Floodplain Management in the United States: An Assessment Report

Volume 1
Summary Report

Prepared for the Federal Interagency Floodplain Management Task Force

1992

Issued in Furtherance of the Decade for Natural Disaster Reduction

The Federal Interagency Floodplain Management Task Force was established in 1975 to carry out the responsibility of the President to prepare for the Congress a Unified National Program for Floodplain Management. Since 1982 the Task Force has been chaired by the Federal Emergency Management Agency. Membership of the Task Force consists of the Departments of Agriculture, Army, Commerce, Energy, Housing and Urban Development, Interior, and Transportation; the Environmental Protection Agency; and the Tennessee Valley Authority.

Design: Mike Campbell, Publications Department, University of Colorado.
Cover photo: Bob Cox, Floodplain Management Section, Louisiana Department of Transportation and Development.

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in the

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The Federal Interagency
Floodplain Management
Task Force

Prepared by
The Natural Hazards
Research and Applications
Information Center,
University of Colorado at Boulder

(Contract No. TV-72105A)

1992

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—Gilbert F. White 67

Preface

The coastal and riverine floodplains of the United States are highly desirable and rewarding sites for most kinds of human activities and contain a wealth of natural and cultural resources of immense importance and value to the nation. Yet they are the source of costly and frequently unnecessary losses of human life and property as well as losses of resources afforded by floodplain environments.

In terms of areas affected and annual economic losses, flooding remains the greatest and most persistent natural disaster facing our nation, despite concerted efforts at all governmental levels and within the private sector to moderate, account for, or adjust to the flood risk. These efforts go back at least to the turn of this century, when initially they were focused on controlling the paths of flood waters. Other flood loss reduction strategies and a myriad of programs have since evolved to complement these initial efforts. More recently, increased attention has been given to preserving the natural functions and resources of floodplains.

This assessment of floodplain management in the United States was commissioned in 1987 by the Federal Interagency Floodplain Management Task Force. Its purpose was to provide an evaluation of floodplain management activities in order to report to the public and to the Congress on progress toward implementation of "A Unified National Program for Floodplain Management" [Section 1302(c) of the National Flood Insurance Act of 1968]. Thus, it is a compilation of available information concerning the nation's floodplains, experience with tools and strategies to reduce losses of life, property, and environmental resources, and a perspective of what has been accomplished.

The assessment is presented in two parts. This summary report (Volume 1) presents the salient information and findings of the full report (Volume 2) and reflects both its content and organization. Sources of information for Volume 1 and additional detail, explanation, and analysis can be found in the full report.

A concerted attempt was made to compile information and available data from numerous sources in an attempt to describe, evaluate, and provide for a balanced view and account of the various activities and management approaches. However, all accounts and contributions to floodplain management may not be adequately documented in this assessment due to the lack of sufficient information or usable data regarding certain subjects or topics. Nevertheless, task force member agencies concurred with the content of this document and believe that this assessment provides the most comprehensive statement available and a foundation for action to improve effectiveness of floodplain management in the United States. It is commended to all parties who make decisions affecting floodplains and their occupants and to those having an interest in learning more about this subject.

Frank H. Thomas
Federal Emergency Management Agency
Chair, Federal Interagency Floodplain Management Task Force

Acknowledgments

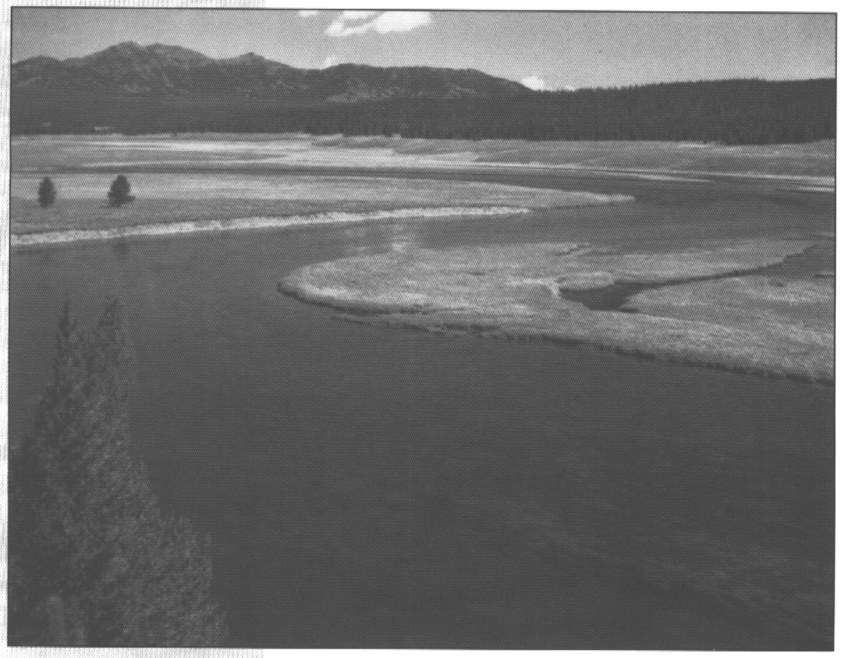
This summary was prepared under the direction of the Natural Hazards Research and Applications Information Center, University of Colorado at Boulder, and is based on the full report prepared by L.R. Johnston Associates. Both reports resulted from contractual arrangements with the Tennessee Valley Authority, which managed the national assessment effort for the Interagency Task Force. Principal authors of the two reports were Jacquelyn L. Monday and the late Larry R. Johnston, respectively.

