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ISSUE PAPER FY 1992 INITIATIVE

Water Resources Forecasting Services (WARFS)



**Office of Hydrology
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce**

April 1990

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"Long Drought May Force New Lifestyle on California"

- Washington Post, Apr 5, 1990

"South Hit by Floods..."

- Washington Post, Feb 17, 1990

"Reno Looks to California to Quench a Growing Thirst"

- Los Angeles Times, Jan 22, 1990

"Lying Low: No Relief Seen for Barge Travel"

- St Louis Post-Dispatch, Dec 28, 1989

"Water Scarcity Threatens Food in the 90's"

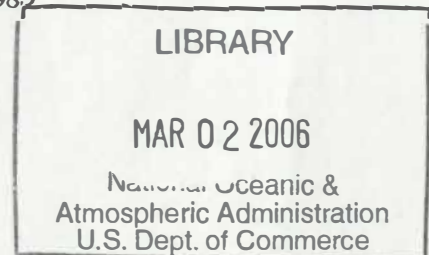
- Science News, Dec 16, 1989

"Justices to Review States Water Rights"

- Washington Times, Dec 8, 1989

"Colorado Venerable Water Law System Isn't Meeting Its Modern Challenges"

- Denver Post, Nov 25, 1989



"Fish and Power in a Riverine Rivalry"

- US News and World Report, Oct 16, 1989

"Persistent Drought Plagues Midwest for a Second Year"

- Los Angeles Times, Jul 16, 1989

"An Oily Blight on the Water"

(Delaware River, Galveston Bay Oil Spills)

- Newsweek, Jul 3, 1989

"The Real Deficit is Water"

- Time, Feb 27, 1989

"Barges Up a Creek"

- Business Week, Aug 8, 1988

This initiative will provide an essential capability that allows the Nation to anticipate and manage water supply crises, not just react to them.

ISSUE PAPER FY 1992 INITIATIVE

National Oceanic and Atmospheric Administration Water Resources Forecasting Services (WARFS)

I. Introduction

In the 1980's, there was an increased awareness of the importance of water resources to the Nation's economy, the quality of our environment, and our overall social well-being. A number of factors have contributed to this awakening. Demands for fresh water now exceed the reliable water supply in many regions of the country. This inhibits growth and creates conflicts between competing water uses. In the West, municipalities have purchased water rights that, in the past, were used for industry and irrigation. The reservoir system in the Upper Colorado Basin filled for the first time in the 1980's. Operation of the system is now extremely complex because of the trade-offs between releasing water to make space available for flood control and holding water for uses such as irrigation and municipal water supply. Heavy pumping of groundwater has depleted supplies in some areas and resulted in salt water intrusion and land subsidence. In some parts of the country, heavy surface water withdrawals combined with irrigation return flows have caused high salt and sediment concentrations and overall poor water quality in our rivers. Low flows and discharges of pollutants stress our fisheries and wildlife and seriously jeopardize our estuaries. Global climate change has become an extremely popular topic, and although there is disagreement over the magnitudes of changes to expect, even small changes could seriously impact our water resources.

The drought of 1988 focused national attention on the role of water resources in our country. Print and electronic media brought us clear images of the consequences of drought -- barges stranded on sandbars in the

Importance of water resources to our national economy and environment

Reservoir operations require trade-offs between conflicting water uses

Global Climate Change impacts water resources

National attention focused on water resources management by 1988 drought

Water Impacts:

- *Agriculture*
- *Hydropower*
- *Transportation*
- *Fisheries*
- *Water Supply*
- *Flood Control*

*WARFS: Water Resources
Forecasting Services*

*Basic WARFS technology -
a proven tool for improving
water management*

Mississippi River, empty reservoirs, and withered corn fields. The drought dramatically illustrated that industries tied to the availability of water are inherently risky. Some parts of the country have never completely recovered from the 1988 drought, but even in those parts that have recovered, risky decisions in water-based industries are a daily fact of life: barge companies decide how heavily loaded each barge should be; electric and water utilities decide how much effluent can be safely discharged into an estuary; hydropower and irrigation release schedules are determined; fisheries are managed; and reservoirs are operated to balance flood control against water supply. In most cases, these water management decisions are based on ad-hoc information systems that force inefficient and wasteful utilization of the Nation's water resources. The capability of advanced hydrologic and climate forecasting technology to significantly reduce the risk in water management decisions has been demonstrated (most notably in the Potomac River Basin, as described below). The Water Resources Forecasting Services (WARFS) Initiative will build on these technological advances and begin to provide water resource forecast services nationwide. By reducing the risk associated with water management decisions, WARFS can fundamentally change the way water managers conduct their business.

Basic WARFS technology has been shown to dramatically improve water resources management capabilities. In 1977, the National Weather Service (NWS) began development of prototype WARFS technology for the Potomac River basin. This activity came in response to requests for assistance in alleviating an impending water supply crisis in the Washington D.C. Metropolitan Area (WMA). Population was growing well beyond the unregulated Potomac River's capability to provide drinking water during drought periods. Proposals to solve the water supply crisis for the politically divided region had heavily relied on construction projects (up to 16 major dams and reservoirs) with large costs and small public support. By the early 1980's, it was clear that local water managers were sold on the soundness of WARFS technology and its cost-effectiveness. In 1983, a series of contracts were signed by the Federal Government, State of Maryland, and Commonwealth of Virginia. These contracts provided for a limited construction program

of two reservoirs and joint operation of the water resources of the region using the prototype WARFS technology. Estimates of the savings to the Federal Government, states, and local governments, in deferred capital costs, ranged from 200 million dollars to more than 1 billion dollars. The "WMA Water Supply Solution" was nominated by the American Society of Civil Engineers as the Outstanding Civil Engineering Achievement of 1983.

WARFS prototype saved millions of dollars in Washington Area

While an improved water resources forecast service is the dominant focus of the WARFS Initiative, it must be clearly understood that it is built on the foundation of existing National Oceanic and Atmospheric Administration (NOAA) river and flood forecast services. WARFS will bring together the next generation of hydrologic forecasting technology and apply it, across the Nation, to all segments of NOAA hydrologic services from flood warnings to long-term water supply forecasts. An unprecedented opportunity now exists to capitalize on existing and planned programs and technology at marginal additional costs, and to dramatically improve the Nation's ability to forecast the state of its rivers and streams, reduce flood damages, and use the Nation's water resources more efficiently. As the Nation's water managers integrate improved WARFS services into their decision-making, this Initiative will generate an increasing stream of economic benefits to the country, which will approach \$200 million annually within a decade.

WARFS is an extension of current NOAA river and flood forecast services

WARFS is integrated with NWS modernization

Potential benefits of \$200 million annually greatly exceed development and delivery costs

II. Colorado Demonstration Project

In 1989, NOAA submitted for Department of Commerce (DOC) consideration, a FY91 budget initiative entitled, "Water Resources Forecasting Services." Although there was general agreement that the service objectives of the Initiative are crucial to efficient use of the Nation's precious water resources, budget rankings precluded approval at the DOC level. Because of the importance of the WARFS Initiative, NOAA is redirect-

FY92 Initiative builds on Demonstration Project begun in FY90

Demonstration Project in Colorado Basin has several advantages

ing low levels of base resources in FY90 and FY91 to begin funding of a demonstration project in the Colorado Basin. These funds will be used for the development and initial implementation of the major WARFS components in the demonstration basin. The project will serve to demonstrate the value of integrating new technologies for the purpose of improving water resources forecasting services in the Colorado Basin, and it will also provide the basis for the planning and preparation for the national program. The Colorado Basin was chosen because: 1) water is an extremely valuable commodity in the basin, and there is strong competition for its use, 2) special Congressional appropriations have already provided resources for data network enhancements, personnel, and computational capabilities, which reduce the additional cost of the demonstration project, 3) much of the WARFS technology can be readily demonstrated in the Colorado Basin, and 4) the strong interagency cooperation that exists in the basin will help to ensure that large benefits are rapidly realized from improved forecasting services.

III. Service Objective

Growing demand for limited water supply results in conflicts among competing interests

Construction of water management structures becoming less viable economically

Improved water management provides a cost-effective alternative

The growing demand for water resources creates conflicts among managers for competing uses of water such as irrigation, municipal supply, hydropower, recreation, wildlife preservation, commercial and sport fisheries, industrial use, and navigation; and among various organizations such as lobbying groups, State and local governments, and industrial groups. The days of securing reliable water supplies through construction of storage and control facilities are drawing to a close as the costs of construction soar, the most desirable sites are used, and environmental concerns mount. Optimal management of existing public water resources is the key to securing reliable cost-effective supplies; and better information is the key to improved management. The NWS Hydrologic Services Program in cooperation with the activities of other agencies is the ideal vehicle to provide authoritative and reliable forecast information for the Nation's water managers from a source independent of any conflict over

operational decisions on water use. Otherwise, decisions may be made on the basis of incomplete information provided by conflicting (and potentially self-serving) sources.

WARFS is built on: 1) existing NOAA programs in river and flood forecast and warning services, weather and climate forecasting services, and links to private sector value-added information services; 2) NOAA programs to modernize the technological base of the NWS; 3) other NOAA scientific support capabilities; 4) data and observations of river, snow, and precipitation conditions that cost local, State, regional, and other Federal agencies well over \$60 Million/year to collect but are provided to NOAA essentially free of charge in return for NOAA services. WARFS extends advanced water resources forecasting approaches to national coverage. These approaches have only been implemented on a limited basis in a few locations because of current constraints on NOAA resources. These services will meet information needs of government and quasi-government water managers and provide the raw material for private sector entrepreneurs to meet the water resources information needs of specific sites and water users through value-added services.

