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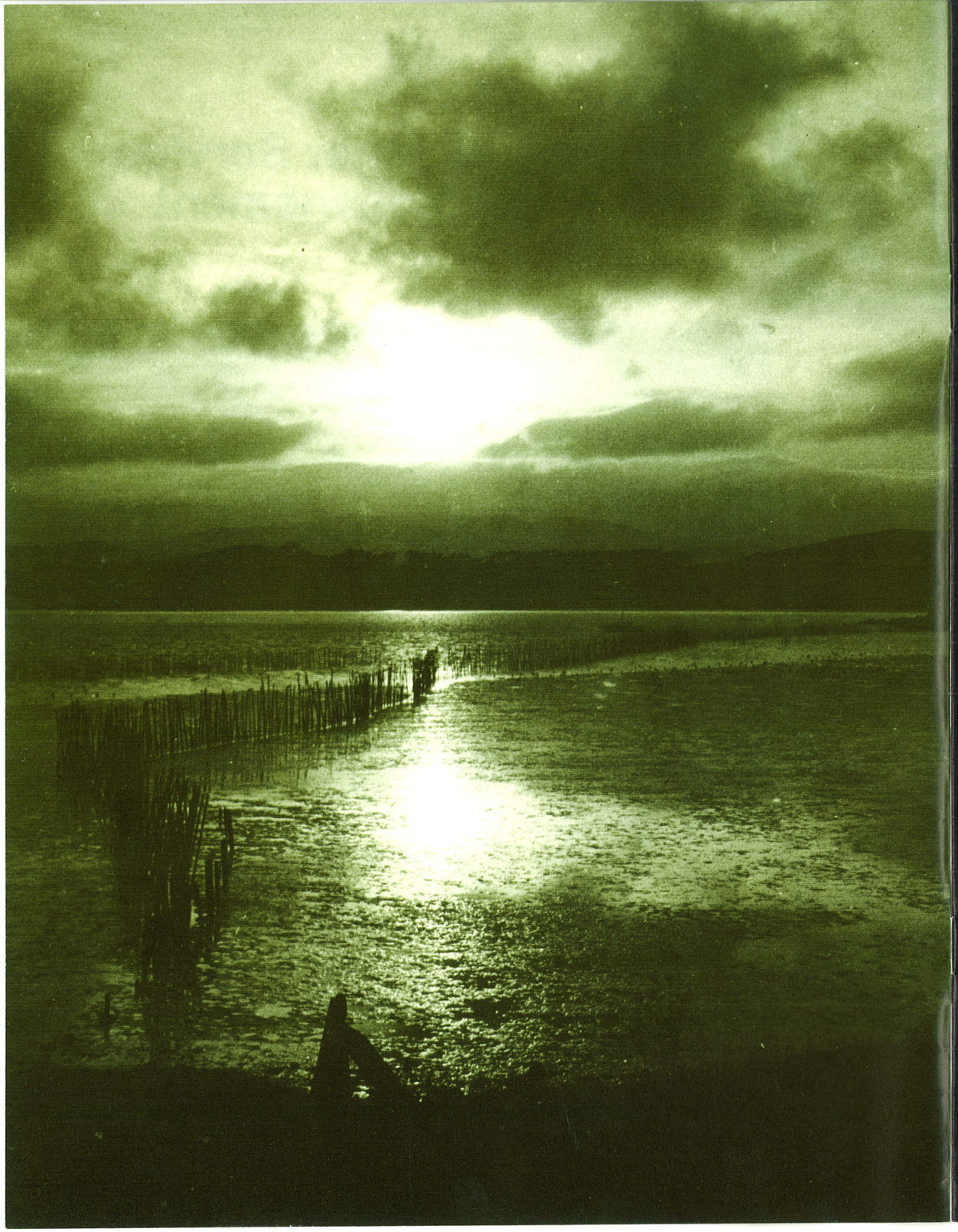
The National Weather Service and Water Management

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

National
Weather Service



Measuring and forecasting the state and behavior of man's natural environment is part of the work of NOAA, the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. This descriptive and predictive effort, where it covers normal, day-to-day changes in environmental conditions, is an essential information service. Then, as these conditions intensify until they threaten life and property, the forecasting service provides timely warning against impending natural hazards.

NOAA's National Weather Service is concerned with atmospheric events, and the generation of routine and destructive weather. But it also describes and predicts those processes which link ocean, atmosphere, and land through a continuous transfer of water—the hydrologic cycle. This continuous cycle from sea to atmosphere to land and back to sea determines the water level in our rivers, the stability and sufficiency of our water resources. Extremes in the hydrologic cycle—too much or too little water at a given time and place—produce the long-term disasters of drought and the seasonal disasters of flooded river valleys.

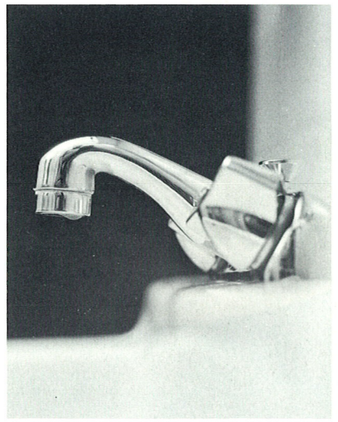
From the National Weather Service network of River Forecast Centers and River Districts, river-flow and water-level forecasts go out to hundreds of users every day. These forecasts are essential for navigation activities, hydro-electric power production, crop irrigation, reservoir operation, pollution control, recreation, fish and wildlife management, and industrial practices along the Nation's rivers. River and rainfall records kept by the Weather Service are also indispensable to riverside industries and to the proper design of bridges and flood protection systems.