Countless others contributed support, information, and ideas. The Federal Interagency Floodplain Management Task Force provided funding for this study, and an Advisory Committee of the Task Force was created to provide direction and guidance throughout the work effort, including review of draft reports. The Association of State Floodplain Managers and the Association of Wetland Managers devoted a portion of their annual conferences to provide information and input to the process. A National Review Committee, comprised of recognized experts and chaired by Gilbert F. White (one of the true pioneers of the floodplain management movement that began around 50 years ago) added valuable insight and proposed an *Action Agenda*. Many individuals, including those representing government agencies and professional and nonprofit organizations, also made important contributions by providing information, data, insights, and perspectives.

James M. Wright
Tennessee Valley Authority
Project Manager

Part I

The Nation's Floodplains, Their Value, and Their Floods



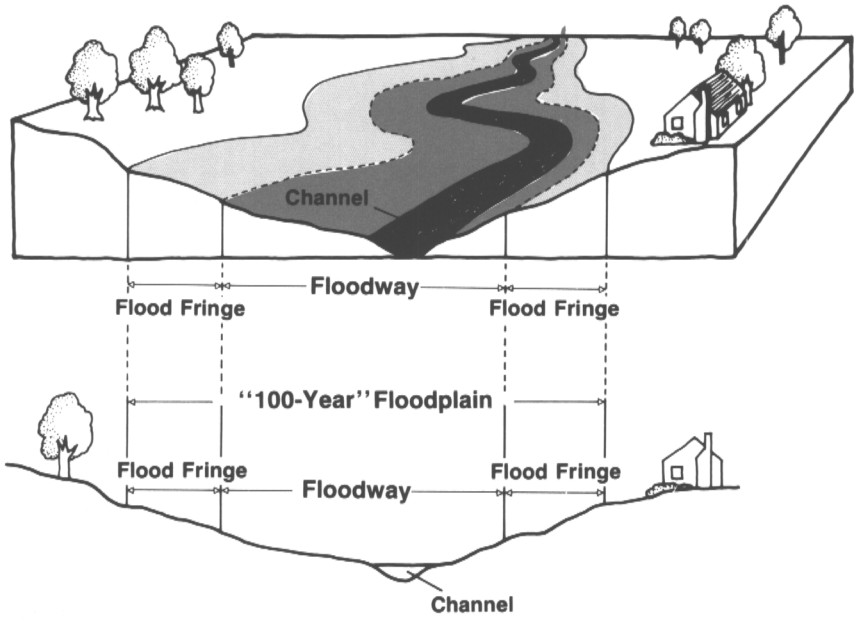
Floodplains

Floodplains are the lowlands adjoining the channels of rivers, streams or other watercourses, or the shorelines of oceans, lakes, or other bodies of standing water. They are lands that have been or may be inundated by flood water. Floodplains are shaped by dynamic physical and biological processes: climate, the hydrologic cycle, erosion and deposition, extreme natural events, and other forces. The products of the complex interrelationships of these processes are many of the nation's most beautiful landscapes, most productive wetlands, and most fertile soils, along with rare and endangered plants and animals, and sites of archaeologic and historic significance. Throughout our history, rivers and other bodies of water have been highways for exploration, migration, and commerce and have been used as disposal systems for the byproducts of industrial society. Almost all major cities are located on a river or at the mouth of a river. Most smaller communities have at least one stream that helps define local character and is an important source of community identity.