- **The fundamental service objective of this Initiative is to expand the information base for water resources decisions.** Specifically, WARFS will provide a benchmark level of water resources forecasting services to the Nation's water managers. NOAA's flood warning services will also be improved to form the basis from which WARFS benchmark information can be provided at marginal cost. The term "benchmark services" is carefully chosen. This benchmark level of water resources forecasting services will allow the Nation's water managers and planners to act from a common information base and will allow the private sector to serve the interests of individual industries through site-specific and industry-specific forecasts developed from this common information base.

WARFS integrates existing and planned capabilities

WARFS allows advanced approaches to be extended nationally

WARFS will provide benchmark information that can serve as a common base for water resources decisions

Benchmark services will be complemented by private sector value-added services

WARFS is a natural extension of existing services with emphasis on water management information

Implementation of WARFS will also improve flood warning capabilities

WARFS enhances ability to effectively manage water resources

WARFS benchmark services will provide the private sector with information which can be used in the preparation of detailed forecasts for specific industrial sites, barge companies, and the like. Benchmark services will vary somewhat from one river system to another. For example, maximum forecast horizons of six months or more may be needed for large river basins with reservoirs that have multi-year storage, while they might be considerably shorter for river basins with smaller projects. The need to adapt benchmark services to meet varying regional needs should not be confused with providing tailored industry-specific forecasts, which is a private sector role.

Meeting the service objective of this Initiative is fundamental to NOAA's mission. The NWS presently provides weather and river warning and forecast services. These services provide a valuable information source for effective water management planning and operations, but current services are structured with the primary focus on flood warning services and limited emphasis on longer term water supply forecasts. The proposed WARFS Initiative is a natural extension and integration of these existing services, because both flood forecasting and forecasting for water management interests utilize much of the same technology, analyses, and research. Indeed, a main benefit of WARFS implementation will be a long overdue comprehensive improvement in existing hydrologic services.

Several specific objectives contribute to the overall service objective of WARFS:

- **Support forecast service requirements of government and quasi-government water managers.** While the Federal government is the major water manager in the Nation, institutional arrangements for managing the Nation's waters also include facilities operated by the states, special regional authorities (e.g., the Salt River Project), and regulated quasi-public concerns (e.g., the Bonneville Power Administration). Although institutional forms vary, the Nation's water managers share two common characteristics: a responsibility to make effective use of the Nation's water resources for competing needs, and the need for reliable forecast information on which to base their decisions. As the

steward of the Nation's increasingly precious water, the Federal sector has a responsibility to manage these resources as effectively as possible. WARFS forecast services will be provided for each of the Nation's significant government or quasi-government water control facilities.

- **Satisfy needs for forecast services at near-, mid-, and long-term time scales for a wide variety of water use situations nationwide.** It is essential that the benchmark level of WARFS services be adjusted for each river system to meet the basic information needs of various water-use sectors (water supply, hydropower, fisheries management, navigation, irrigation, etc.) on a nationwide basis.
- **Provide critical information on forecast reliability.** As the length of the forecast period increases, the reliability of the forecast decreases. Water managers have a critical need to know the reliability of the information on which their decisions are based.
- **Improve forecast sensitivity to weather and climatic forecasts.** Current water resources forecast techniques make little use of growing NOAA skill in medium- to long-range weather and climatic forecasts. WARFS will take advantage of these accomplishments by incorporating much of this information into its technology and procedures.
- **Provide water resources forecasts to private sector intermediaries, who in turn serve specific industries.** WARFS information will be available to private sector value-added service companies. These companies will tailor information products to serve such concerns as riverine navigation companies, riverine construction sites, industrial sites along the Nation's waterways, irrigation companies, and the like. A partnership between the DOC and this private intermediary industry is essential to achieving the full value of WARFS for the Nation's water users. The partnership between DOC and the private sector is described in the Annex.

WARFS adapted to varying hydrologic situations and different water-use sectors

Quantifying forecast reliability allows more refined water management decisions

Using weather and climate information, WARFS will extend forecast horizon

WARFS relies on private sector to deliver services tailored for specific industries

*Implementation of WARFS
is cost-effective because it
relies on existing and
planned programs*

The NWS can meet these service objectives by nationwide implementation of proven forecast technologies which have been applied at selected sites on a limited basis due to resource constraints. WARFS will capitalize on the scientific and technological advances associated with the NWS modernization to provide the next generation of hydrologic forecasting technology. The required expenditure is relatively modest because of the resource base provided by other existing and planned programs including Next Generation Weather Radar (NEXRAD), Automated Surface Observing System (ASOS), the numerical weather and climatic forecasting capabilities of the National Meteorological Center, the existing NWS river and flood forecasting service, and numerous existing programs under the aegis of other agencies at the Federal, regional, State, and local levels.

IV. Proposed Initiative

*Use of private sector
eliminates much of the need
for additional federal
employees and offers the pos-
sibility of bringing WARFS
on line more quickly*

The WARFS Initiative uses a strategy similar to the one contained in the FY91 submittal. Private sector involvement through contracts and a cooperative institute eliminate much of the need for additional federal full-time employees (FTEs) and promise to bring WARFS services more quickly to much of the Nation. The major change from the FY91 submittal is consideration of the FY90 start-up of the demonstration project in the Colorado Basin. The Initiative still employs a strategy of early implementation of WARFS services in critical areas followed by gradual nationwide implementation. The proposed Initiative is presented in three sections. The first section provides a brief description of activities in each of the three budget components depicted in Figure 1. The second section addresses the relationship of WARFS to other NOAA initiatives, and the relationship of this Initiative to the congressionally mandated enhancements in the Colorado and Susquehanna basins. The final section presents, by fiscal year, the major objectives to be addressed each year.

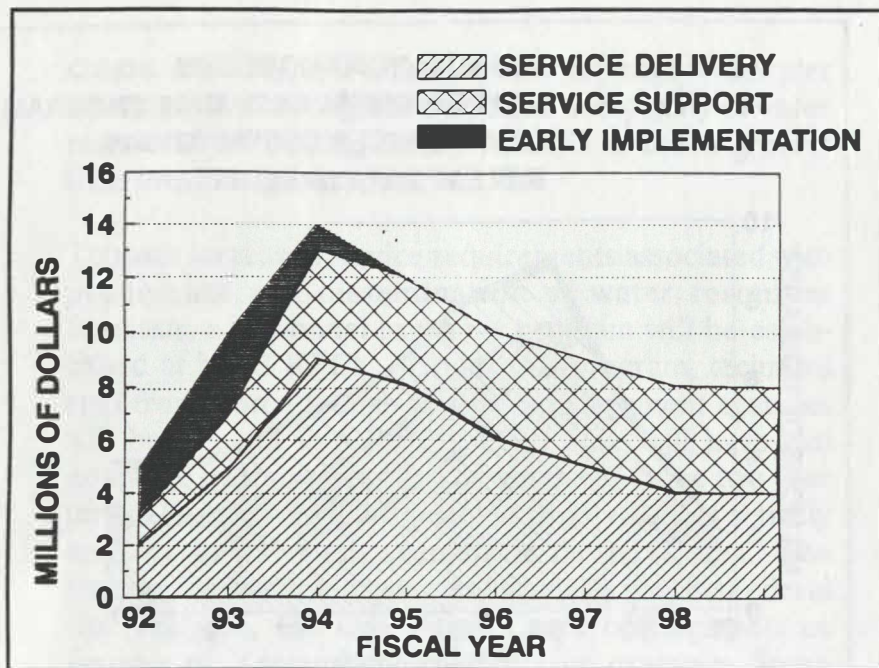


Figure 1. WARFS Cost Profile

BUDGET COMPONENTS

Service Delivery

The activities under this component are primarily associated with enhancements needed to enable the NWS RFC staff to deliver WARFS services. The evolution of these costs are summarized in Figure 2. While costs for this component peak in FY94 (\$9 Million) long-term outlays are expected to be less than half this maximum amount.

Costs associated with the delivery of WARFS services taper off after FY94

Advanced Modeling (Budget Item 1(A))

Data preparation and calibration of the advanced modeling systems on which WARFS are based are major requirements for implementing WARFS services. The first stage of this process requires assembling and processing the historical data base of streamflow and hydrometeorological observations for each forecast point. The second stage entails calibrating hydrologic and hydraulic models that are directly used in providing WARFS services. The scale of these tasks can be partly illustrated by noting that the number of RFC forecast points is currently 3000. Data preparation tasks are ideally suited for private sector performance, and will be accomplished primarily through contracts. This strategy