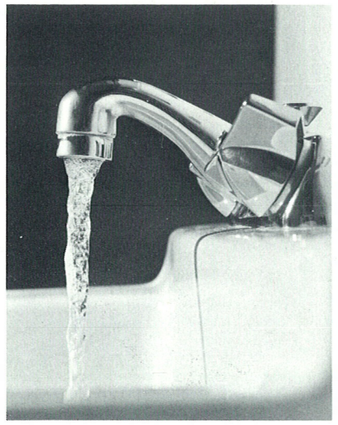
The flood and flash flood warnings developed and issued by the National Weather Service are the first line of defense against the deadly, destructive, and discouraging floods which strike through some of our river valleys every year.

The hydrologic services of the Weather Service help conserve the nation's vital water resources, and protect life and property in time of flood. They also help mitigate environmental pollution, which threatens this and future generations of Americans.

WATER

A Vital, Threatened Resource





It is believed that, since Earth cooled enough to permit the existence of liquid water, the world supply of this essential fluid has neither increased nor diminished. But the usable portion of this fixed supply has been steadily encroached upon by increasing demand and spreading pollution.

Water is essential to human life, but our need for water has expanded far beyond drinking, cooking, and bathing. With modern washing and sanitation systems in most homes, the average American now uses from 50 to 150 gallons of water per day. But home water needs amount to less than one-tenth of the huge quantities required by industry and agriculture, which bring the average American's daily water use to 1,800 gallons. In the next 15 years, as the use of water increases and the population grows, our national requirement for water is expected to double.

If our country's precipitation were distributed evenly, each person's share would be nearly 20,000 gallons per day. However, precipitation occurs without regard to man's convenience. Our major water problems today are caused by uneven seasonal and geographic distribution of precipitation and by concentrations of people in urban areas. Increasing use of the fixed supply of water has introduced serious problems of managing water quantity and quality.

The trend in concentration of population in cities has led to four significant problems in water management. The first of these is the need to supply increasing quantities of water for municipal and industrial use. This use of the water leads to the second problem, namely pollution. We have traditionally dumped waste materials in our rivers. However, as greater quantities of water are withdrawn from natural sources, streamflow is diminished and it is more difficult to manage the additional pollutants of the growing population.

The third problem of urbanization is the increased need of people for wholesome outdoor recreation, much of which is water oriented. Fishing, swimming, water-skiing—all such activities—take place in water which must be protected from pollution.

The fourth problem is urban storm drainage. Urban development has encroached on many small natural floodways and has greatly increased the damageable property subject to local flooding.

Wise programs of water management and conservation are needed now to ensure maximum use of available water supplies. Huge quantities of this valuable resource are wasted through pollution and flooding. Methods must be developed to avoid such losses, as well as to reduce flood damage. The river, flood, and water supply forecasting services of the National Weather Service are central to present programs and future plans for water management.

ORGANIZED TO FORECAST AND WARN

OFFICE OF HYDROLOGY

The National Weather Service's Office of Hydrology at Silver Spring, Maryland, develops policies and procedures for the field offices that conduct the river forecasting program. To ensure that the most modern techniques are employed in providing this important service, the Office of Hydrology conducts a continuing research and development program. In fulfilling its role in water management, the Office of Hydrology prepares hydrometeorological analyses for use in planning and design of such water-related structures as dams and levees, as well as airport, highway, and urban drainage systems.

RIVER FORECAST CENTERS

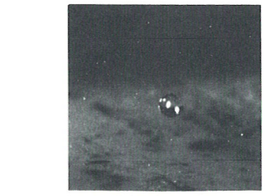
Weather Service field offices, called River Forecast Centers, are staffed by professional hydrologists and devoted solely to the preparation of river and water supply forecasts. Twelve River Forecast Centers serve 97 percent of the United States including Alaska, predicting river flow and water levels at more than 2,500 points on our nation's rivers. This service is being extended to Hawaii and Puerto Rico.

