost-effective system. To this end, systemwide automation, improved satellite systems, surface-based remote sensors, better use of FAA radars, and improved numerical forecast techniques are all ready or will be ready for implementation in the next 5 years. Some mechanism is needed to evaluate these new concepts in operational situations and to develop recommendations on the "best mix" for the flash flood program. Once started, this will be a continuing effort.

Support will come from studies and directed research activities in the operational elements of NOAA. Examples are: evaluating the usefulness of revised alerting procedures by the QPB; efforts in NESS to integrate, in real time, radar data and satellite imagery; and improved flash flood guidance material from RFCs and NMC. Additional support will be necessary through the transfer of technology from development and research programs such as PROFS and SESAME, and mesoscale work in ERL's Atmospheric Physics and Chemistry Laboratory (APCL).

The Prototype Regional Observing and Forecasting Service (PROFS) and the Severe Environmental Storms and Mesoscale Experiment (SESAME) are two mesoscale programs that will include research efforts in parallel to this flood program. These programs will be coordinated, and some people, facilities, and techniques will be common to more than one program.

3.4 NOAA Objectives for the Flash Flood Program

To carry out the program and attain the goals, four objectives have been adopted. The objectives encompass an implementation plan, the modular concept, centralized support facilities, and technical support to field operations. These are further defined by subobjectives for each fiscal year.

OBJECTIVE 1--Develop the Management and Implementation Plan.

Discussion. The NOAA management philosophy is to (1) provide overall policy and guidance at the NOAA main line component (MLC) level with input from the main program elements (MPEs), principally NWS and NESS, and (2) implementation at the MPE level. A team at the MPE level with direct participation by ARC will coordinate program implementation, act as a working level interface with other agencies and, within the policy guidance agreed to by the MLC-MPE-ARC directors, devise strategies for attaining the objectives of the NOAA-ARC flash flood program.

The appropriate interactions with FEMA will be included as that Agency's role evolves.

Designated NOAA Manager. The NOAA manager of the flash flood program is the Deputy Assistant Administrator for Oceanic and Atmospheric (OA) Services. This person relies on a flash flood program coordinator who is on his staff in the Environmental Services Division. Additional technical support is provided as needed by focal points on the OA staff. The principal management tool is a quarterly review at which policy, priorities, and overall resource levels are established, and program performance examined in detail.

NOAA-Level Program Coordinator. Two main functions are performed by this person. First, he is responsible for NOAA-level liaison between NOAA-ARC-FEMA and similar agencies. He is also responsible for coordinating the NOAA budget for flash floods and for providing the NOAA Manager with technical input as needed. Second, he participates actively with the implementation team and serves as the chairman.

Quarterly Review. The purposes of these reviews by the NOAA Program Manager are to assess program performance; review and act on recommendations from the MPEs and ARC; and set policy, objectives, and allocation of resources. The participants in these reviews are NOAA, NWS, NESS, ERL, EDIS, and ARC. Other agencies will be added if necessary to ensure full review and coordination.

MPE Roles. The principal NOAA MPEs involved are NWS and NESS. Through the mechanism of the quarterly reviews, the MPE Directors will participate in establishing broad policy, determining priorities, and allocating reources. Individually, they are responsible for implementation and operation of the NOAA flash flood program. This latter work is coordinated through a joint implementation team.

Flash Flood Implementation and Strategy Team (FIST). FIST is a staff group comprising principals from NWS, NESS, and ARC and is chaired by the NOAA Program Coordinator. Other elements actively supporting implementation are involved as appropriate.

The responsibilities of the team are to:

(1) Devise a coordinated implementation plan for the flash flood program, given the goals, objectives, and policy guidelines established at the quarterly review.

(2) Coordinate the interaction of the various groups responsible for implementation.

(3) Act as the technical and working-level interface for coordinating the work of NOAA with that of other agencies.

(4) Act as a technical focal point in NOAA to consider priorities, focus issues, and work out acceptable milestones.

(5) Assess progress and prepare recommendations for the Directors of the MPEs and ARC on actions necessary to ensure that program objectives are met.

Major Decisions. Four crucial top management decisions are to be made in the 1979-81 time frame. The first, in 1979, is to extend the four-State nucleus program throughout the Appalachian Region. The second, in 1980, is a decision to create a prototype HMAS Unit to serve the Appalachian Module. The third, in 1982, is to start a second module. The fourth, in FY 1984, is the commitment to extend the modular concept nationwide.

Strategy. To realize fully an effective national, coordinated, flash flood program, NOAA management will develop complementary programs with various other Federal and State agencies.

The guiding management principle for Program development and implementation is to conduct thorough system analyses and evaluations of alternatives, mixes of people, facilities, communication/display systems, sensing systems, and new technologies so NOAA can meet its goals at least cost. To carry out this strategy, four management subobjectives have been adopted.

Subobjective 1.1 (FY 1979). Develop a National Flash Flood Program Implementation Plan and initiate a cooperative effort with ARC and FEMA in a 12-county nucleus area.

Close interaction among NOAA, ARC, and FEMA is essential; however, owing to the newness of FEMA, time will be required to establish the operational interfaces among FEMA and the other two agencies. For FY 1979, NOAA and ARC agreed on a technical program to provide observing and communications equipment for critical areas, to evolve strategies with the States for implementing improved warning programs, and to begin developing improved forecast techniques. These early actions will be coordinated with those of FEMA, which will be responsible for preparedness planning and education to develop an effective community response to flash floods.

Agency Responsibilities

NOAA

NOAA is responsible principally for (1) improving the preparation of forecasts and warnings of flash floods and (2) initiating the development of supporting techniques and equipment. This includes procuring, siting, and installing observing and communications equipment to augment the existing system.