Accurate model calibration crucial to effectiveness of WARFS

Data preparation and model calibration supported by private sector

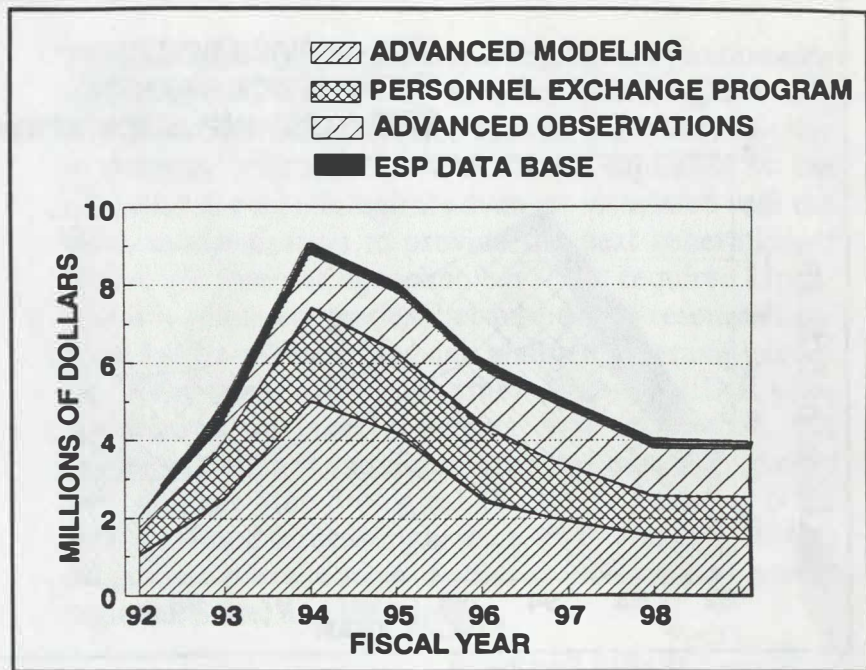


Figure 2. Cost Profile for Service Delivery Component

River Forecast Centers (RFC) focus on calibration of technically difficult basins

will provide data of uniform quality on a timetable that permits accelerated delivery of WARFS services. Under the proposed Initiative, calibration of hydrologic and hydraulic models for selected benchmark basins (approximately 300) with high-quality input data would be performed by the private sector. It should be emphasized that RFC staff must be closely involved in the calibration activity. The private sector component of model calibration will provide a baseline calibration product for RFC staff. This product will allow RFC staff to focus their attention and calibration skills on difficult basins and to develop accurate parameter values for basins with incomplete calibration data. Clearly, advanced model development and calibration will continue at a lower level as a result of improved scientific understanding, improved data quality, land use and river system changes, etc.

Personnel Exchange Program (Budget Item 1(B))

RFCs better able to meet water resources forecasting needs

Data preparation and model calibration are just one part of the additional burden placed on RFC staff by WARFS service delivery. The actual production and dissemination of water resources forecasts entails additional responsibilities. Not only must the RFC produce additional types of forecasts for current forecast points, but the number of forecast points will also significantly in-

crease. Although RFC staff have experience with water resources forecasting, the scope and complexity of water resources forecasting under WARFS is much greater than previously faced by RFCs.

To meet increased service requirements associated with production and dissemination of water resources forecasts, a personnel exchange program will be established at NWS RFCs. Under this program, technical staff from a broad range of water management agencies will be brought into RFCs. Each RFC will have two exchange hydrologists, each of whom will serve two year terms. Personnel will be selected from agencies actively involved in water management in the RFC area. The appropriate water management agencies may be Federal (for example, the U.S. Army Corps of Engineers or Bureau of Reclamation), State (for example, South Florida Water Management District), interstate (for example, Ohio River Sanitation Commission) or even perhaps local (for example, Orange County California Department of Public Works). During the first three years of the Initiative, costs of the exchange program will be fully covered under the Initiative. For the next two years, the Initiative will cover half of the salary cost and relocation costs. In subsequent years, the Initiative will only cover relocation costs.

The exchange program is designed to meet several objectives. It will provide RFCs with additional staff required to provide WARFS services to the water resources community. In addition, exchange hydrologists will bring to the RFCs a deeper understanding of the details and intricacies of water management. Through information transfer from the interns to the RFC staff, RFCs will become more capable in the development of useful forecast information for management of the Nation's water resources. Finally, the exchange hydrologists will return to their own agencies with a greater appreciation of NWS forecast capabilities. This appreciation will greatly facilitate expanded use of NWS forecasts by the water management community.

Delivery of services will be enhanced by exchange of personnel with local water management agencies

The exchange programs will: 1) augment RFC Staff, 2) provide input from end users, and 3) make end users more knowledgeable about services

Advanced Observations (Budget Item 1(C))

High-quality operational input data are crucial to WARFS products

Planned NWS programs will provide a wealth of data

Adequate resources are needed to integrate observations into water resources forecasting

Two aspects of delivering high-quality WARFS services have been addressed above. We need accurate, well-calibrated hydrologic models, and we need trained people to use the models. One final critical piece must be added. We also need high-quality operational input data. Other NOAA initiatives provide resources for technical advances in observations (especially ASOS and NEXRAD). Other Federal, State, and local agencies also provide crucial observational data. In the data-rich advanced technology environment of the 1990's, there is a tremendous opportunity to improve estimates of rainfall and snow (as well as other hydrologically significant data). This potential can only be realized, however, if adequate resources are available to integrate observations from various observing systems for maximum cost-effectiveness in improving the hydrometeorological input used for water resources forecasting. WARFS will integrate the Nation's observational resources through several mechanisms including: 1) supporting a national real-time precipitation data base, 2) providing planning for real-time hydrometeorological data networks, and 3) supporting the upgrade of sensors in other agency networks to meet NOAA needs.

ESP Data Base (Budget Item 1(D))

New observing systems and hydrologic techniques require enhanced data management

The Extended Streamflow Prediction (ESP) procedure (described in detail in Section VI) is the fundamental technological component which provides NWS long-range hydrologic forecasting capabilities. The procedure has been applied on a limited basis at several sites (including the Potomac River Basin and the Chattahoochee River Basin in Georgia). Implementing ESP nationwide will impose an additional load on the NCCF (NOAA Central Computer Facility). Costs of meeting the additional processing and data storage requirements of ESP will be covered under the Initiative.

Service Support

Activity under this component is directed toward supporting the integrated hydrologic forecast system needed to provide WARFS services. As shown in Figure 3, service support costs are stable over the long term. The major support activities include: 1) development of procedures to integrate a variety of snow observations (satellite, airborne, and ground-based); 2) completion of multiple sensor precipitation estimation procedures (NEXRAD, rain gages, and satellite); 3) enhancements to extended streamflow prediction procedures to satisfy benchmark WARFS service requirements; 4) development of climatological forecast procedures and interfaces to the ESP procedure; 5) development of more precise models of orographic precipitation and incorporation of these procedures into operational precipitation estimation; 6) improvements in precipitation frequency analyses and their integration into ESP; and 7) improving the spatial and temporal scales at which hydrologic models are applied. Currently, the minimum temporal scale is approximately six hours and the minimum spatial scale is approximately 200 square kilometers for RFC modeling. The temporal scale of advanced observations will be one hour or less, and the spatial scale will be approximately 20 square kilometers.

Integration of data from planned advanced observing systems with existing experimental techniques

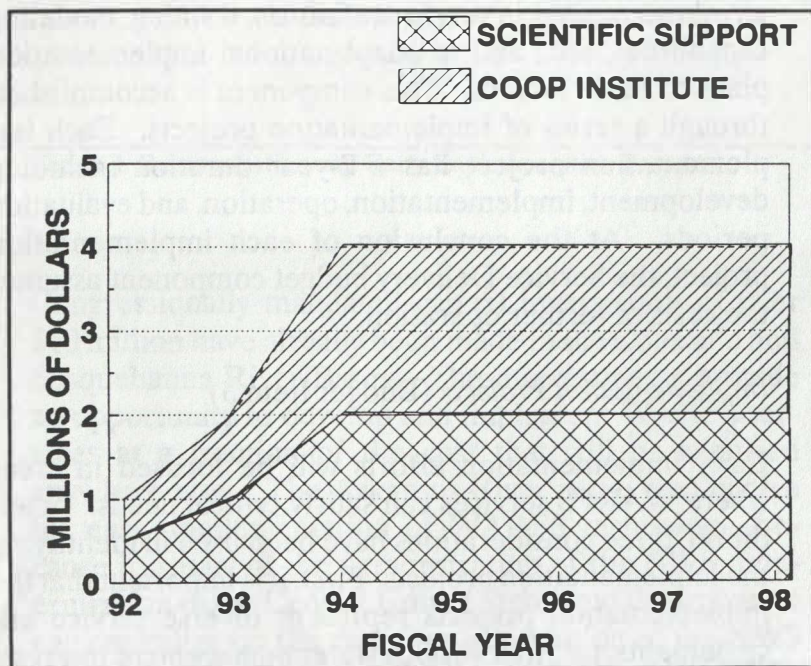


Figure 3. Cost Profile for Service Support Component

Scientific Support and Cooperative Institute (Budget Items 2(A) and 2(B))

Cooperative Institute

- NWS, Universities,
- Private Sector
- Research & Development
- Technology Transfer

It is proposed that the scientific support activities for WARFS be met by a combined effort of NOAA research and development (R&D) groups (including the Hydrologic Research Laboratory, the Water Management and Information Division, the National Operational Hydrologic Remote Sensing Center, the Climate Analysis Center, and potentially other NOAA scientific components), private sector interests, and a Cooperative Institute established at a university (or among a consortium of universities). The Cooperative Institute will not only carry out R&D initiatives, it will also serve as a testing ground for R&D activities of all groups. The Cooperative Institute will be closely involved in transferring R&D support activities to operational implementation. It will include participation by cooperating agencies and private sector interests.

Early Implementation

Implementation projects will provide: 1) selective early implementation, and 2) opportunities to refine technology and initial delivery of services

The purpose of the Early Implementation budget component is to quickly implement the WARFS technology in critical areas; to achieve significant benefits from improvements in services as soon as possible; to determine any shortcomings in service definition, training, modeling capabilities, etc.; and to adapt national implementation plans to these lessons. This component is accomplished through a series of implementation projects. Each implementation project has a 2-year duration including development, implementation, operation, and evaluation periods. At the conclusion of each implementation project, the Service Delivery budget component assumes the costs of further operation.