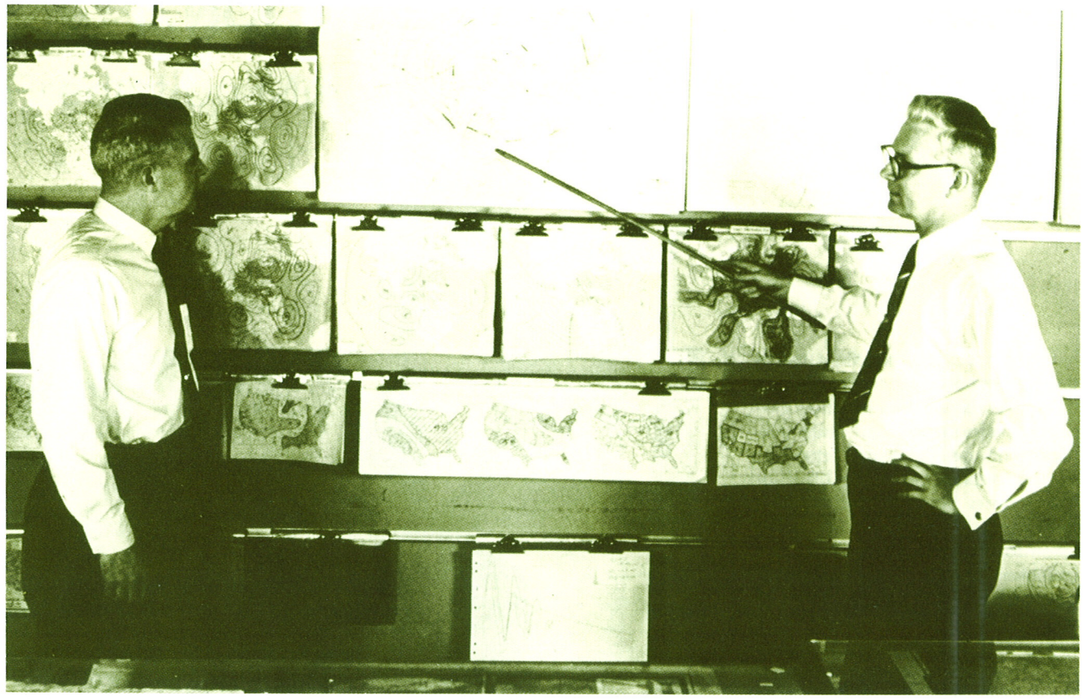
Individual river basins vary in size, topography, soil, ground cover, and climate, and they generally have engineering works that affect the flow of water. Hydrologists in the River Forecast Centers therefore must design forecasting procedures for each river system individually. The procedures must be updated frequently, as natural and man-made changes take place in the stream channels and basins.

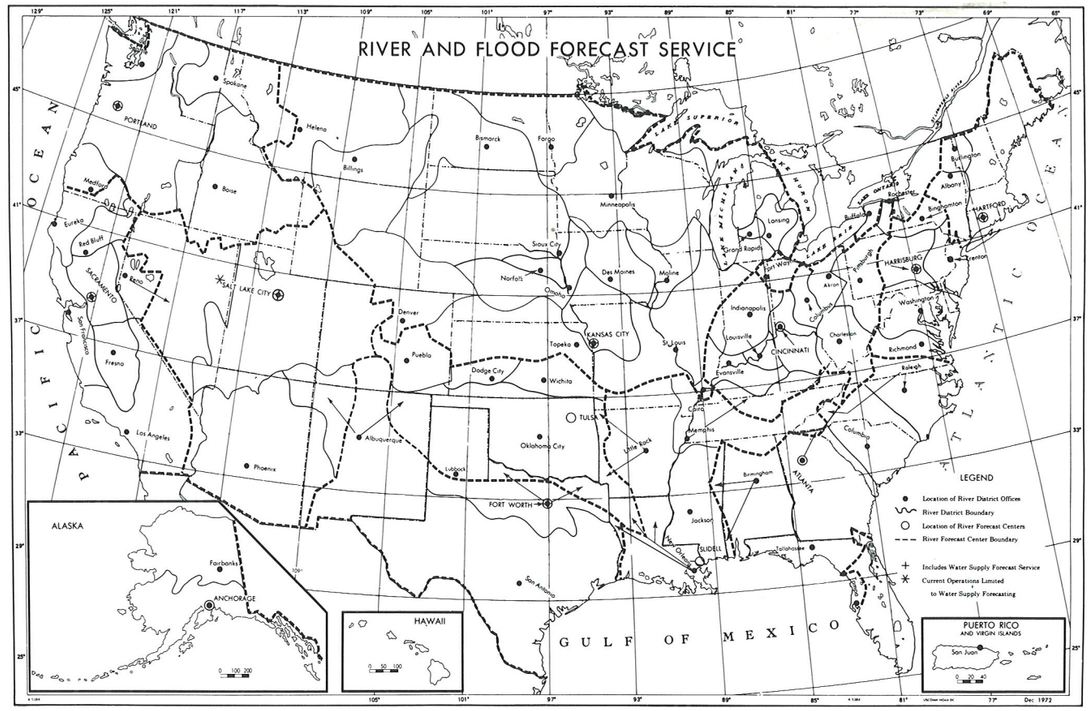
The River Forecast Centers have the latest national, regional, and local weather information to use in preparing their predictions. Forecasts of expected amounts of precipitation come from the Weather Service's National Meteorological Center at Washington by way of high-speed communications. A network of powerful weather radars provides up-to-the-minute observations of storms. From telemetered networks and River Districts, the Centers receive reports of river, rainfall, and other meteorological data. Computers are used to speed the preparation and increase the accuracy of river forecasts and flood warnings.

RIVER DISTRICTS

The area served by each River Forecast Center is divided into several River Districts with a Weather Service Office designated to service each District. A network of observing stations that report river stages and precipitation amounts is maintained within each River District. These reports are collected by the designated Weather Service Office within the District and relayed to the River Forecast Center. Forecasts prepared at the Center then are transmitted back to the local Weather Service Office for distribution to the public in the District by radio, television, and newspapers, and to agencies responsible for flood protection.







MEASUREMENT AND PREDICTION...