ARC

The principal interaction with States, in terms of their technical involvement, is through ARC. The Central Appalachian Development Project (CADP), with headquarters in Pikesville, Ky., is the ARC direct contact with State and local people in the nucleus area. Agreements with States and communities to participate in both the early stages and the FY 1980 program are being arranged through ARC and CADP. These agreements include appropriate cost sharing arrangements.

FEMA

FEMA will have the major role in an "all-hazards" preparedness program, including public education and preparedness planning with State and local agencies. The specific interactions with FEMA will be defined during FY 1979, as FEMA comes into being.

Subobjective 1.2 (FY 1980). Develop comprehensive coordination concepts at Federal/State/local level.

The nucleus effort begun in FY 1979 will be incorporated into the FY 1980 program. This will establish the basis for coordinated work between the Federal and State agencies, and will provide the assessments necessary to establish specific work priorities in FY 1980.

With ARC and FEMA, the role of the States and local agencies will be defined. The flash flood forecasts and warnings will be integrated with community-developed programs for disaster preparedness and disaster training. Specific actions will be undertaken to provide for both cost sharing with the States and the meshing of locally operated flash flood warning systems. In addition, strong coordination will be developed with the Department of Agriculture Soil Conservation Service; Department of Defense, Corps of Engineers; and other Federal groups.

FIST together with Headquarters and Regional staff will evaluate the FY 1979 nucleus effort and establish a specific work plan for the four-State thrust to begin in FY 1980. Details are found under objectives 2, 3, and 4.

Subobjective 1.3 (FY 1980-83). Evaluate the centralized facilities and support capability and the prototype Appalachian module in terms of agency roles (operations) and cost sharing.

In the FY 1980-83 time frame, several commitments will affect NOAA and NOAA/Federal/State operations. These are: extend the four-State nucleus program throughout the Appalachian Region, NOAA's role in a national radar program, and the creation of a prototype Hydrometeorological Mesoscale Analyses Support (HMAS) Unit.

- The implementation of the flash flood program in the early years relies heavily on ARC/FEMA and the established ARC-State relationships to develop the detailed plans for implementation and arrangements for local and State cost sharing. The NOAA-ARC-FEMA interaction in Appalachia will establish the pattern for later NOAA-FEMA/State agreements as the program expands nationwide.

• FAA is planning a comprehensive program (contract award Sept. 1978) to obtain and assimilate meteorological data from all of their air traffic control radars, and to combine these data with those from NWS network and local use radars. Previously, the FAAS radar displays suppressed weather. The potential is present for national weather radar coverage to complement satellite imagery so that a nationwide flash flood monitoring program can be developed. NOAA and the FAA are coordinating their respective radar programs, and the flash flood program will incorporate the results of the combined effort.

• In 1980, the decision to fund a prototype HMAS Unit in support of the Appalachian Module will be made. At this time the key elements will be the NMC/NHPU and NESS/SFSS contributions to the Appalachian flood program, NWS River Forecast Centers (RFCs), the WSFO/WSO network, and the LFFWSs.

At present there appear to be two primary options for providing the services of a HMAS nationwide: (1) the unit could be appended to the NHPU and take on national responsibility and (2) HMAS could be located at a WSFO or key RFC.

It is premature to select between the two options listed above or specify the number of units required nationwide without more complete analysis of data collection and processing and then communication and usage at the local level. Much will be learned during AFOS and NHPU implementation and from the NESS effort to map radar data on the satellite grid and transmit both to some WSFOs for time-lapse display. By the 1982-83 period, enough will be known to decide upon tactics for implementing the national program.

Subobjective 1.4 (FY 1983-84). Develop guidelines for the national thrust.

The purpose of the national thrust is to provide greatly improved monitoring and forecasts of conditions leading to flash floods, as well as more accurate and timely alerts of flash flood events. This goal includes the development and continuing implementation of modular flash flood programs in high-risk areas. Guidelines for these modular programs will include procedures for assessing the risk and determining the level and kinds of equipment needed, the kinds of interactions necessary with other Federal and State agencies, the benefits possible, and the centralized forecast support required.

Specific guidelines will be developed to support, in 1984 and beyond, implementation of the national flash flood program. These guidelines address:

- Implementation of additional modules. The selection will be based on a risk assessment, results of the Appalachian program, and the degree the States are willing to enter into cost sharing.
- Implementation of HMAS/appropriate nationwide interfaces with AFOS and development of specialized regional/national forecast procedures for each module.
- Optimal satellite support including image display and analysis equipment.
- Operational technology transfer and model development. Remote sensing and automated gages and alarms will be evaluated in terms of cost and effectiveness. Advanced satellite procedures and hydrologic/meteorological forecast models will be evaluated in terms of spatial and temporal accuracy.

OBJECTIVE 2--Develop the basis for nationwide implementation of regionally coordinated flash flood programs at the local level.

Discussion. Flash floods are local phenomena. The nature of the threat varies substantially over the 3,000 highest risk areas of the country and largely depends upon localized variations in terrain, weather, population density, and life styles. The response to the flash flood threat has an important local component both in terms of self-actuated warning systems and NOAA's watch and warning efforts.

While the flash flood threat has many variables, common factors can be identified based on large-scale patterns in geography and weather regimes. These common factors make it possible to define geographical regions where the individual local flash flood programs will be similar in character and where the hydrometeorological problems can be dealt with by a common approach.