Implementation Projects (Budget Item 3)

Five 2-year implementation projects will consider diverse water management interests over a wide range of geographic and hydroclimatic areas

Early implementation efforts will be focused in areas where WARFS services can satisfy critical needs. In addition, three considerations have been used in identifying the implementation projects. First, it is important that the implementation projects represent diverse service environments, i.e., that various water management interests (water supply, riverine navigation, hydropower, flood

control, irrigation, fisheries, and wildlife management, etc.) be considered. Second, physiographic and climatic diversity is important. Finally, it is desirable that the implementation projects be geographically distributed to place at least one in each NWS administrative region. (Of course this objective is complementary to the second.) The selected implementation projects are shown in Figure 4. A more complete justification of the selection of implementation projects is given in the WARFS Program Development Plan (May 1986). As shown in Figure 5, costs associated with this component are short-lived.

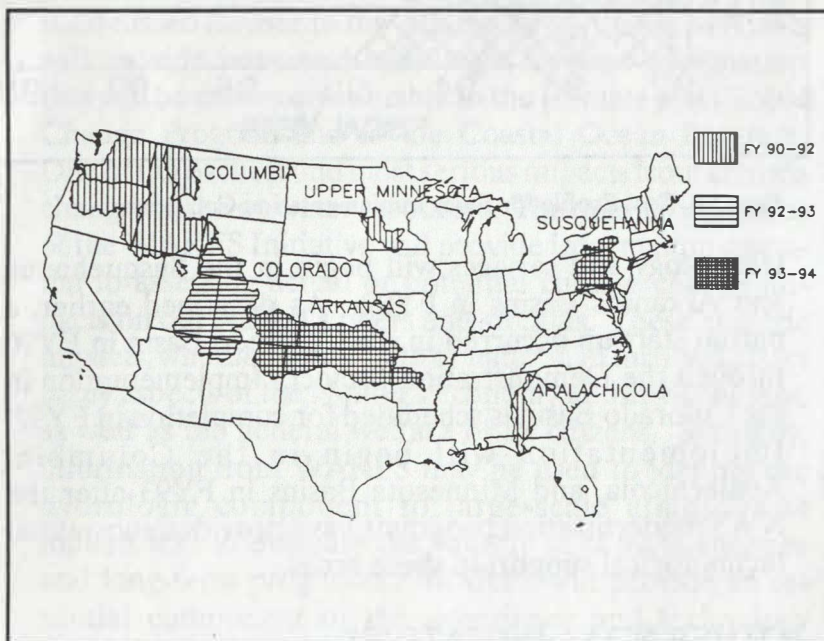


Figure 4. Demonstration and Early Implementation Projects

Congressionally mandated capital investments of over \$10 million have already been made in the Colorado and Susquehanna River Basins. These investments provide an opportunity to develop and implement WARFS services at a fraction of the cost that will be required anywhere else. The Arkansas River is the next choice for early implementation of WARFS technology, because it is part of the demonstration of the NWS modernization in the Central United States and the Initiative can capitalize on the early implementation of the NWS modernization programs. Implementation of WARFS

FY90-92 Demonstration:

- Colorado River Basin

FY92-93 Implementation:

- Susquehanna River Basin
- Arkansas River Basin

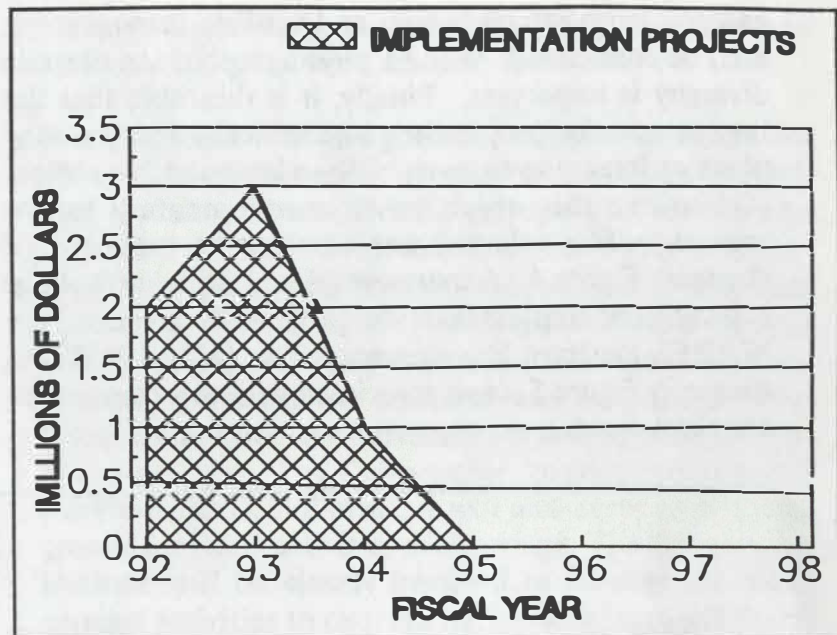


Figure 5. Cost Profile for Early Implementation Component

FY93-94 Implementation:

- Columbia
- Apalachicola
- Minnesota

technology and services will begin in the Susquehanna and Arkansas Basins in FY92. As described earlier, a partial start-up occurred in the Colorado Basin in FY90 through the Demonstration Project. Implementation in the Colorado Basin is scheduled for completion in FY92. Implementation will begin in the Columbia, Apalachicola, and Minnesota Basins in FY93 after the NWS modernization programs have provided substantial technological support in these areas.

OTHER NOAA INITIATIVES

WARFS Initiative complements and takes advantage of major NOAA programs associated with NWS modernization

This Initiative has been coordinated with other NOAA initiatives to ensure that plans are complementary and supportive across NOAA and that a duplication of effort is avoided. Major NOAA initiatives support the NWS modernization program which provides technological support for WARFS and for the NWS Hydrologic Services Program in general. Initiatives related to NWS modernization include the basic technological modernization programs (NEXRAD, Class VII Computers, ASOS, GOES NEXT, AWIPS), as well as support for demonstration of a modernized NWS under the Modernization and Associated Restructuring Demonstration Initiative (MARDI). The relationship of this Initiative to

NOAA technological improvements is described in Section VI below. MARDI will provide support in the demonstration area for all NWS service programs including hydrologic services, but is not based on and does not directly support the additional services to be supported by this Initiative.

The WARFS Initiative depends on and provides information to other technological programs in the global climate and environmental information areas and will contribute to coastal initiatives aimed at improved estuary and fisheries management. The relationship between WARFS and other major NOAA program thrusts is discussed further in the Annex. In particular WARFS will provide improved hydrologic forecast information that will be extremely valuable to the Climate and Global Change Program and to the Coastal Ocean Program. One of the earliest and most serious impacts from climate change will be on water resources. The operational focus of the WARFS Initiative will provide information essential to assessing actual or potential climate change impacts on our Nation's rivers and streams. These climatic impacts, whether man-made or natural, in turn will affect many aspects of the Nation's economy and environment, as well as the general welfare of its citizens. Similarly, information from WARFS may be used to identify the hydrologic component to large-scale atmospheric models and to evaluate the validity of climate analyses and long-term prognoses. WARFS will provide an essential component of the experience and technology needed to enable the Nation to manage the consequences of Global Climate Change.

Equally strong relationships exist between the WARFS Initiative and the Coastal Ocean Program, especially as related to estuarine areas. Solutions to better management of estuarine ecosystems, including fisheries management, are critically dependent on accurate assessments of fresh water levels and inflows. WARFS extended forecasts will enable more accurate assessments of future water balances as they relate not only to quantities but to salinity and pollutant concentrations.

NOAA-wide programs

- *Climate*
- *Environmental Information*
- *Coastal Zones*

WARFS will provide essential information for assessing important impacts of climate change

WARFS will identify water balance components important to water quality assessment

MAJOR OBJECTIVES BY YEAR

Major objectives and milestones of this Initiative for each fiscal year (1992-1996) are given briefly below:

Fiscal Year 1992

Develop training materials and plans for RFC exchange personnel. Complete WARFS demonstration on the Colorado River. Begin WARFS planning and implementation on the Susquehanna and the Arkansas Rivers. Expand data and hydrologic model calibration efforts. Select Cooperative Institute. Begin R&D/technology transfer. Begin Exchange Program at RFCs.

Fiscal Year 1993

Complete implementation projects in Susquehanna and Arkansas River Basins. Begin implementation projects on the Columbia, Apalachicola, and Minnesota River Basins. Continue calibration effort. Expand R&D/technology transfer and operation of Cooperative Institute. Continue Exchange Program.

Fiscal Year 1994

Complete implementation projects on the Columbia, Apalachicola, and Minnesota River Basins. Begin nationwide implementation. Continue calibration, R&D/technology transfer, and Cooperative Institute operation at full effort. Operate the Exchange Program at full funding.

Fiscal Year 1995

Complete initial phase of calibration effort. Begin phase-out of Initiative funding for Exchange Program. Continue R&D/technology transfer and Cooperative Institute operation.

Fiscal Year 1996

Continue operation of WARFS. (As shown in Figure 1, funding decreases to uniform level by FY98.)

WARFS cost-benefit analyses rely heavily on similar NEXRAD study

V. Benefits

The WARFS cost-benefit study relies heavily on the study of economic benefits of the NEXRAD system.

In the WARFS benefit study, the potential benefits of improved water resources information and flood forecasts which were estimated in the NEXRAD study

are used as the baseline from which total WARFS benefits are estimated. Two adjustments are required to translate potential benefits to WARFS benefits. The first adjustment is needed because only a portion of the potential benefits can be attributed to improvements brought about by WARFS (the remainder is due to other programs, such as NEXRAD). The second adjustment accounts for the reduction in potential benefits due to institutional and legal constraints in water management (these were not directly accounted for in the NEXRAD study).