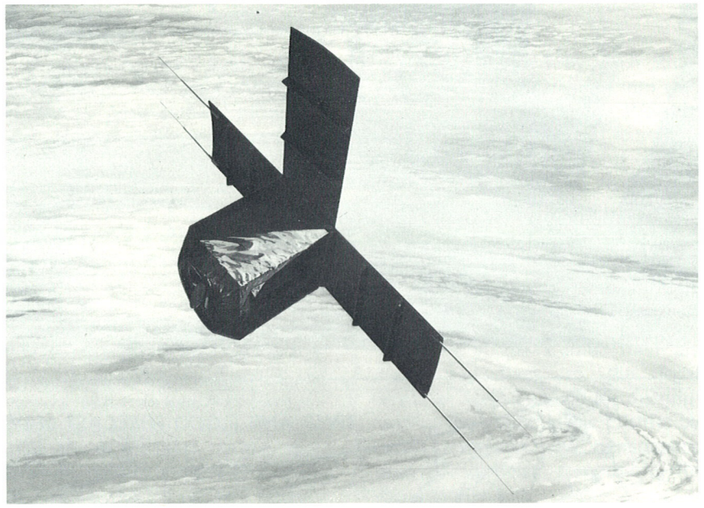
The Technology

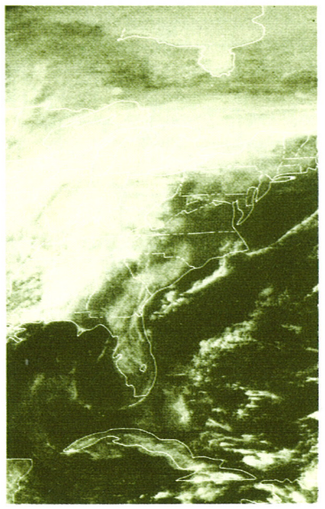
In the space age, satellites watch the weather all over the earth. Pictures taken by weather satellites give general information on cloud systems, and on large-scale distribution of ice and snow cover. This information is being applied in river forecasting. Steps are also being taken to establish a hydrologic data collection system using a geosynchronous satellite (GOES). This will make possible continuous real-time acquisition of observations from a large number of remote stations where it is now nearly impossible to obtain current data.

Radar, one of the most useful tools of modern meteorology, is a valuable aid to river forecasters. The National Weather Service has an extensive network of high-powered weather radars to monitor areas of rain or snow minute by minute as storms grow or diminish in size and intensity. Hydrologists use radar data to estimate the rate of rainfall, times of beginning and ending, and extent of areal coverage. Techniques are being tested on these radars for the automatic measurement of rainfall.

In addition to the large-scale picture as seen by satellites and radar, point-by-point measurements of river stage and rainfall are also needed for accurate river and flood prediction.

Rainfall measurements are made at regular intervals by Weather Service offices and the offices of cooperating government agencies. Measurements are made voluntarily by more than 5,000 private citizens providing additional data during storm periods.





Some of these private citizens, called cooperative observers, also report river stage information which must be known by hydrologists in order to forecast river levels. The river stage is the height of the water surface above a reference point.

Conventional river and rainfall data collection networks are now gradually being replaced by completely automatic equipment under the AHOS (Automatic Hydrologic Observing Systems) program. This automation will ensure the rapid acquisition of hydrometeorological data in a routine manner by landlines or radio, including satellite relay. The lead time of river and flood forecasts will be greatly increased by this program.

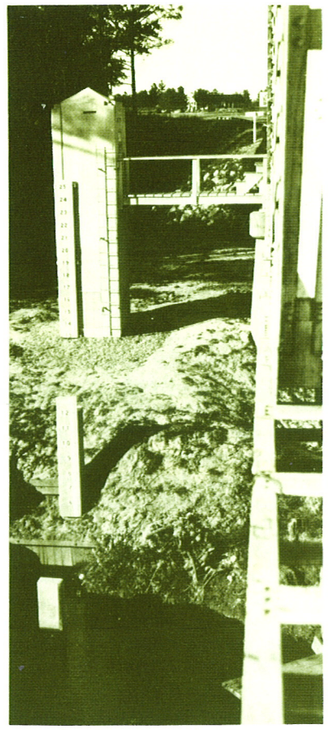
Prediction Methods

Water flows from the headwaters of a drainage basin, where the river system begins, into the tributaries and finally to the main stem of the river. Along this course, its volume may be augmented as additional tributaries flow into the main stream.

River stages and floods can be predicted because there is a natural time delay (or lag) between rainfall or snowmelt and the resulting rise in the river. This lag usually increases downstream, allowing more time to take action upon the forecast.

River forecasting methods may vary for each part of a river system. Moreover, the techniques must be adapted to the size, terrain, and climate of an individual basin, as well as the effects of the man-made reservoirs and other structures in it.

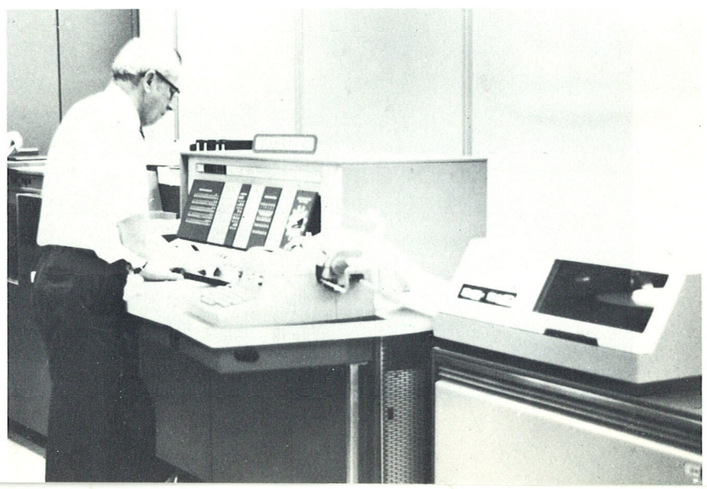
Hydrologists in the River Forecast Centers develop forecast procedures by studying the past history of each stream and the relationships of storm, melting snow, soil, and river conditions to floods. Through these analyses, they develop river forecasting procedures for predicting the amount of water that will find its way into the rivers—and the time it will take to reach them—under different conditions of temperature, soil moisture, and precipitation. With the advent of computer technology, these analyses have led to the development of sophisticated conceptual models of the various factors which determine streamflow. These models, which are practical only where computers are available, are being introduced into the River Forecast Centers and will eventually supplant the more elementary procedures previously used.