Ten areas are defined by the following broad geographical descriptions:

1. Appalachia
2. Eastern Piedmont
3. Ohio and Northern Mississippi River Valleys
4. Central plains
5. Badlands
6. Southwest
7. Eastern Rockies
8. Intermountain west
9. Southern West Coast
10. Northwest Pacific Coast

Across the country, guidelines will be the same for developing the individual programs in each of these areas. Specific components, such as automation, remote sensing, and data processing, largely will be the same in each module and will vary primarily in number and location. Reasonably consistent flash flood "modules" can be defined and cost estimates established for implementation of individual programs, region by region, across the country.

The need for a modular concept is well established by the local nature of flash floods and the demography of the country. The specific mechanisms for implementing modules are not well defined, and important questions remain. Primary among these are:

1. What is the best mix of facilities and people for each module and what should be the basic structure of a given module?

2. What are the appropriate roles for State and local agencies vis-a-vis Federal agencies and what should be the nature of cost sharing?

3. How should the modules be implemented to obtain a cost-effective national program?

4. How should national, regional, and local hydrometeorological services be linked to best support the modules?

5. What is the priority for new modules?

Before implementation of modules can proceed, these questions need answers, and a basis is required for answering them and for planning that implementation.

Strategy. The strategy to provide the basis for implementing the modular concept is to (1) establish a prototype module in Appalachia, (2) evaluate the operation, and (3) develop an overall system design based on the experiences with the prototype. Much will be learned about effectively linking the national, regional, and local hydrometeorological information and services, implementing new technology within an operating system, and stimulating the interaction of Federal, State and local programs. To carry out this strategy, four subobjectives have been adopted.

Subobjective 2.1 (FY 1979). Establish a nucleus project in 12 counties of central Appalachia to begin the process of improving the local warming program.

The flash flood warning program will be developed and implemented through a coordinated effort among many NOAA elements, field offices (table 3.4), and several Federal, State, and local groups. The warning program will involve two complementary warning systems: the Local Flash Flood Warning System (LFFWS) and the NOAA-operated flash flood watch/warning system. Within many NOAA elements, considerable work is underway or planned for FY 1979 that will contribute toward solution of some aspects of the flash flood problem in Appalachia. Additionally, the Appalachian Regional Commission has established a Flood Plain Development Project in central Appalachia with important work beginning in FY 1979. The NOAA and ARC efforts have been coordinated to provide a base of available resources to begin the work.

For FY 1979, the work has two purposes: (1) establishing a base for FY 1980 and (2) implementing a modest increase in the data acquisition program to support current flash flood warning programs. Specifically:

1. A coordinated program will be started in NOAA and ARC for the flash flood warning program with emphasis on the nucleus area comprising 12 adjacent counties in Kentucky, West Virginia, and Virginia.

2. An in-depth assessment of the flash flood risk in the nucleus area will be started as a guide for the implementation of the FY 1980 program.

3. Development of agreements will be pursued with the States for technical support, as will definition of NOAA-ARC-State roles, including cost sharing on the part of the States.

4. Limited procurement will be made of observing and communications equipment essential to the current warning program in the nucleus area. This equipment will be incorporated into the FY 1980 program.

5. Procurement and installation of the eastern Kentucky radar (WSR-74S).

Table 3.4 Appalachian Flash Flood Program; FY 79 nucleus area

County	NWS Region	Responsible RFC	Warning Responsibility WSFO/WSO (Region)
Johnson, Ky.	Central	All counties are in the Cincinnati area of responsibility.	Huntington, W. Va. (Eastern)
Floyd, Ky.	Central		Louisville, Ky. (Central)
Magoffin, Ky.	Central		Louisville, Ky. (Central)
Martin, Ky.	Central		Huntington, W. Va. (Eastern)
Pike, Ky.	Central		Louisville, Ky. (Central)
Logan, W. Va.	Eastern		Huntington, W. Va. (Eastern)
McDowell, W. Va.	Eastern		Beckley, W. Va. (Eastern)
Mingo, W. Va.	Eastern		Huntington, W. Va. (Eastern)
Wyoming, W. Va.	Eastern		Beckley, W. Va. (Eastern)
Buchanan, Va.	Eastern		Roanoke, Va. (Eastern)
Dickenson, Va.	Eastern		Bristol, Tenn. (Southern)
Wise, Va.	Eastern		Bristol, Tenn. (Southern)

Subobjective 2.2 (FY 1980-81). Establish the four-State test and evaluation project in central Appalachia.

Refinement and evaluation of the program in the nucleus area, expan sion to the four-State area of Kentucky, Virginia, West Virginia, and Pennsylvania, followed by analyses of data sensitivity and cost/benefit will lead to definition of an efficient modular system that can be implemented as the basic building block in the national program.

In the 12-county area in the Levisa and Tug Fork drainages, about 20% of the local community monitoring network will be automated. Automated equipment would be both precipitation and river alarms and self-reporting measuring devices. This equipment would represent a wide spectrum of sophistication and cost. Maintenance will be by ARC/State /county personnel. About 100 automated devices are envisioned. Automatic data collection, data exchange with NWS, and emergency backup local forecasting will be done by minicomputer at a State facility.

Communication between field offices:

a. Establish dedicated hotlines between:

- Pittsburgh, WSFO
- Charleston, WSFO
- Huntington, WSO
- Roanoke, WSO
- Louisville, WSFO
- Lexington, WSO
- Bristol, WSO
- (New) eastern Kentucky, WSO

b. Explore, through testing, the possible usefulness of telefax equipment between QPB/SSFS and WSFOs Charleston and Louisville.

All existing appropriate telephone/radio systems will be used, including KEWS-Kentucky Emergency Warnings System, ARRL--American Radio Relay League, and REACT-Radio Emergency Associated Citizen Teams. At the county level the first echelon will be dedicated telephone links (such as NAWAS) tying all county action agencies and NWS field offices together. The second echelon is radio links between participating counties. Good quality CBs as well as multicounty public service frequencies will be used.