NEXRAD cost-benefit analyses adjusted to ensure realistic evaluation

Benefits were estimated for five categories. Figure 6 shows the categories and percent of potential benefits represented by each category. Figure 7 gives the annual stream of estimated benefits (in 1990 dollars) for the WARFS Initiative. The estimated present value benefit stream rises rapidly, from less than one million dollars in FY92 to more than 60 million dollars annually in FY98.

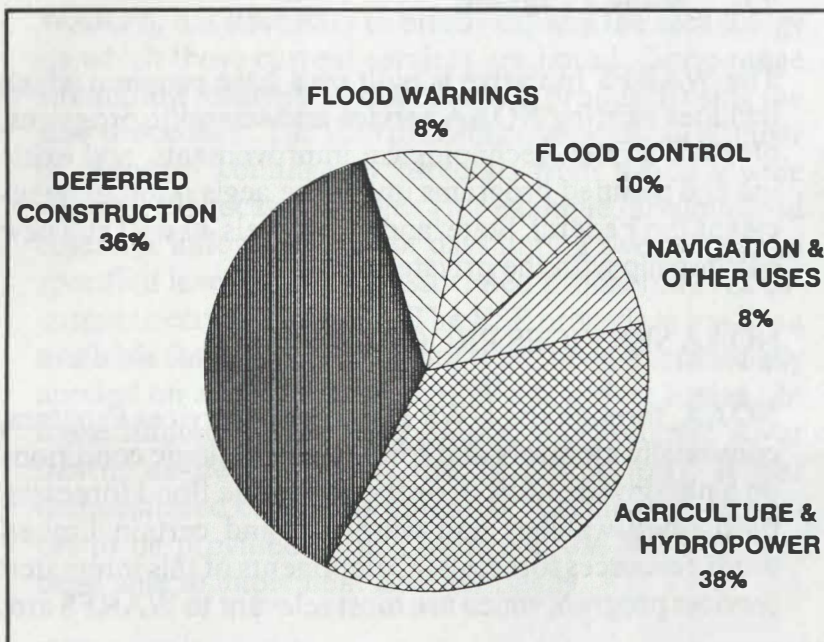


Figure 6. Benefit Categories for WARFS

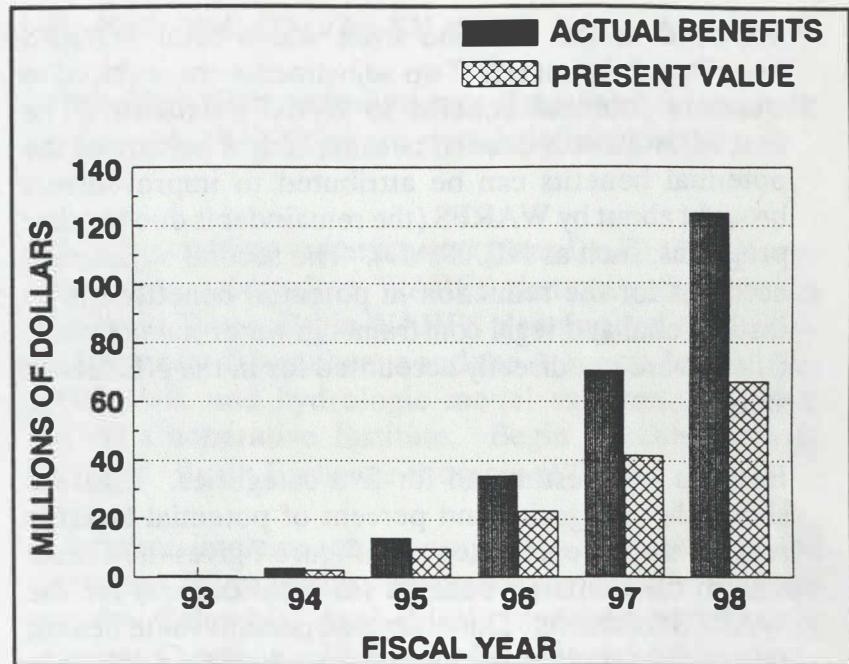


Figure 7. Annual Benefit Stream for the WARFS Initiative

VI. Base Program

WARFS based on existing and planned NOAA programs and cooperation with other Federal, State, and local organizations, and the private sector

Current NWS Hydrologic Services Program components that will serve as the basis for WARFS:

- Continuous data collection and flood forecasting nationally

The WARFS Initiative is built on a base program which includes existing NOAA service and scientific programs, planned NOAA technological improvements, and existing and planned programs under the aegis of other agencies at the Federal, State, and local levels, as well as a new partnership with the private sector.

NOAA SERVICES PROGRAMS

NOAA, through the NWS Hydrologic Services Program, continually monitors and forecasts hydrologic conditions on a nationwide basis in order to provide flood forecasts, flash flood watches and warnings, and certain limited water resources forecasts. Components of this integrated services program which are most relevant to WARFS are:

1) At approximately 3000 forecast points, most of which are on mainstem rivers, hydrologic conditions are monitored and forecast on a continuous basis. Flood forecasts for the Nation's 30,000 flood-prone communities are related to routine forecasts for these locations as conditions warrant. Since conditions must be

continuously monitored for flood forecast purposes, a very limited set of forecast products is produced for water management interests (e.g., reservoir operators, navigation interests) at some of these locations on a regular basis.

2) Monthly, long-term forecasts of water supply are produced at 760 locations. These are generally restricted to the snowmelt season and to the western United States and portions of New England. These water supply forecasts generally employ statistical regression-based procedures.

3) Seasonal snowmelt flood outlooks are prepared primarily for the Mississippi Valley and released twice a month in February, March, and April.

Aside from these three types of services, more sophisticated forecast services similar to WARFS are provided or planned for limited areas of the country. In order to understand the expansion of services proposed under WARFS, it is necessary to briefly explain the technology on which these current services are based. Long-range streamflow forecasts can be currently produced using the ESP procedure. The ESP procedure generates a number of potential contingency forecasts from which a wide variety of forecast variables (for example, accumulated reservoir inflow, number of days until a river exceeds a specified level) and their associated probabilities of occurrence can be extracted. The ESP procedure has been available for over a decade, but it has been operationally applied on a limited basis in only a few river basins. In these limited areas (for example, the Potomac River basin, as described in the Introduction), it has demonstrated enormous potential. Lacking the resources to be provided by this Initiative, the NWS has not been able to implement ESP nationally.

ESP techniques improve the accuracy of the forecast by providing better daily simulation of rapid snowmelt and the effects of daily hydrologic and weather changes. Using physically based models, ESP can account for extreme hydrologic conditions and unusual weather patterns, while the purely statistical models currently used for seasonal water-supply forecasting cannot. ESP can also reflect short-term and long-term peaks and volumes

- Limited regional water supply forecasting

- Seasonal snowmelt flood outlooks for the Mississippi Valley

Limited resources have precluded implementation of Extended Streamflow Prediction (ESP) procedures which serve as a major component of WARFS

ESP procedures have proven cost-saving potential in demonstration projects

ESP procedures provide: 1) better physical simulation, 2) ability to account for extreme conditions, and 3) quantification of forecast reliability

ESP procedures will allow more refined water management

Congressional concern with water management issues evidenced by numerous special appropriations

Improvements in water management also enhance operational flood forecasting

WARFS capitalizes on NEXRAD, ASOS, and AWIPS

NEXRAD and ASOS will provide enhanced data

and their probabilities of occurrence, while statistical techniques cannot. Other types of information are also available using ESP, e.g., projected days of flow above or below a given level.

Products generated from ESP procedures permit the NWS to: 1) provide continuous predictions of the time and volume distribution of water, and 2) provide both short-term and long-term streamflow predictions and associated probabilities for a wide range of hydrometeorological conditions, so that water managers can investigate various management strategies.

Congressional concern has been demonstrated by special appropriations for the Colorado River Basin beginning in 1984 and 1985 and in the Susquehanna River Basin beginning in 1986. These special appropriations served as the resource base for implementing and, to a lesser extent, maintaining data collection and flood forecasting enhancements in these basins. In these areas, as well as on the Potomac, Apalachicola, and Minnesota River systems, enhanced water resource forecast procedures have only been developed and operated on a limited basis.

Although the WARFS service objective is focused on water resources forecasts, the modeling systems and data analyses advances, and the expansion of forecast locations supported by this Initiative will be fully integrated into the NWS Hydrologic Services Program. As a result, improvements in the accuracy and value of flood and flash-flood forecasts will be, in fact, an automatic positive result of WARFS.

NOAA TECHNOLOGICAL IMPROVEMENTS

WARFS capitalizes on three major planned NOAA technological improvement programs: NEXRAD, ASOS, and AWIPS.

The NEXRAD and ASOS programs will provide much of the necessary technology to observe precipitation amounts on a nationwide basis at the temporal and spatial resolution required. Achieving the required accuracy of precipitation estimates, however, will require data management, integration, and analysis procedures which

employ not only the network of precipitation gages to be provided by ASOS [and its counterparts in the Federal Aviation Administration (FAA) and Department of Defense (DOD)], but also a large variety of precipitation data sources from other Federal, State, and local gage networks.

NEXRAD computers will complete the first stage of organizing, processing, and analyzing the radar data in combination with network gage data. Much of this software has already been developed. The second stage of analysis and processing will take place in the AWIPS system where data from other sources will be formatted, processed, and then merged with the NEXRAD-processed data. AWIPS will also accomplish a third stage of processing at the RFCs in which data fields for one geographic area will be joined with data fields from adjacent areas to form large area mosaics of rainfall data. Processing and integration of snow observations from ground measurements and remote sensors (satellite and aerial gamma radiation) are also important, and complex extensions to the precipitation processing requirements.