FLOODPLAIN MANAGEMENT

Floodplain Management is a decisionmaking process the goal of which is to achieve wise use of the nation's floodplains. "Wise use" is any activity or set of activities that is compatible with the risk to natural resources (natural and beneficial functions of floodplains) and human resources (life and property). Compatibility is acheived through the strategies and tools of the Unified National Program for Floodplain Management.

The Floodplain with Floodway



The U.S. Water Resources Council estimated in 1977 that about 7%, or 178.8 million acres, of the total area of the United States, including Alaska and Hawaii, Puerto Rico, and the Virgin Islands, was within the 100-year floodplain. The Federal Emergency Management Agency, in a 1991 study that examined nearly 17,500 mapped floodprone communities in the 50 states and the District of Columbia, estimated that there are about 94 million acres. The largest areas of floodplain are in the southern part of the country, but the most populous are along the north Atlantic coast, in the Great Lakes region, and in California.

The Value of Floodplains

In their natural state, floodplains have enormous but often unrecognized value. These complex dynamic systems contribute to the physical and biological support of water resources, living resources, and cultural resources. Floodplains are important to the nation's water resources because they provide natural flood and erosion control, help maintain high water quality, and contribute to sustaining groundwater supplies. Floodplains have living, or biologic, resource value, because they support a wide variety of flora and provide

Previous page: The Yellowstone River and Hayden Valley in Yellowstone National Park are a river and floodplain relatively undisturbed by human intrusion.

habitat for fish and wildlife. The cultural resources of floodplains include the maintenance of a harvest of natural products, places for recreation, scientific study, and outdoor education, and sites of historic and archeological interest.

Although the value of these resources is now well recognized and most of the processes contributing to them reasonably well understood, it has proven difficult and sometimes impossible to assign economic values to the functions served and benefits provided by floodplains.

Water Resources

Water can be put to human use either while it is in the stream or other water body or when it is diverted and used elsewhere. Offstream, surface water can be used for irrigation, for industrial and municipal purposes, and energy production. These uses reduce the flow or level of water, at least temporarily, and inevitably degrade its quality somewhat. Instream uses of water include navigation, fish and wildlife propagation, waste transport, hydropower generation, agricultural and industrial uses, recreational activities, and supplying drinking water. Instream uses usually require a minimum flow or water level and hence tend to compete with offstream uses.

Flood and Erosion Control

Natural, unaltered floodplain systems can reduce flood velocities, reduce flood peaks, and reduce wind and wave impacts because their physical characteristics affect flood flows and, typically, provide space for the dispersal and temporary storage of flood waters until the natural drainage can carry them away. This natural function obviously can reduce the potential damages and loss of life from floods. One acre of a floodplain can store about 325,000 gallons of water if flooded to a depth of only one foot. Floodplain vegetation,

Natural and Cultural Resources of Floodplains

Water Resources

Natural Flood and Erosion Control
- Reduce flood velocities
- Reduce flood peaks
- Reduce wind and wave impacts
- Stabilize soils

Surface Water Quality Maintenance
- Reduce sediment loads
- Filter nutrients and impurities
- Process organic and chemical wastes
- Moderate temperature of water
- Reduce sediment loads

Maintain Groundwater Supply and Quality
- Promote infiltration and aquifer recharge
- Reduce frequency and duration of low flows; i.e. increase/enhance base flow

Living Resources

Support Flora
- Maintain high biological productivity of floodplain and wetland vegetation
- Maintain productivity of natural forests
- Maintain natural crops
- Maintain natural genetic diversity

Provide Fish and Wildlife Habitat
- Maintain breeding and feeding grounds
- Create and enhance waterfowl habitat
- Protect habitat for rare and endangered species

Cultural Resources

Maintain Harvest of Natural and Agricultural Products
- Create and enhance agricultural lands
- Provide areas for cultivation of fish and shellfish
- Create and enhance forest lands
- Provide harvest of fur resources

Provide Opportunities for Recreation
- Provide areas for active and consumptive uses
- Provide areas for passive activities
- Provide open space values
- Provide aesthetic values

Provide Areas for Scientific Study and Outdoor Education
- Provide opportunities for ecological studies
- Provide historical and archaeological sites

Coastal barriers are constantly changing land forms. They protect much of the Atlantic and Gulf coast from the direct effects of high water, waves, currents, and severe storms. Development on a coastal barrier, Grand Isle, Louisiana.