For the headwaters, early forecasts and flash flood warnings may be based on radar and quantitative precipitation forecasts, or on observed amounts of rainfall and the arrival of a flood crest upstream. In these situations, warnings can be issued only a few hours in advance.

To forecast for points on major tributaries, hydrologists use reports of rainfall and of antecedent river flow and soil conditions. These forecasts may be issued hours to days in advance of the flood peak.

Stages and flows on the main stem of the river are predicted by combining all tributary forecasts and computing the time it will take the water to reach the forecast points. Main river flood forecasts can be issued several days or even weeks in advance. Seasonal water supply forecasts are made months in advance.



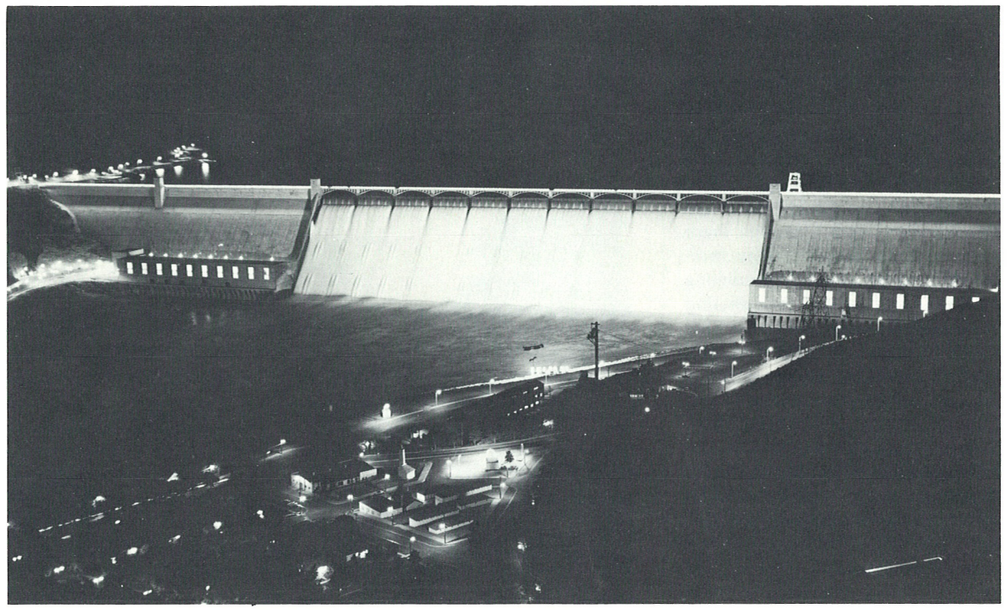
HYDROLOGIC SERVICES

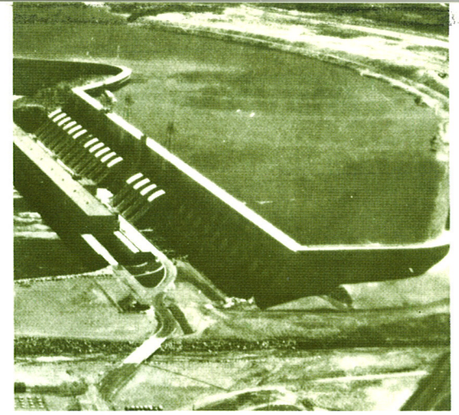
Every day, operators of reservoirs, power plants, irrigation works, and water supply systems make decisions based on expected future river conditions. They must, for example, determine whether control gates should be closed, partially open, or wide open. When a reservoir manager receives accurate river and flood forecasts well in advance, he can safely plan for optimum discharge and reservoir elevations for flood control, power, water supply, and other purposes.