The AWIPS system provides a modern interactive processing environment which is essential to WARFS, because it will be the center of all forecast operations in an office. Data analysis, forecast modeling, and product formulation will be carried out interactively at modern workstations, providing forecasters with a milieu for efficient and timely development of WARFS products and services. The enhanced communication capabilities available with AWIPS are also needed to provide for expanded exchange of information among NWS offices.

The existing NOAA Family of Services and its planned successors will provide the data and information sources to serve the needs of the private sector for the benchmark water resources forecasts and information provided by WARFS.

COOPERATIVE PROGRAMS

In addition to existing NOAA service and science programs, and associated planned technological improvements, various cooperative programs (involving contributions by Federal, regional, State, and local agen-

Major data management/analyses effort required to optimally use enhanced observing systems along with other data sources

NEXRAD data processed in AWIPS system

Capabilities of AWIPS are crucial to implementation of WARFS

Dissemination of WARFS products via NOAA Family of Services

Cooperative programs key to WARFS

Stream gage network operated and maintained by the USGS with financial support from Federal, State, and other sources

Water resources assessment provided by USGS complements WARFS

The NWS Hydrologic Services Program depends on non-NWS stream gage networks

cies and the private sector) form the foundation of WARFS. The cooperative stream-gaging program is one of the most crucial of these programs to WARFS.

The actual operation and maintenance of the national network of stream gages and their record of flows is the mission of the U.S. Geological Survey (USGS). This is a multi-purpose network, i.e., stream gages are installed not only to serve real-time forecasting needs but also to monitor sediment and water quality, to serve special needs of the states or localities in which they are situated, and to record the inflows and outflows of reservoirs. The USGS operates and maintains the network, but costs are shared among the USGS, State and local governments, Bureau of Reclamation (Department of the Interior), U.S. Army Corps of Engineers (Department of Defense), and others. Federal agencies negotiate agreements each year for services at specific gages and transfer funds to the USGS for these services. The states and local jurisdictions similarly negotiate agreements; their funds are matched by Congress and given to the USGS. Funding arrangements can be quite complex when various agencies require different services at a specific gage. Approximately \$40 Million were spent by USGS in FY 1984 for maintaining the network and collecting and processing the streamflow data. Of this \$40 Million, approximately \$11 Million were contributed as the local share.

A close tie exists between the NWS and the USGS, since the USGS is the principal source of streamflow information. In addition to this tie, the USGS is the premier Federal agency with the responsibility for overall assessment of the status of the Nation's groundwater and surface water resources. This responsibility provides critical complementing activities to WARFS. The relationship between the NWS and the USGS is also discussed in the Annex.

NWS receives virtually no funds for the operation and maintenance of streamflow gages, and many of the network's functions are outside the basic NWS mission. Although the recurring costs of such a program are

prohibitive for the NWS, the Hydrologic Services Program of the NWS and the WARFS Initiative are dependent on the continuation of the cooperative stream gaging program.

In addition to the interagency support NWS receives in the stream gaging programs, many other agencies and parties contribute to the Nation's snow and precipitation data bases. For example, the snow data collection programs of the Soil Conservation Service (SCS) of the Department of Agriculture require about \$4 Million/year. The costs of precipitation data collection are widely dispersed through the Federal, State, and local levels (in fact, they include significant volunteer efforts by private citizens), but are well in excess of \$20 Million/year.

Strong cooperation and complex interdependencies exist between NOAA's hydrologic services program and the many diverse organizations that manage the Nation's water. NOAA has the responsibility of forecasting the state of the Nation's rivers and streams for the protection of life and property and in support of the economy. This necessitates the maintenance of a continuous river watch and integrated forecasting system for the entire country. In addition, knowledge of the current status and planned operations of the reservoirs, locks, and other control facilities along the Nation's waterways is essential in forecasting river conditions downstream of these facilities. Likewise, it is impossible for water management agencies to make the best decisions concerning operation of water control facilities without knowledge of current and forecast meteorological and hydrological conditions. The WARFS Initiative does not eliminate the requirement that water management agencies locally maintain their own hydrologic modeling procedures for facility operation, but it will provide improved forecasts and forecast reliability information that is critical for efficient operation of these facilities. The partnership between NOAA and the Nation's water managers is also discussed in the Annex.

Essentially every agency in the water resources community is in some stage of automating their real-time data resources. It is essential to WARFS that the NWS be in a position to exchange information with Federal, State,

Additional key snow and precipitation data come from non-NWS sources

Complex relationships exist between NOAA and water management agencies

Interagency plans are in place for coordination of data exchange

and local agencies in an efficient, automated manner and to provide benchmark services to the private sector for value-added marketing. This exchange requires close cooperation among agencies in acquiring, processing, and to a lesser extent, in analyzing water resources data. The NWS participates in individual Memoranda of Understanding with the COE, the SCS, and the USGS for computer-to-computer data exchange and helps set the standards for automated real-time water data exchange among all Federal agencies through the Office of Water Data Coordination of the Department of Interior.

VII. Alternatives

Current collaborative funding arrangements are inadequate to support WARFS implementation

Resource sharing through collaboration and cooperation with other Federal, State, and local agencies is a major part of the proposed program. Hydrometeorological forecasting services are a significant part of the program responsibility of NOAA, and current funding mechanisms are insufficient to meet the Nation's needs for improved Water Resources Forecasting Services. Requests for significant increases in financial support from current collaborators could jeopardize existing cooperative arrangements.

Piecemeal funding such as Congressional additions, is not cost effective:

Piecemeal approaches to funding, such as the recent Congressional add-ons for the Colorado and Susquehanna River Basins, are costly, non-permanent solutions to a national problem which looms even larger as we look to the future. These individual solutions are less efficient than funding a national program because they:

- duplication

1) require duplicate resources for planning multiple efforts;

- difficult after-the-fact integration

2) force after-the-fact integration into other NWS technologies and programs, often requiring cumbersome interfaces;

- failure to fully capitalize on modernization

3) encourage costly localized additions such as radars and computers which should be covered by the major NWS modernization programs;

4) impose special maintenance and recurring costs on the national program;

- maintenance not covered when add-on ceases

5) discourage a national approach to water policy issues, concentrating only on regional solutions; (Thus, the NWS is continually faced with regional adjustments to programs because of non-standard interagency interfaces in hardware and in software, and product formulation and distribution.)

- regional projects that diffuse efforts to coherently treat water policy issues from a national perspective

6) result in continued deficient resources to most effectively coordinate the real-time exchange of data and forecast information between NOAA and cooperating water resources agencies; and

- problems in coordination between NOAA and cooperators

7) fail to establish the required basic data and benchmark forecast information to foster a strong private sector role.

- hindrance in development of a strong private sector role

Failure to act on this Initiative will forego opportunities to: improve the efficient use of the Nation's critical water resources and produce significant economic benefits; discourage the further development of expensive piecemeal regional solutions to a nationwide problem; enhance the Nation's ability to anticipate and manage the effects of significant climate variations such as drought; and assume a fundamental Federal responsibility to ensure that the Nation's water resources are used wisely. Deferring action on this Initiative will not only defer substantial benefits but also further complicate integration of WARFS with planned NOAA technological improvements and serve to further convince regional interests that their water resources forecasting needs are not a national priority.

Failure to act will result in:

- lost benefits
- piecemeal approaches
- complicated integration of WARFS with planned NOAA technological improvements

VIII. Resource Summary

Table 1 summarizes the current and future year costs for the program. The current and future year costs are structured as described earlier. Federal funding must be provided on a recurring basis to maintain the forecast system on which the service program is based. Without such recurring funds the program is not viable.

Continued Federal funding of forecast system essential to viability of program

TABLE 1
WARFS Summary Budget
(Millions of Dollars)

	Fiscal Year									
	Demonstration		Initiative							Initiative
	90	91	92	93	94	95	96	97	98	TOTAL
1. Service Delivery										
A. Advanced Modeling	0.2	0.7	1.0	2.5	5.0	4.2	2.5	1.9	1.5	18.6
B. Personnel Exchange Program	0.0	0.0	0.6	1.5	2.4	2.1	1.8	1.4	1.1	10.9
C. Advanced Observations	0.1	0.2	0.4	0.5	1.4	1.5	1.5	1.5	1.2	8.0
D. ESP Data Base	0.0	0.0	0.0	0.5	0.2	0.2	0.2	0.2	0.2	1.5
Subtotal, Service Delivery			2.0	5.0	9.0	8.0	6.0	5.0	4.0	39.0
2. Service Support										
A. Scientific Support	0.2	0.5	0.5	1.0	2.0	2.0	2.0	2.0	2.0	11.5
B. COOP Institute	0.0	0.0	0.5	1.0	2.0	2.0	2.0	2.0	2.0	11.5
Subtotal, Service Support			1.0	2.0	4.0	4.0	4.0	4.0	4.0	23.0
3. Early Implementation	0.6	0.8	2.0	3.0	1.0	0.0	0.0	0.0	0.0	6.0
TOTAL	1.1	2.2	5.0	10.0	14.0	12.0	10.0	9.0	8.0	68.0