WETLAND FLOODPLAINS HELP MAINTAIN WATER QUALITY

- *Studies of heavily polluted waters flowing through Tinicum Marsh in Pennsylvania have revealed significant reductions in biological oxygen demand, phosphorous, and nitrogen within three to five hours.*
- *The value of Georgia's 2,300-acre Alcovy River Swamp for water pollution control has been estimated at $1 million a year. The bottomland forested wetlands along the river have been shown to filter impurities from flood waters.*

Riparian habitats sustain ecosystems that include many large mammals such as bear, white-tailed deer, and caribou.

White-tailed deer, St. Andrews Bay, Florida.

especially in wetlands, can reduce erosion by binding the soil with its root systems. Moreover, friction between the vegetation and the water dampens waves and reduces current velocity. Coastal barriers—elongated, offshore formations of sand and other unconsolidated sediments lying generally parallel to mainland coastlines—protect large portions of the coast, including estuaries, bays, and wetlands, from the direct effects of high water, waves, and currents caused by both normal and storm conditions.

Floodplains and wetlands not only help maintain water quality, they also provide a natural environment for diverse species.

Bottomland hardwood swamp, Louisiana.

Surface Water Quality Maintenance

Natural floodplains can reduce the cost of waste water treatment and water quality maintenance; they can reduce sediment loads, process chemical and organic wastes, and reduce nutrients, thereby protecting the physical, biological, and chemical integrity of water. Floodplains buffer rivers, streams, lakes, and estuaries from upland sources of pollution.

Groundwater Supply and Quality

Conditions beneath undisturbed floodplains can facilitate the infiltration and storage of water, permit groundwater recharge, purify water entering the aquifer, reduce flood peaks, and ameliorate the frequency and duration of low flows in groundwater systems. These functions help maintain and improve conditions for municipal and private wells, wildlife, irrigation, and watering livestock during drought.

Living Resources

Floodplains are among the most productive of the planet's ecosystems. Because of their relative abundance of water, they provide habitat for a multitude of plant and animal species, and the energy and nutrients from their healthy function are passed along to organisms in adjacent and downstream areas.

Wetlands

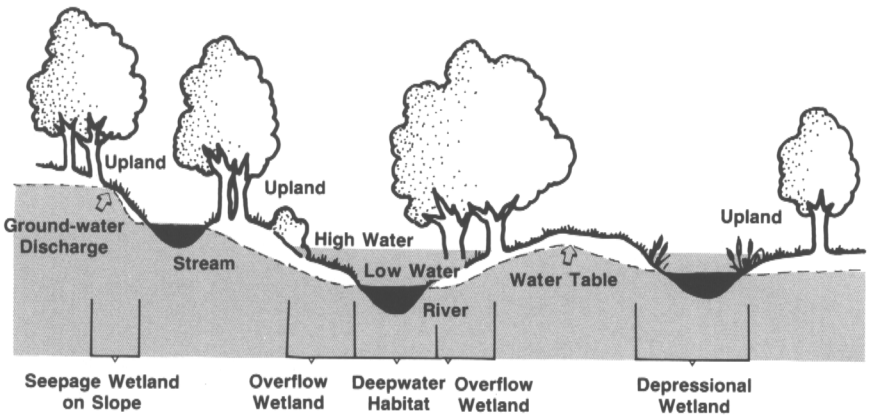
Wetlands are perhaps the most prominent and familiar of floodplain resources. They are lands transitional between terrestrial and aquatic systems and are covered by shallow water or have a water table at or near the surface. There are slightly in excess of 100 million acres of wetlands in the 48 contiguous states, and the majority of these are in floodplains. Florida, Louisiana, and Alaska have the most wetland acreage.

Wetlands are classified by the U.S. Fish and Wildlife Service according to five ecological systems, of which estuarine and palustrine wetlands are best known. Estuarine systems include such coastal wetlands as salt and brackish tidal marshes, mangrove swamps, and intertidal flats, as well as the deepwater habitats associated with bays, sounds, and coastal rivers. Palustrine wetlands

account for about 90% of all U.S. wetlands. They are inland, freshwater areas of marshes, bogs, and swamps, and some brackish and salt marshes in arid and semi-arid areas.