The four-State area will further serve as a test bed for the evaluation of new technology and techniques for nationwide application.

Actions will be taken to:

1. Deliver to the public at least a 30-min warning of flash flood events.
2. Increase the 3-h forecast accuracy in terms of timing, location, and severity of heavy precipitation over the central Appalachian areas of Kentucky, West Virginia, Virginia, Tennessee, and Pennsylvania, by applying the improved data base and new technology, including mesoscale hydrometeorological models.
3. Improve the data base to support both the warning and forecast efforts.
4. Establish a coordinated program to develop and evaluate new technology and techniques relating to flash floods.
5. Define with ARC and FEMA the role of the States and local agencies. The flash flood forecasts and warnings will be integrated with community developed programs for disaster preparedness and disaster training.

The FY 1980 budget request has three parts, one of which is to provide four positions and $2000K for the four-State program. With these resources, NOAA will provide local flash flood warning systems to communities in this this area, including 600 river alarms, 1,200 precipitation alarms, 3,000 plastic rain gages, and 1,800 river staff gages. This instrumentation forms the core of cooperative observing networks and local LFFWS. In addition, 1,000 touch-tone telephone reporting devices will be furnished to equip observers in the cooperative heavy rain spotter network with the means to relay reports directly into a National Weather Service (NWS) mini-computer. To complement the local automated network, NWS will install and maintain 100 automatic rain gages. These latter data will be collected and transmitted via the Geostationary Operational Environmental Satellite System. Network facilities operated by NOAA in support of the local flash flood warning systems will also be procured, including communication interfaces and prototype remote sensors. Studies will be conducted in-house and on contract to evaluate alternative configurations for modular implementation and to assess the impact of new technology. Once the test program is completed, the program will remain in these States as an operational system for flash flood detection and the test bed for future improvements.

The FY 1981 budget submission will contain further requests to complete the observing program and to expand the program assessment and evaluation phase (cost/benefit).

Subobjective 2.3 (FY 1981-83). Fully develop and evaluate the Appalachian module as the prototype for national implementation.

Keeping the four-State project as the core of the module, the local flash flood program will be extended to at least 175 counties in Appalachia with the highest risk. Different combinations of resources will be used during this phase. Prototype observing systems and forecast techniques will be operated and evaluated to assess their usefulness for the flash flood program. Mesoscale data analyses techniques will be incorporated into an analysis support unit, and the functions of the unit will be evaluated.

Subobjective 2.4 (FY 1983-84). Determine the basic module configuration and system design for nationwide implementation.

Based on experiences gained in the operation of the Appalachian prototype module in FY 1982-83, criteria and assessment techniques will be devised for determining the configuration of the modules to be implemented nationwide. Cost estimates will be determined, and the nationwide system designed. The decision will be made in 1984 whether to proceed with further implementation.

OBJECTIVE 3--Develop the capability to provide centralized forecasting, monitoring, and alerting functions in support of the flash flood program.

Discussion. Warnings and watches serve substantially different purposes. Flash flood warnings are short-fused. Even shorter fused are self-initiating alarm systems that sound a local warning when the level of water in a stream reaches a preset, critical level. Warnings are effective in saving lives only when people understand the threat and are prepared to react in minutes.

Watches are meant to give proper time to consider the options available, prepare for orderly evacuation, and take measures to protect property. To be most effective, watches should be issued prior to the onset of heavy rainfall, thus establishing the need for forecasting.

Centralized facilities are needed to monitor weather patterns over large areas and to alert local forecasters to the potential for flash flood producing rainfall. At the present time there is no national flash flood monitoring and coordinating function within NOAA. Such national responsibilities have proven highly effective in the hurricane (National Hurricane Center) and severe local storm and tornado (National Severe Storm Forecast Center) warning programs and are needed for flash floods. The national unit would provide heavy rainfall guidance tailored to the flash flood problem and would be a central source of heavy rainfall/flash flood expertise. The unit will be supported by satellite specialists who will use the expanded facilities of the Washington Satellite Field Service Station to integrate satellite imagery with other data such as from radar and surface stations.

<u>Strategy</u>. Beginning with enhancements of the Quantitative Precipitation Branch in FY 1979 and collocation of a modernized SFSS in FY 1980, steps will be taken to establish and operate a National Heavy Precipitation Unit (NHPU) at the National Meteorological Center with forecasting, monitoring, and alerting functions. During the period FY 1981 to 1983, NHPU will be augmented to operate a prototype HMAS unit. Decisions on the structure, location, and responsibilities of the HMAS unit will be made in FY 1983.

A flash flood training program for field personnel will be expanded in FY 1980, FY 1981, and FY 1982. A training course has been initiated at the Kansas City Technical Training Center. This training will ensure maximum field use and applications of hydrometeorological products. Approximately 100 field personnel (by FY 1981) will attend annually.

Subobjectives by Fiscal Year

Subobjective 3.1 (FY 1979). Enhance the Quantitative Precipitation Branch and include limited satellite analysis capabilities.

The capability of the Quantitative Precipitation Branch, National Meteorological Center, has been improved by the implementation of new techniques to forecast heavy precipitation and the additional capability to integrate satellite information.

As a prelude to implementation of the Heavy Precipitation Unit in FY 1980, QPB will evaluate the usefulness of new and revised forecast and alerting procedures such as the Excessive Rainfall Potential Outlooks. Evaluations of these will also be made by the NWS field offices. Further, NESS will provide the equivalent of 3 person-years of effort to help QPB use satellite imagery to estimate heavy rainfall.