Annex

WATER RESOURCES FORECASTING SERVICES RELATIONSHIPS

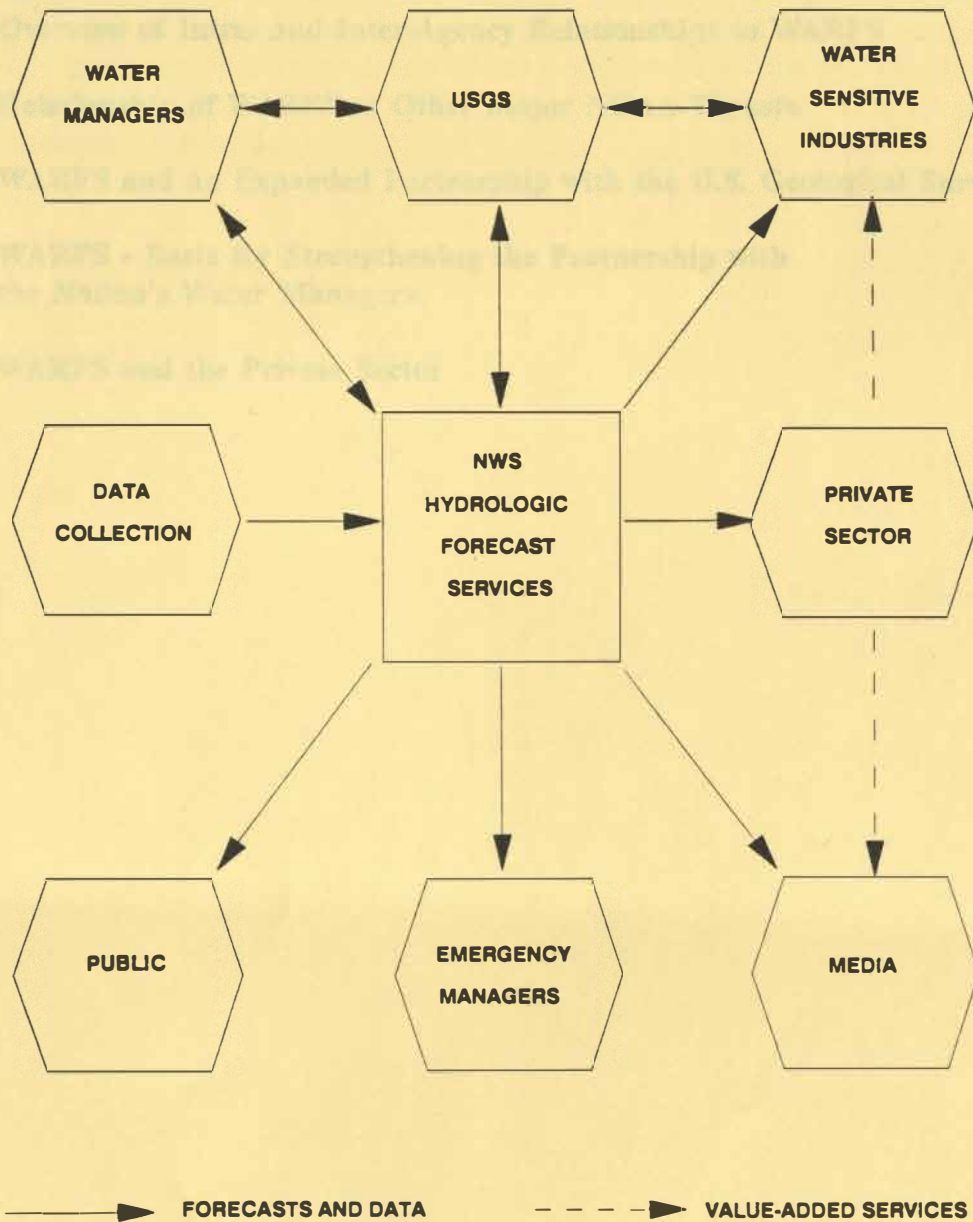


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- v. WARFS - Basis for Strengthening the Partnership with the Nation's Water Managers**
- vi. WARFS and the Private Sector**

i. Preface

The material contained in this Annex provides additional information on the relationships of WARFS to other major programs and cooperators. In some cases the material is partially redundant with that contained in the main body of the Issue Paper, but it provides an increased emphasis on particular aspects of certain WARFS interrelationships. In other cases, the material presented in the Annex complements that in the main body of the Issue Paper. It is not intended to be all inclusive in the discussions of WARFS interfaces, but when viewed collectively with the remainder of the Issue Paper, this Annex should provide a reasonable level of understanding of the most significant interfaces.

- i. providing data and technical support during droughts
- ii. carrying out water conservation
- iii. planning for water supply
- iv. controlling water pollution and
- v. carrying out numerous other water programs in states.

Because of the diverse nature of the many agencies and the various tasks involved associated with water resources, it is imperative that the Federal, state, and local governments work closely together. The close cooperation is needed in addition to planning, development, individual actions, and other programs water-related activities for the mutual benefit of all agencies concerned, as well as for the general public.

Among many water-related activities, there is an increased emphasis on the need to better manage our Nation's water resources. This fact is illustrated by the current growing emphasis on water conservation, as evidenced by the many law groups and studies underway which call for an individual agency program and program areas. Some of these activities are:

- b. The Interagency Working Group on Data Management for Climate Change
- c. The Cooperative in Earth Science and the National Water Quality Assessment Program focused on carrying activities in specific individual water resources areas.

ii. Overview of Intra- and Inter-Agency Relationships to WARFS

The monitoring, assessment, management, and prediction of our Nation's water resources are achieved through a complex infrastructure of participants and cooperators. These include Federal, state, multi-state, and quasi-governmental agencies, river basin commissions, municipalities, and local interests.

Federal agency responsibilities include:

- o planning, designing, constructing, and operating water projects;
- o providing river and flood forecast warning services;
- o assessing existing water resources;
- o planning for water supply;
- o controlling water pollution; and
- o carrying out numerous other water resources functions.

Because of the diverse missions of the many agencies and the complexities of activities associated with water resources, it is imperative that the Federal, state, and local governments work closely together. This close cooperation is needed to minimize duplications, complement individual actions, and share common water-related experiences for the mutual benefit of all agencies concerned, as well as for the general public.

Among many water resources agencies, there is an increased awareness of the pressing need to better manage our Nation's water resources. This fact is illustrated by the current growing emphasis on water resources issues, as evidenced by the major task groups and studies underway which cut across individual agency missions and program areas. Some of these activities are:

- o The Interagency Working Group on Data Management for Global Change;
- o The Committee on Earth Sciences and the National Water Quality Assessment Program (pursuant to ongoing activities to resolve individual water resources issues);

- o U.S. Army Corps of Engineers Drought Management Study Team;
- o Western Governors Association Development of Water Related Drought Strategies; and
- o Federal Government Investment in Ground Water Research, as shown in the table below.

Water data monitoring generally fills one or more of three functions: 1) to monitor compliance with laws, 2) to determine changes in status (water quality, quantity, etc.) or 3) to serve as a basis for making management decisions. Hydrologic forecasts significantly enhance the capability for making reasonable decisions for future actions.

NOAA and DOC clearly have the protection of life and property and support of the Nation's economic welfare as an important part of their mission. Prediction services to support the water resources community are a vital part of this mission. The figure on the first page of the Annex and the sections of the Annex that follow, describe (together with the information listed in the main body of this document) the relationships of WARFS to some of the most significant cooperators.

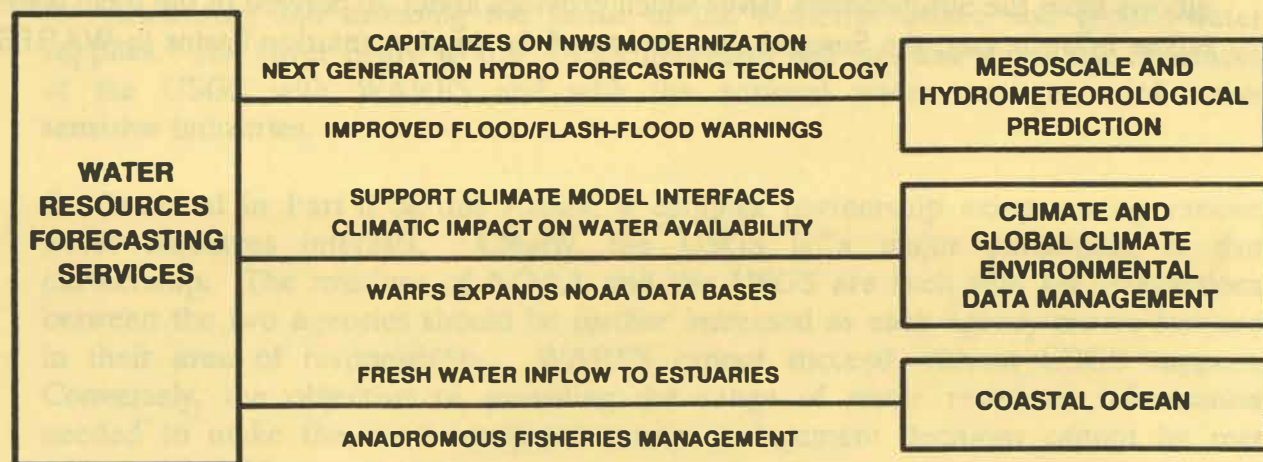
Cumulative investment (in millions of dollars) by Federal agencies over the fiscal years 1986-90.

Department of Interior	\$ 442.8
Department of Agriculture	217.3
Environmental Protection Agency	90.3
Department of Energy	57.9
Department of Defense	27.1
National Science Foundation	25.4
National Aeronautics and Space Administration	14.2
Total	\$ 875.0

iii. Relationship of WARFS to Other Major NOAA Thrusts

As explained in some detail in the main body of the Issue Paper, the Program Development and Analysis Plan, the ADP Concept Study, the Cost/Benefit Analysis, and various briefing packages, NWS modernization goals are integral to the successful implementation of WARFS technology as are the collaborative and cost-sharing activities of many other governmental, quasi-governmental, and private sector organizations. The external relationships also are discussed in some additional detail in the other parts of this Annex. What is not explained at the same level of detail is the relationships between WARFS and other high priority DOC/NOAA programs. These are the Climate and Global Change, Coastal Ocean, Mesoscale Weather Prediction, and Management of Environmental Data programs. The figure below illustrates the linkages between WARFS and these priority program areas.