Wetland plants are particularly efficient converters of solar energy. Their major food value is achieved when they die and fragment to detritus. Numerous fish and wildlife species feed in marshes and swamps or on organisms that were produced in such areas. Some animals spend their entire lives in floodplain wetlands, while others use the wetlands primarily for reproduction,

Typical Inland Wetland



nursery grounds, or for drinking water. About 50% of the endangered species in the United States require wetland habitat at some point in their life cycles; wetlands are crucial to the survival of the American crocodile, the manatee, the whooping crane, and the Mississippi sandhill crane. Both coastal and inland wetlands also provide valuable habitat for such furbearers as muskrat, beaver, otter, mink, and raccoon, as well as numerous reptiles and amphibians. Large mammals, such as black bears, white-tailed deer, and caribou, also find refuge and food in wetland areas.

Riparian Systems

Riparian floodplains are distinct associations of soils, flora, and fauna that occur in narrow strips along rivers, streams, or other bodies of water and depend for survival upon high water tables and occasional flooding. They are

Healthy riparian ecosystems are essential for maintaining the biological diversity of the nation's flora. They also provide aesthetic pleasure.

Wetland vegetation, Joyce Kilmer Memorial Forest, North Carolina.

FLOODPLAINS AS HABITAT

- *Black ducks migrating in the Atlantic flyway use the northern salt marshes as their primary wintering grounds.*
- *Intertidal mudflats along the coasts are the principal feeding grounds for migratory shorebirds; most shorebirds breed in Alaskan and other tundra wetlands.*
- *Mississippi River floodplains are the major resting and feeding grounds for ducks and geese during their fall and spring migrations.*
- *During droughts in the prairie pothole region, Alaska's wetlands are heavily used for nesting by North American waterfowl.*
- *Hawaii's wetlands are especially important to endangered birds.*
- *Arizona's native cottonwood-willow associations support higher densities and a greater diversity of breeding bird species than any other desert habitat.*
- *The prairie pothole region of the Dakotas is the main breeding area for waterfowl in the United States.*
- *The San Pedro River's riparian ecosystem in southeastern Arizona provides nesting, migratory, or wintering habitat for at least 20 raptor species and about 210 species of other birds. A study recorded 78 species of mammals in the grasslands corridor between the riparian woodlands and adjacent mountains, the second-highest mammalian diversity in the world.*

Canvasback duck, salt marsh, New England.

Great blue heron, Merrimack River, New Hampshire.

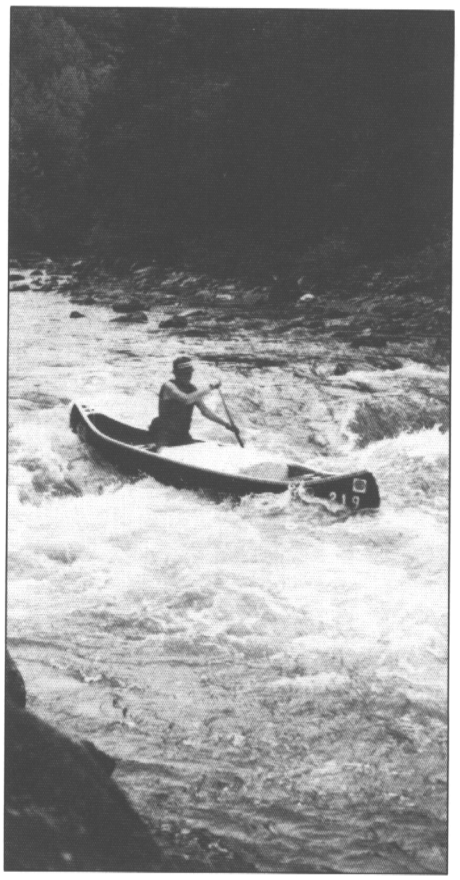
generally more biologically diverse than the surrounding uplands and encompass a broader range of moisture and soil conditions and a greater diversity of flora and fauna than wetlands do. The Soil Conservation Service estimates that there are 16 million acres of riparian land along streams, canals, lakes, reservoirs, and tidal shorelines of rural, nonfederal portions of the United States. Bottomland hardwood forests also are a major riparian ecosystem, and they account for about 52 million acres, mostly in the South.