Subobjective 3.2 (FY 1980). Establish the National Heavy Precipitation Unit with monitoring, forecasting, and alerting functions and collocate a modernized SFSS.

The capability will be developed to analyze the potential for heavy precipitation from combined displays of satellite, radar, surface, and upper air data, in large part building on the work begun in FY 1979. The work of NHPU will address directly the heavy precipitation forecast problem nationwide. It will apply recent technologies and scientific advances to improve (1) quantitative precipitation forecasts (QPF), (2) NOAA's ability to forecast the conditions giving rise to flash floods in a given area, and (3) the timing of flash flood warnings given to the public.

For the FY 1980 budget, two elements have been requested to support subobjective 3.2. Five positions and $350K are needed to establish the NHPU. Three positions and $850K are required to provide a modernized SFSS collocated with NHPU and the people to operate it. Of this total, $750K will be used to purchase equipment (Interactive Flash Flood Analyzer--IFFA) that will allow real-time, interactive procedures to be developed and used to integrate satellite and other data. These procedures will be fundamental to assessing the potential for heavy rain over large areas for periods of 2 or 3 to 6 h.

Subobjective 3.3 (FY 1981-82). Establish a prototype hydrometeorological mesoscale analysis support (HMAS) unit at NHPU.

Mesoscale analysis and forecasting is the foundation of forecasting for for flash flood situations. The mesoscale analysis function is made even more important by the availability of new data, particularly from satellite and surface-based remote sensors and automated observing systems. Analysis support (HMAS) units will distill and format the data so they can be transmitted to local stations equipped with AFOS and a modest amount of image sequencing equipment. Products must be formatted for easy transmission and ready access in the local units with specific needs. In addition to products needed by WSFO and WSO meteorologists, selected forecasts, advisories, and flood information could be displayed on less expensive preprogramed terminals for use by nonmeteorologists. Examples of such user locations would be river control district offices and FEMA offices. Flood alert, watch, warning, and status information could be depicted along with selected weather charts and satellite/radar image sequences.

A main new information system to be evaluated is a regional weather radar display system patterned after those being developed by FAA for their Central Weather Support Units (CWSU). All NWS (RADAP) and appropriate FAA weather radar data in the region will be collected in digital form and composited at short intervals (e.g., 15 min) for viewing in time lapse and for remapping onto the GOES projection. NWS network radars will include Nashville, Tenn., Bristol, Tenn., Patuxent River, Md., Pittsburgh, Pa., Cincinnati, Ohio, and Volens, Va. Other radars will include those in Raleigh, N.C., Akron, Ohio, Louisville, Ky., Charleston, W.Va., and the new NWS site being established in eastern Kentucky.

One particularly important task of this unit will be systematic precipitation analyses in real time, followed by postanalyses when additional hourly and daily rain gage data are available. The Satellite rainfall estimates, radar rainfall estimates, and rainfall forecasts will be evaluated in Appalachia and incorporated as appropriate into operational programs. Analyses will be made for average and peak values on all scales and compared with stream flow observations and forecasts. The analysis procedures and data base can be used for data sensitivity studies to design observation networks as the nucleus area is expanded.

The HMAS unit will be different from any existing NOAA element. Computer-generated products and displays developed at the National Severe Storms Forecast Center (NSSFC) and those developed for AFOS will be incorporated where appropriate for the flash flood program. NHPU will provide the basic structure leading to the start of the prototype HMAS unit in FY 1981. While NHPU will continue to serve the entire Nation, the prototype unit will concentrate on the Appalachian module.

Subobjective 3.4 (1983-84). Develop the design and functional concepts for the operational HMAS unit.

The systems design and functions of the operational HMAS units will evolve as experience is gained with the prototype. By FY 1983 enough experience will be had through NHPU and the prototype unit serving Appalachia, that decisions can be made on how the operational HMAS unit should be structured best to fit into the overall flash flood program. An important consideration will be given to the possibility that each one or two modules may need support from a separate unit.

OBJECTIVE 4--Provide technical support for field operations.

Discussion. A technological revolution in hydrometeorolgoy is just beginning. The change from manual to automated and direct to remote sensing equipment is accelerating dramatically. Systems long under development are being applied at an increased rate. Some examples are self-initiating radio relay rain gages; acoustic, infrared, and vertical sounders; doppler radar; and the family of advanced satellite sounders.

To apply these new data operationally, such technological advancements need to be matched by improve analysis and prediction technologies.

Mesoscale kinematic models to extrapolate radar, satellite, and rainfall patterns are requisite contributions to improved short-range forecasts. Ground-based infrared sensing of liquid water and water vapor, coupled with prediction techniques, will be developed. Terrain influences on precipitation distribution under different flow, moisture, and stability conditions will be determined.

Short-range forecast and warnings of minutes to a few hours will be more precise in the location and timing of events and their sequence. These forecasts, thus, will be more valuable to assessment of the potential for flash flooding, but they will also be more perishable. Delivery will be accelerated through automation such as AFOS. The synoptic flash flood classification and mesoscale modeling capabilities of ERL/APCL will be used in both PROFS and the flash flood program to integrate the extensive data sets that will be available from ground-based remote sensing systems. The PROFS program and the flash flood program will exchange improved methods for real-time data processing and display techniques, improved parameterization procedures, and methods for extrapolation and short-term forecasting.

Several hydrologic models need careful attention. Improved headwater advisories will be forthcoming through use of the new NWS River Forecast System. An operational model is needed to describe the sheets of water running off hilly terrain owing to very high precipitation rates. Contingency plans are needed in case of dam breaks. Expanded application of the Dam Break/Flood Forecast Model is needed so local officials will have guidance on local responses that are essential should one or more dams in their area fail during unusually heavy precipitation.