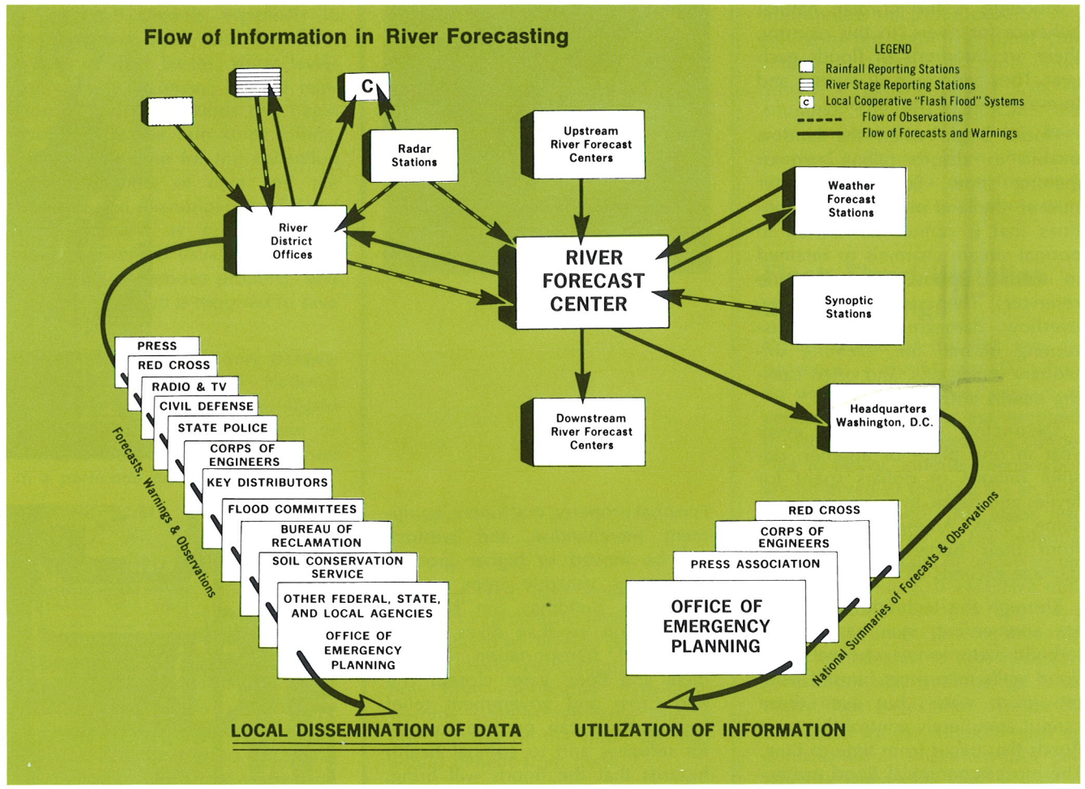
The National Weather Service's daily river forecasts help power producers decide when to shift between water and steam power generation. Irrigators can be prepared to use water while it is available. Discharge of municipal and industrial wastes into rivers can be regulated to keep stream pollution within safe limits. When forecasts indicate low water levels, wastes can be stored until increased flow is available.

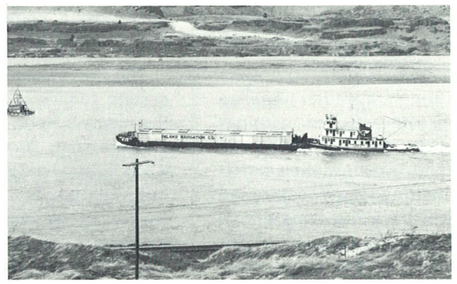
River forecasts are used to schedule construction work on dams, bridges, and riverside structures. Waterborne transportation interests plan cargo loads according to the expected river depth and velocity. In some parts of the United States—especially the western mountain states—the water supply depends largely upon winter accumulations of snow. Irrigation, industrial, and hydroelectric interests in these areas need to know far in advance how much water will be available during relatively dry spring and summer months.

Weather Service hydrologists have developed methods of forecasting the amount of water that will enter the streams and rivers of a drainage basin when the winter's snow accumulation melts. Using these techniques, seasonal water supply forecasts are prepared each month during the late winter and spring for about 400 places in the West and Northwest. These forecasts give water users a basis for planning and provide the first clues to the dangers of spring floods.









FORECASTS AND WARNINGS

Floods

Flooding is the normal, natural behavior for rivers. In this country, there are hundreds of floods each year. They happen in all seasons and in every part of the nation.

Floods begin when the land is unable to absorb falling rain or melting snow. Sometimes water runs off the land in such large quantities that it cannot be carried in normal stream channels or retained in natural ponds and man-made reservoirs. Then streams and rivers overflow, damaging property, disrupting normal life, creating unsanitary conditions, and often causing deaths and injuries.

Destructive floods occur every year in one place or another, despite billions of dollars spent for levees and dams. In an average year some 75,000 Americans are driven from their homes, and property damage exceeds $1 billion.

Through the techniques of modern engineering, man has learned to build dams, levees, channels, and flood walls to protect himself from too much water, but even these cannot completely control the great floods that occur from time to time. The most economical flood protection programs combine flood-control works, intelligent flood-plain management, river forecasts, and community disaster plans.

The National Weather Service issues flood forecasts and warnings when enough rain has fallen to cause rivers to overflow their banks or when melting snow combined with rain will have the same effect. Early flood warnings allow time for residents to leave low-lying areas.

Personal property, machinery, equipment, merchandise, and livestock can be moved to higher ground. Sometimes, valuable crops can be harvested. Buildings can be protected with sandbag dikes, levees reinforced, transportation rescheduled, and flood gates closed. The Red Cross and government relief organizations can prepare to care for refugees and to combat health hazards that the floods will bring. With careful planning and constant readiness, a community can make the most of early flood warnings.

The flood warning and river forecasting service is an integral part of the nation's flood control and water management program. The flood warning service saves countless lives and millions of dollars each year—exceeding by many times the cost of the entire river forecasting service.

...and Flash Floods

On small streams, especially in mountainous areas and the headwaters of river basins, water levels rise quickly in heavy, intense rainstorms, and flash floods can begin even before the rain stops falling. There is no time for the collection and processing of data and the issuance and dissemination of flood crest forecasts as previously described. There is usually little time to protect or remove property, and immediate action is required to save lives.

To cope with these very dangerous situations, NOAA's National Weather Service has developed three basic methods any one or combination of which may be used in a particular community.