It is now accepted by scientists, engineers, and policy makers alike that improved management of the quality and distribution of our Nation's fresh water resources is one of the top priorities of the country. WARFS offers solutions to the critical component needed to meet this national challenge -- improved hydrologic forecast information. WARFS is based on the implementation of proven advanced data and modeling technology, leading to a new generation of service products. The payoffs from WARFS will be immediate and large, and WARFS' relationships to the Climate and Global Change and Coastal Ocean Programs are direct and mutually supportive.



One of the earliest and most serious impacts from climate change will be on water resources. The drought of 1988 vividly brought home this fact. The operational focus of WARFS will provide information essential to assessing actual or potential climate change impacts on our Nation's rivers and streams. These climatic impacts, whether man-made or natural, in turn will affect many aspects of the Nation's economy and indeed the general welfare of its citizens.

A primary objective of the Climate and Global Change Program is to improve our understanding of global hydrologic processes through participation in the international Global Energy and Water Balance Experiment (GEWEX). Information from WARFS will provide extremely vital inputs to GEWEX, including information needed by scientists to better evaluate the validity of their analyses and long-term prognoses. As advances are made in the Climate and Global Change Program, WARFS will translate them into improved water resources information products. Clearly WARFS also will support the Management of Environmental Data Program by providing expanded and better managed hydrometeorological data bases to complement other environmental data managed by NOAA. WARFS will also be a user of improved data services.

Equally strong relationships exist between WARFS and the Coastal Ocean Program, especially as related to estuary areas. Solutions to better management of estuarine ecosystems, including fisheries management, are critically dependent on accurate assessments of fresh water levels and inflows. WARFS extended forecasts will enable more accurate assessments of future water balances as they relate not only to quantities but to salinity and pollutant concentrations. For example, seasonal prognosis of ecosystem conditions in the Chesapeake Bay requires advance knowledge of expected inflows from the Susquehanna River which provides about 70 percent of the fresh water inflow into the bay; the Susquehanna is one of the implementation basins in WARFS.

iv. WARFS and an Expanded Partnership with the U.S. Geological Survey

NOAA and the U.S. Geological Survey (USGS) are the principal Federal government agencies responsible for observation, assessment, and prediction of the various components of the hydrosphere. A description of the USGS's role in management of the Nation's stream gaging network and its critical importance to the WARFS Initiative is discussed in some detail in the main body of the WARFS Issue Paper (section VI). Other areas of cooperation, which represent complementing or supporting activities to WARFS, will be discussed briefly here.

NOAA and the USGS have enjoyed an excellent relationship through the years. Close coordination is maintained at the national level through meetings between top NOAA and USGS officials on the Interagency Committee for Program Coordination (ICPC). These meetings occur about twice a year. In addition, the subcommittee on hydrology convenes quarterly between top managers of the hydrology programs of both agencies. A research coordination meeting is held between the two agencies every two years. Finally, the two agencies coordinate a wide range of activities and work toward problem solutions through the interagency coordination offices of the two agencies. The principal coordination offices are the Office of the Federal Coordinator for Meteorology (OFCM) and the Office of Water Data Coordination (OWDC) which are hosted by NOAA and the USGS, respectively.

The above coordination mechanisms, and others, provide the means for close cooperation between the two agencies. The USGS is the primary Federal agency for monitoring and assessing the status of the Nation's surface and ground-water supplies. The cover figure to this Annex illustrates this fact and shows the interfaces of the USGS with WARFS and with the national water managers and water sensitive industries.

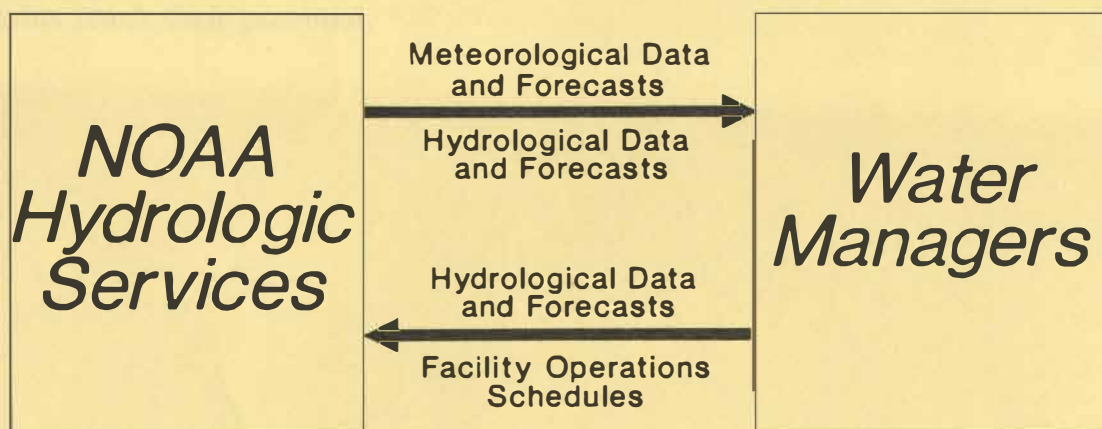
As discussed in Part ii of this Annex, a complex partnership exists among various water resources interests. Clearly, the USGS is a major participant in this partnership. The missions of NOAA and the USGS are such that the interactions between the two agencies should be further increased as each agency moves forward in their area of responsibility. WARFS cannot succeed without USGS support. Conversely, the objective of providing the range of water resources information needed to make the most intelligent water management decisions cannot be met without WARFS-type forecasts.

On a "global" scale, exchanges between the two agencies of information pertaining to a variety of environmental problems should substantially grow. A good example of this is illustrated by the recent increased concern with climate and global change. Clearly, consideration of processes taking place in the hydrosphere must include atmospheric, as well as land (and ocean) water phases. Simply stated, finding solutions to many of our "global" environmental problems will forge closer ties between NOAA and the USGS.

v. WARFS - Basis for Strengthening the Partnership with the Nation's Water Managers

Who are the Nation's water managers? A handful of Federal government agencies including the **U.S. Army Corps of Engineers**, the **Bureau of Reclamation**, the **Soil Conservation Service**, and the **Tennessee Valley Authority** come to mind immediately as operators of major water control projects. But there are literally hundreds of Federal, regional, State, and local organizations which control the use and flow of water in our country. Efficient management of the Nation's water requires close cooperation within this water management community, and this leads to strong interdependencies. Agencies rely heavily on one another for the exchange of data, reservoir release information, and weather and river forecasts. Although NOAA does not control or regulate water supplies, it is already a part of this interdependent water management community, and it will use the Water Resources Forecast Services (WARFS) initiative to expand this relationship and to strengthen the NOAA contribution to this partnership.

The interdependent nature of NOAA's Hydrologic Services Program and the Nation's water managers is depicted in the diagram below. To forecast river and flood conditions it is essential to know the current status and planned operations of the reservoirs, locks, and other control facilities along the Nation's waterways. Likewise, to make the best decisions concerning operations of water control facilities, it is essential to know current and forecast meteorological and hydrological conditions.



Both NOAA and the Nation's water managers operate hydrologic modeling and forecasting procedures. NOAA's procedures must provide complete national coverage for the time and space scales that are appropriate for its mission. However, NOAA cannot begin to meet all of the Nation's needs for hydrologic modeling expertise in support of water facility operators (even if WARFS were expanded tenfold). Each water manager needs hydrologic modeling components imbedded in their procedures in order to make operating decisions within their project area, but none of the Nation's water managers have NOAA's combination of national coverage, round-the-clock operation, meteorological monitoring and forecasting expertise, and contacts with the media and emergency response agencies. Each partner has an important role in assuring efficient management of the Nation's water resources.

WARFS proposes no radical surgery in the relationship between NOAA and the Nation's water managers. Rather WARFS proposes to build a more effective partnership between NOAA and the Nation's water managers. WARFS will do this by: 1) installing proven hydrologic forecast procedures that take full advantage of other technological modernization programs of NOAA, 2) providing improved forecasts at all time scales, but especially those of interest to water managers, 3) providing forecast reliability information critical to risk-based decision making, and 4) inviting full, working-level participation by the water management community in NOAA River Forecasting Centers.

vi. WARFS and the Private Sector

The fundamental service objective of the WARFS Initiative is to expand the information base for making water resources decisions. Specifically, WARFS will provide a benchmark level of water resources forecasting services to the Nation's water managers and planners. This benchmark level of services will allow the Nation's water managers and planners to act from a common information base, and it will also provide the basis for a private sector industry which serves particular water resources forecast needs of individual users. The benchmark level of services will be provided at specific forecast points in a river basin and for specific forecast horizons. The density of forecast points, lengths of the forecast horizons, frequency of forecast updates, and format of the forecast products will vary from one river basin to another because of differences in climatology and physiography, sizes of the basins and storage capacities of the reservoirs, and the water uses in the basins. The need to adapt benchmark services to different regional needs should not be confused with providing tailored industry-specific forecasts, which is a private sector role.

A partnership between NOAA and the private sector is essential, since it is only through the delivery of specialized services by the private sector that the full benefits of WARFS can be realized by the Nation's water managers. WARFS benchmark guidance information will be available to private, value-added, service companies. In turn, they will tailor the WARFS information and combine it with information from other sources to serve the interests of individual users at specific sites. Examples of those served include navigation companies, industrial and construction sites along the river, irrigation companies, hydropower companies, etc. In addition to encouraging investment by the private sector, WARFS will develop a partnership between NOAA and the private sector that will ensure that the WARFS benefits reach their potential.