Limited-area, high-resolution numerical weather prediction models will be tested in terms of reliability and sensitivity to improved initialization, particularly in moisture analyses. Performance sensitivity to model physics, model resolution, domain size, and numerical methods will be evaluated.

Statistics play a key role in the flash flood problem. Statistical relationships are necessary to interface phenomena on different scales and to interface meteorological and hydrologic models. The linkage of meteorological models and hydrologic models must be carefully examined to avoid any mismatch. For example, if reliable meteorological information is to be provided, $(4\ \text{km})^2$ hydrologic models may have to be fed by meteorological models with (40 km)^2 resolution. To do so, a statistical interface would be required, as (4 km)^2 forecast information will only be available in statistical terms for input to the hydrologic model.

Determining relationships between different observations is particularly important. Flash floods depend on area- and time-averaged precipitation, but we must learn how to design an optimum observation network and analysis system. There are many more observations than are being systematically analyzed. We must combine precipitation data from 1-h, 6-h, and 24-h observations and radar data. MDR and RADAP must be used as well as interpretations of composited radar data and satellite images.

The economic impact of good statistical relationships is substantial. With a good statistical analysis system, the network of gages, radars, satellite, and other observing tools and associated data handling systems can be designed to do the job at least cost. Finally, an accurate flash flood hazard climatology can be established when demographic and economic information is combined with reliable precipitation information.

PROFS and SESAME, funded separately, are two broad developmental programs with major potential for improving the flash flood system. While the flash flood program can proceed independently of either PROFS or SESAME, both will make important contributions to the employment of new data collection systems as well as the development and use of analysis and prediction techniques. PROFS will concentrate on exploratory development initially and will not be deployed operationally for at least 8 years. However, important intermediate development can be evaluated in the Appalachian module for potential implementation in the years immediately after 1984.

SESAME's goal is understanding of mechanisms responsible for the formation and evolution of severe convective storms. The approach in SESAME is to have intensive field programs of limited duration. Numerical modeling is central to SESAME, on the regional scale of limited-area forecast models as well as the local scale where the use of advanced simulation models will be concentrated. In SESAME '79 (April, May 1979) special observations will be made to support these modeling efforts.

Interfaces with developmental efforts, particularly APCL, PROFS, and SESAME, will provide a mechanism for transferring technology into the field program. Through close interaction with ARC and FEMA, techniques will be developed to assess the risk due to flash floods so that each module to be implemented nationwide can be tailored to the local problems in a cost-effective manner.

Subobjective 4.1 (FY 1979). Initiate the test bed concept for the nucleus area.

NESS will initiate a limited real-time experiment to test the benefits of interactive analysis equipment in diagnosing flash flood situations. Efforts will be made to incorporate radar and surface data with satellite imagery. The scope of the experiment of necessity will be restricted until equipment in the FY 1980 budget is obtained. The FY 1979 experiment will include monitoring of a limited number of both convective rain days and hurricane-induced events, should the latter occur.

Currently NESS is working on a program to evaluate different techniques of estimating precipitation amounts using satellite imagery. Postanalyses of rainfall events will be made for the 12-county region to improve diagnostic skills and to provide a basis for improving operational techniques.

A lack of understanding of flash floods severely limits predictability. Classification of flash floods from two different perspectives will begin. Case studies will be made on storms in this region to determine how they form, how they behave, and how they end. The impact of rainfall depends upon the topography, land use, and the initial hydrologic condition as well as on a combination of rainfall rate, areal extent, and duration. These factors interact in complex ways to produce an impact that, if understood and anticipated, will alter radically the community response to the flash flood threat. We have to standardize classes of floods in terms of their potential impact. Broad terms, such as flash flooding, urban flooding, small-stream flooding, drainage flooding, and river flooding, need to be standardized to facilitate community response as well as hazard assessment.

The Environmental Data Information Service will start developing a flash flood hazard climatology for the region. They will assist both ARC and the NWS regional people in assessing the risk in the 12-county area and in designing the appropriate data collection network to be implemented starting in FY 1980.

Subobjective 4.2 (FY 1980). Provide a base for capitalizing on the technology of AFOS, PROFS, and APCL models.

The real-time experiment, begun in 1979 to develop data analysis techniques based primarily on satellite imagery and radar data, will be completed and the results incorporated into operational procedures.

Techniques for analysis and display of information unique to flash floods will be evaluated for use in AFOS. As AFOS is implemented in the region during the early 1980's, these techniques will be evaluated in operational environments.

Advanced developmental or prototype equipment, as in PROFS, will be given an operational evaluation before deployment in the field. This will include both remote sensing and automated observing equipment as well as new techniques for collecting and processing data using mini-computers. Mesoscale analysis and extrapolation techniques suitable for WSFO use and subsequent adaptation to the AFOS will begin. Methods will also be evaluated for faster, more effective dissemination of warnings to officials as well as to the general public.

With the exception of $200K for developing mesoscale and extrapolation techniques, resources have not been included in the FY 1980 flash flood budget request for these activities. They will be conducted as extensions to programs funded in other areas.

Subobjective 4.3 (FY 1981-83). Provide a mechanism for technology transfer on a broad spectrum.

The FY 1981-83 time period is developing into a major convergence zone for the availability of greatly improved forecast and analysis techniques and technology. Advanced satellite systems such as TIROS-N and VAS will be operating. The basic AFOS systems will be operating throughout the Appalachian module. RADAP will be nearing the end of the implementation phase and doppler radar will be ready for implementation. The expanded FAA weather radar program will be well underway. The results of PROFS likely will have spinoffs usable in the flash flood program.