Community Self-help Systems

A network of rainfall and river observing stations is established in the area, and a qualified local flood-warning representative collects reports from the network. The representative is authorized to issue public flash-flood warnings, based on procedures prepared by the National Weather Service which show the local flooding that will occur under different conditions of temperature, soil moisture, and rainfall. On the basis of reported rainfall and these forecast procedures, the representative can prepare a flood forecast and issue a warning within minutes.

Successful operation of a flash-flood warning system requires active community participation and planning, but very little financial outlay. Considerable time and skill are required to develop procedures. The relatively few communities that now have cooperative flash-flood warning systems represent only a tiny fraction of the hundreds that would benefit from them.

Flash Flood Alarm System

This system consists of a sensor located at some optimum point upstream from the community to provide both an accurate indication of flood danger and to give as much warning time as possible. The rising flood waters activate this sensor and the signal is carried downstream by appropriate electronic circuitry to a police or fire station or other continuously staffed location from which a general alarm can be sounded. The alarm indicates that some critical flood level has been reached upstream from the community. No specific crest forecast is possible as in the self-help system.

Flash Flood Watches and Warnings

When neither of the first two approaches is feasible–usually where no well-defined streams exist–more generalized warnings are required. If meteorological conditions conducive to heavy, intense precipitation are observed or forecast for an area, a *watch* is issued. This alerts residents of the area to the potential occurrence of rainfall which could result in flooding. If excessive rainfall or actual flooding is reported, a *warning* is issued. This requires residents of the area to take necessary precautions against flooding. Automated rain gages that can be interrogated by the meteorologist on demand are an important tool, particularly when they can be used in conjunction with observed radar echoes which delineate potential trouble areas.

Flash Flood Specialists have been assigned to some River Forecast Centers and major Weather Service Forecast Offices to aid communities in determining which of the above methods is best for their area. They will prepare procedures for the self-help system and select a location for the flash-flood alarm sensor.

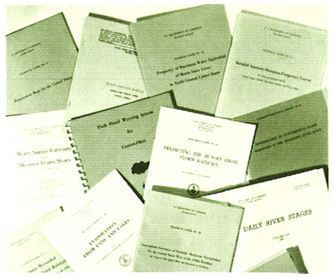
HYDROMETEOROLOGICAL STUDIES

The National Weather Service, together with other agencies concerned with water resources, flood prevention, and protection from flood damages, collects, publishes, and interprets hydrometeorological data—information on precipitation, river stages, tidal surges, and floods. These records and analyses are indispensable to builders of reservoirs, or other flood control works, irrigation systems, power plants, waterworks, culverts, airports, urban storm sewers, and in the nation's flood insurance program.

A knowledge of past or potential rainfall and runoff is essential to the design of any structure that retains or channels water—even the simplest culvert. The designer needs to know how much rain fell in a given storm. How often is this intensity equalled or exceeded? How great an intensity occurs on an average once in 50, once in 25, or once in 10 years? What is the maximum ever recorded? Even more important for many large water control structures, what is the probable maximum precipitation? Knowledge of these factors is fully as important in design as knowledge of the strength of building materials.

The coastal plains of this country are the sites of some of our largest centers of population. A knowledge of tidal flooding from large storms, both past and potential, is essential for the effective utilization of coastal lands. This information is also needed on a frequency basis. What tidal surge can be expected at the open coast on an average once every 10 years or once in 100 years?

For a number of federal agencies, the Office of Hydrology prepares estimates of probable maximum precipitation and snowmelt in river basins, studies of rainfall frequency, reservoir evaporation, and tidal surge frequency studies. Many of these studies have been published as Technical Memoranda, Technical Reports, and Professional Papers.



RESEARCH...

Today's Commitment to Tomorrow

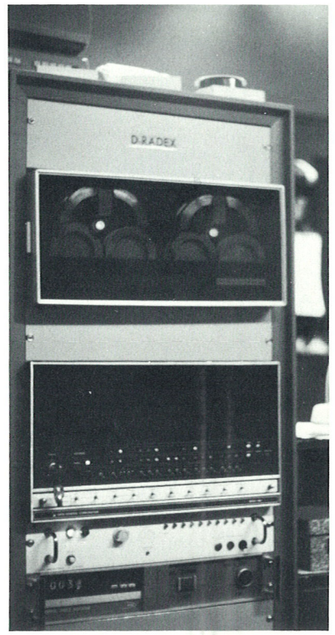
The research and development programs of the Weather Service's Office of Hydrology aim at improving present understanding of the hydrologic cycle and developing ways of applying new knowledge to hydrologic forecasting and related water resource problems.

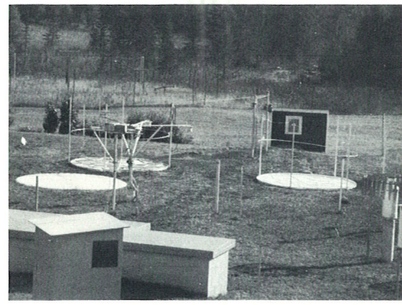
A considerable research effort has been devoted to development of conceptual hydrologic models which provide continuous simulation of streamflow. Such models are being implemented in the field to provide an increase in accuracy and reliability of operational river forecasts. Concurrently, research is devoted to improvement of quality and availability of basic data required for full utilization of forecast procedures. Weather Service scientists are conducting a large-scale digitized radar experiment (D/RADEX) to obtain improved areal and temporal values of precipitation for operational forecasting and identifying potential flash flood conditions. Research is underway on use of aerial and surface observations of natural gamma radiation from the soil for measurement of water equivalent of snow on the ground, a critical value in predicting snowmelt floods.