Careful management and focused evaluations will be needed to assess the potential of these systems for use in the flash flood program. What is required is a systematic test and evaluation program in the Appalachian region leading to design criteria for the national flash flood program. This activity will be paralleled by the evaluation of hydrometeorological models. Efforts will be made to better forecast the effects of flooding from dam bursts and to provide officials with better information on the probability of rainfall exceeding critical values once a storm has begun.

Developments of ground-based remote sensing and automated (direct) sensing systems will be integrated into the flash flood observing program. These will include improved automated radio reporting river and rain sensors; doppler radar; microwave techniques for path averaging of area rainfall; ground-based acoustic and microwave techniques for obtaining vertical profiles of water vapor and wind shear; and advanced processing techniques for quantifying data from existing network and local use radars. The precipitation modeling capabilities of APCL will be used in both PROFS and the flash flood program to integrate the extensive data sets that will be available from automated direct and ground-based remote sensing systems. The PROFS program and the flash flood program will exchange improved methods for real-time data processing and display techniques, improved parameterization procedures, and methods for extrapolation and short-term forecasting.

Subobjective 4.4 (FY 1983-84). Implement AFOS-oriented analysis and forecast techniques in the field offices.

AFOS has been designed to be the major communication and display system for hydrometeorological data and products. It will provide an interface for information exchange between differing agencies as well as with the general public and industry. The basic AFOS system will be operating nationwide before 1984. By then, NWS will be in a position to use the computer concept at the heart of AFOS for local data analysis and forecasting. Techniques developed earlier, in a general sense for mesoscale analysis and flash flood situations, will be adapted for AFOS-equipped field offices.

The purpose of this effort will be to assemble a set of hydrometeorological techniques for use at the local level that would be included in each module.

4.0 SUMMARY AND NOAA BUDGET

4.1 Time Line and Decision Points Summary

Table 4.1 summarizes the timing and decision points for implementing the flash flood program, nationwide.

The important actions, broken down by objective, are:

Objective 1. Develop the Management and Implementation Plan

FY 1979

- develop NOAA Program Implementation Plan and formalize the partnership with ARC
- define specific interactions with FEMA

FY 1980

- develop coordination concepts at the Federal/State/local level

FY 1981-83

- evaluate the prototype Appalachian model in terms of agency roles and cost-sharing strategies
- develop guidelines for nationwide implementation.

Objective 2. Develop the basis for nationwide implementation, at the local level, of regionally coordinated flash flood programs.

FY 1979:

- establish a nucleus program in 12 counties of central Appalachia

FY 1980:

- establish the four-State test and evaluation program in Appalachia

FY 1981:

- develop the Appalachian module as the prototype for nationwide implementation

Table 4.1--Top management decisions* to be made

Objective #1	1978	1979	1980	1981	1982	1983	1984
Develop the Management and Implementation Plan							
Program Implementation Plan	A						
Management team	A						
Implementation							
Full Appalachian module		M					
Extensions					M		M
Program evaluation		A	M	D	D	M	M
Objective #2							
Develop the basis for nationwide implementation, at the local level, of regionally coordinated Flash Flood Programs							
Nucleus start-up		A					
Initial Appalachian module			A				
Full Appalachian module		M		A			
Cost/effectiveness studies			A	D	D	D	D
Start a second module					M		
Extension nationwide							M
Objective #3							
Develop centralized facilities and support capability							
NHPU			A				
NWS QPB		A					
NESS support/NHPU			A				
Interactive Flash Flood Analyzer (IFFA)			A				
Hydrometeorological Mesoscale Analysis Support (HMAS)			M	A	A	M	
Training field personnel	A		A	A	A		
Objective #4							
Provide technical support for field operations							
• Enhancement of sensing and communication systems							
- Radar:							
RADAP	A			D			
FAA	A			D			
- NESS experiment		A					
- VAS				A			
- AFOS				A	A		
- NWS test and evaluation				A			
- PROFS (technological transfer)			A	D	D	D	D
• Development of hydrometeorological models and technologies							
- Deterministic		A		A	A		
- Statistical		A		A	A		
- Classification		A		A			
- Risk assessment		A				D	
- SESAME		A					

KEY: A = Action begun or an increased effort initiated   D = Decision point   M = Major Decision point

*Assumes decisions are made 2 years before first year resources are available.

FY 1982-83:

- develop criteria and assessment techniques for determining the best mix of people, facilities, communication/display systems, sensing systems, and new technologies so NOAA can meet its goals at least cost.

FY 1984:

- extension of modules to other areas.

Objective 3. Develop centralized facilities and support capability.

FY 1979:

- NMC/QPB heavy precipitation outlook with Satellite support

FY 1980:

- establish NHPU with monitoring, alerting, and forecasting functions, and implementation of the Washington SFSS with IFFA capability

FY 1981-82:

- establish and operate the prototype Hydrometeorological Mesoscale Analysis Support (HMAS) Unit.

FY 1983-84:

- evaluate the prototype HMAS unit and develop a design for nationwide implementation.

Objective 4. Provide technical support for field operations.

FY 1979:

- conduct the NESS experiment
- evaluate possible (pre-)PROFS support
- begin a hazard analysis of central Appalachia
- increase efforts on model development

FY 1980:

- APCL model development
- technology transfer from PROFS

FY 1981:

- begin integration into the AFOS environment
- model/forecast technique development for NHPU
- develop techniques for using VAS data
- evaluate the impact of radar programs (RADAP/FAA/Doppler)

FY 1982-83:

- integration into the National Radar Program
- model development for regional modules.

4.2 Program Evaluation

Beginning in FY 1979 and continuing throughout program implementation, the various program elements will be evaluated as follows:

(a) effectiveness of preventing loss of life;

(b) effectiveness of reducing property damage and disruption of commerce and human activities; and

(c) cost of various alternative approaches.

The guiding principle is to conduct thorough system analyses, evaluating alternatives, mixes of people, facilities, communication/display systems, sensing systems, and new technologies so NOAA can meet its goals at least cost.

The "National/Regional" warning program will be developed in the initial nucleus 12-county area and expanded to the four-State area of Appalachia in FY 1980. This will be followed by a prototype Appalachian Module, which will be the basis for nationwide expansion in the latter 1980s. Therefore, considerable attention will be devoted to evaluation of its strengths, weaknesses, and costs of the Appalachian Module. Table 4.2 summarizes the cost of the flash flood program through FY 1984 and includes full implementation of the Appalachian Module and partial implementation of one other.

Table 4.2.--Proposed NOAA budget for the national flash flood program

	Fiscal Year (thousands of dollars)				
	1980	1981	1982	1983	1984*
Objective #1 Develop the Management and Implementation Plan					
• Program Implementation Plan • Management team • Implementation decisions • Program evaluation		NO NEW RESOURCES REQUESTED			
Objective #2 Develop the basis for nationwide implementation at the local level of regionally coordinated Flash Flood Programs	4/1800[1]	8/4000	12/3300	12/3300	12/3300
• Equipment	0/1150	0/2200	0/600		
• Contract/grants	0/200	1/800	1/1200		
• Operations/maintenance/communications	4/450	7/1000	11/1500		
Objective #3 Develop centralized facilities and support	8/1200	13/1400	16/2100	16/2100	16/2100
• NHPU	5/300	6/300	6/300		
• NESS support NHPU	3/100	3/100	3/100		
• Interactive Flash Flood Analyzer (IFFA)	0/750	0/150	0/150		
• Hydrometeorological Mesoscale Analysis Support (HMAS)		3/600	6/1200		
• Training	0/50[2]	1/250	1/350		
Objective #4 Provide technical support for field operations	0/200[1]	4/1300	6/1300	6/1300	6/1300
A. Enhancement of sensing communication systems					
• RADAP FUNDED FY 78 (2/1900)					
• NWS/NESS design-test-evaluate		2/100	2/100		
• VAS techniques		0/350	0/350		
• Enhanced AFOS communication and display		0/350	0/350		
B. Development of hydrometeorological models and techniques	0/200	2/500	4/500		
TOTAL PROGRAM FUNDING LEVEL	12/3200	25/6700	34/6700	34/6700	34/6700

[1]The FY 1980 budget submission shows these two items combined under "the Four-State" Flash Flood Program.
[2]The FY 1980 budget submission shows this item under the National Heavy Precipitation Unit.
*FY 1984 resources do not include nationwide implementation of modules.

LIST OF ACRONYMS

AD	Applications Division, NESS
AFOS	Automation of Field Operations and Services
AMS	American Meteorological Society
APCL	Atmospheric Physics and Chemistry Laboratory, ERL
ARC	Appalachian Regional Commission
ARRL	American Radio Relay League
CADP	Central Appalachian Development Project
CAR	Central Appalachian Region
CEA	Center for Environmental Analysis
CWSU	Central Weather Support Unit, FAA
DCPA	Defense Civil Preparedness Agency
DVIP	Digital Video Integrator and Processor
EBS	Emergency Broadcast System
EDIS	Environmental Data Information Service
ERL	Environmental Research Laboratories
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FFAS	Flash Flood Alarm System
FIST	Flash Flood Implementation and Strategy Team
GOES	Geostationary Operational Environmental Satellite
HMAS	Hydrometeorological Mesoscale Analysis Support
IFFA	Interactive Flash Flood Analyzer
KEWS	Kentucky Emergency Warning System
LFFWS	Local Flash Flood Warning System
MDR	Manually Digitized Radar (data)
MLC	Major Line Component
MPE	Major Program Element
NAWAS	National Warning System
NESS	National Environmental Satellite Service
NHEML	National Hurricane and Experimental Meteorology Laboratory

NHPU	National Heavy Precipitation Unit
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center
NWP	Numerical Weather Prediction
NWS	National Weather Service
OH	Office of Hydrology, NWS
OM&O	Office of Meteorology and Oceanography, NWS
OR	Office of Research, NESS
OTS	Office of Technical Services, NWS
PDP	Program Development Plan
PROFS	Prototype Regional Observing and Forecasting System
QPB	Quantitative Precipitation Branch
RADAP	Radar Digitizing and Processing
REACT	Radio Emergency Associated Citizens Teams
RFC	River Forecast Center
SESAME	Severe Environmental Storms and Mesoscale Experiment
SDO	Systems Development Office, NWS
SFSS	Satellite Field Service Station
TIROS	Television Infrared Observation Satellite
TOVS	TIROS Operational Vertical Sounder
VAS	GOES Vertical Atmospheric Sounder
WPL	Wave Propagation Laboratory, ERL
WSFO	Weather Service Forecast Office
WSMO	Weather Service Meteorological Observatory
WSO	Weather Service Office
WSR-74S	Weather Service Radar--design finalized 1974, S band

Z-R Relationship = Equations relating the intensity of radar reflections (Z) from water in the beam to the rate of rainfall (R).

REFERENCES

American Meteorological Society, May 1978: Flash Floods--A National Problem. Bulletin of the American Meteorological Society 59: 585-586.

Mogil, H. Michael, Monro, John C., and Groper, Herbert S., June 1978: NWS's Flash Flood Warning and Disaster Preparedness Programs. Bulletin of the American Meteorological Society 59: 690-699.