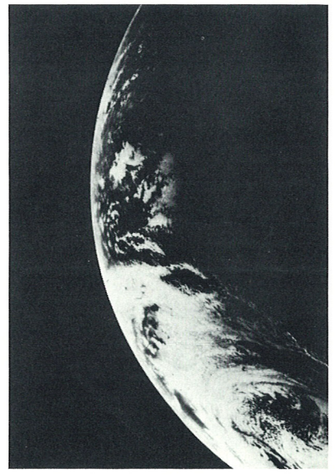
Studies continue on the hydrologic applications of satellites such as the evaluation of areal extent of snow cover, snow line elevation in mountainous terrain, soil moisture, and ice conditions on rivers and lakes. Research continues on the development of improved techniques for hydrologic data collection, such as use of the planned Geostationary Operational Environmental Satellite (GOES) for communications, especially from remote areas.

Because the water level in rivers is so highly dependent upon weather, any improvement in weather observing and forecasting also benefits river forecasting. Thus a large portion of NOAA's meteorological research is potentially valuable to the solution of water problems. Meteorological research projects closely related to hydrology include the development of computerized meteorological knowledge and advanced meteorological satellites, as well as investigations of the atmosphere's general circulation, of clouds and precipitation, and of hurricanes and other severe storms.

River forecasting is not merely one of several alternative methods for water management, but is an essential ingredient in any program for managing our water resources. Forecasting consists of solving and projecting the hydrologic cycle for areas tributary to our rivers. The better the phenomena of the hydrologic cycle are understood, the better the public can be served. The key to better understanding is research.







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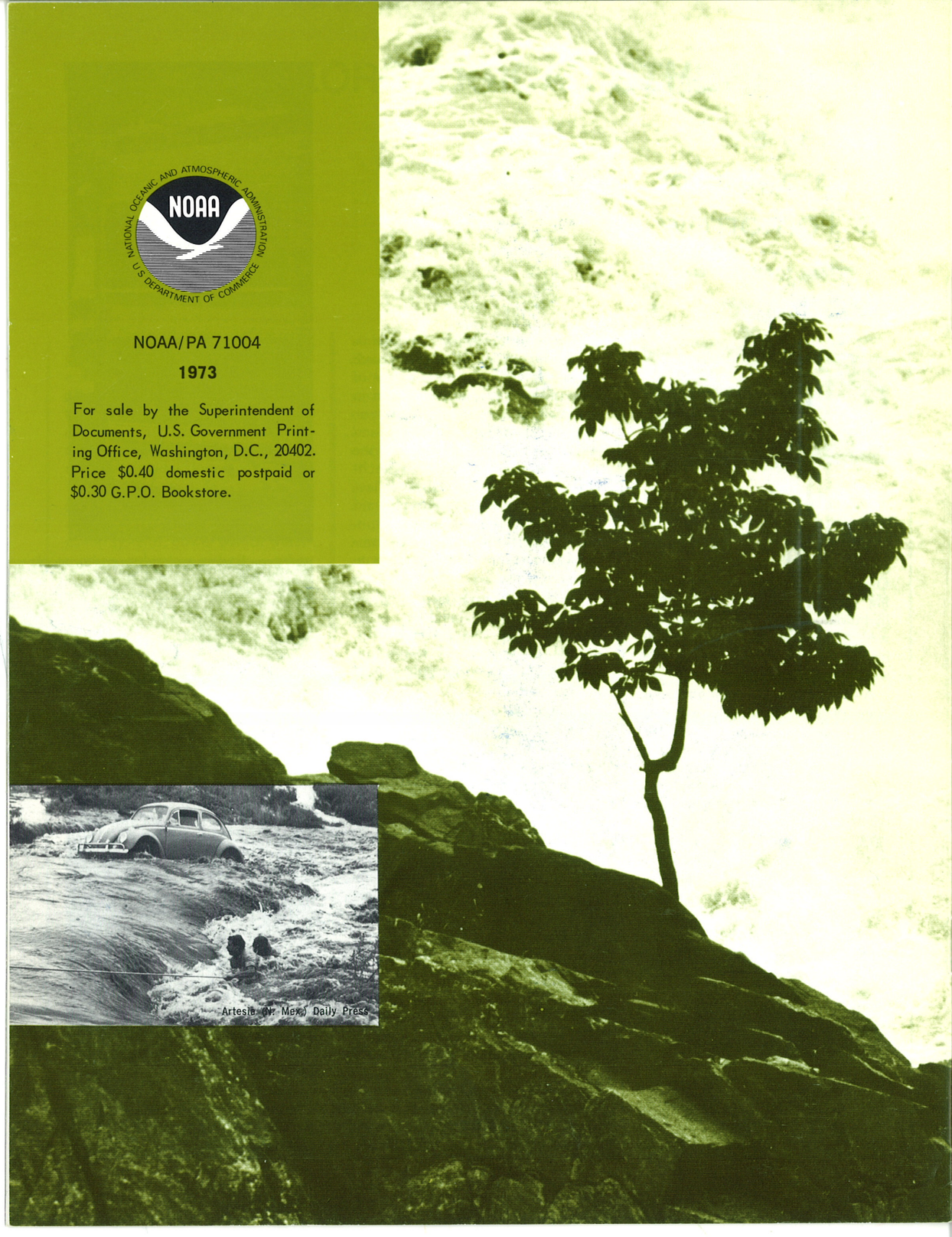

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