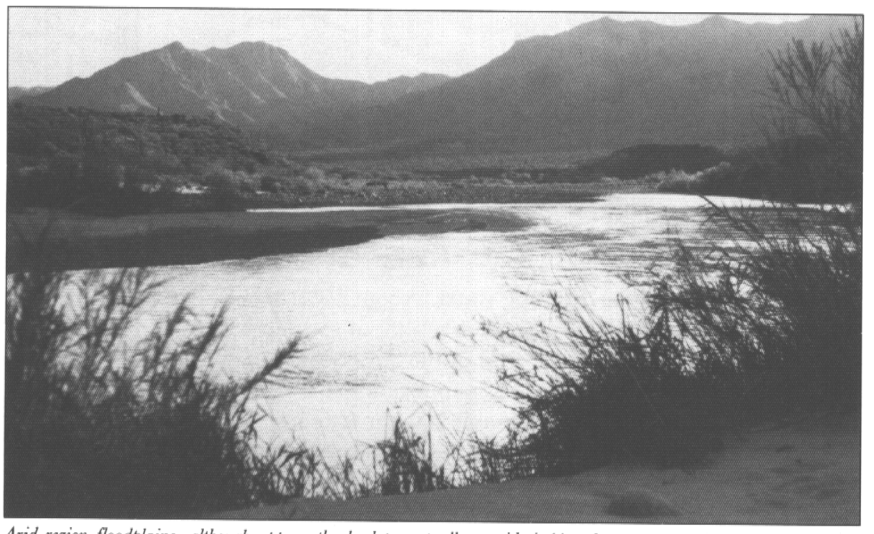
Healthy riparian ecosystems provide community structure for raptors, safe passage corridors to water for mammals, habitat for amphibians, and cover and nutrients for fish. At elevations below 3,500 feet, they take the form of lush strips of streamside vegetation that interrupt the desert landscape. These linear communities provide habitat for up to 80% of the West's wildlife species, and are essential for maintaining its healthy fish and wildlife populations. Cottonwood groves provide a high canopy and open understory essential to certain birds of prey for hunting, while mesquite bosques provide lower, denser vegetation ideal for colonial nesting by whitewing doves. Also dependent on riparian habitats are grey squirrels, river otters, muskrats, summer tanagers, canyon frogs, tree frogs, and dove-tailed hawks.

Rivers and floodplains provide numerous recreational opportunities—including hiking, camping, hunting, fishing, boating, swimming, bird-watching, picnicking, jogging, photography, ice skating, and simply observing nature.

Above: Bicyclist, Boulder Creek Pathway, Boulder, Colorado.

Below: Canoer, Nantahala River, North Carolina.





Arid region floodplains, although apparently desolate, actually provide habitat for most desert wildlife species. Channel, floodplain, and riparian habitat, Verde River, Tonto National Forest, Arizona.

Cultural Resources

As used in this report, the cultural resources of floodplains include their historic and archaeological sites, their scientific, recreational, and aesthetic uses, as well as the harvest of the floodplains' natural and cultivated products. Because water has always been basic to human survival, transportation, and commerce, many sites of historic and archaeological significance lie in floodplains. Floodplains provide opportunities for hiking, camping, hunting, fishing, boating, swimming, bird-watching, picnicking, jogging, photography, ice skating, nature observing, as well as for scientific study and research, educational activities, and less tangible aesthetic benefits. Floodplains can provide urban communities with a tremendous open-space and greenbelt resource.

Inland floodplains are great sources of commercial timber. Much of the 82 million acres of commercial forested wetlands in the 49 continental states lies within floodplains. The standing value of southern wetland forests alone is $8 billion. The floodplains along larger rivers are prime agricultural lands because of their flat terrain, abundant water supplies, and rich alluvial soils periodically replenished by flooding. From 1956 to 1975 about 60% of the U.S. commercial fish and shellfish harvest was made up of wetland-dependent species. Several billion dollars are generated annually from this harvest and from wetlands-dependent sport fishing.

Floods

Floodplains are, by definition, lands that are formed by and continually subject to inundation by water. Depending on the location, topography, soils, and weather conditions, that flooding can take a variety of forms. Riverine floods can result not only from heavy rainfall and rapid snowmelt but also from dam and levee failure, ice jams, and channel migration. Coastal flooding can be caused by hurricanes, winter storms, tsunamis, and rising sea level. Individual storms and long-term climate variations cause flooding around lakes. Other floodprone areas include alluvial fans, unstable and meandering channels, and areas affected by land subsidence and ground failure. In addition, flooding due to surface runoff and locally inadequate drainage can be a major problem, particularly in rapidly urbanizing areas.

Riverine Flooding

Riverine flooding—overflow of water from the channel onto the adjacent floodplain—is the most common type of flood. Hundreds occur each year in the United States.

- *Flash flooding* occurs in all 50 states: in narrow, steep valleys, on alluvial fans, on denuded areas, and along urban drainage courses, usually as a result of high intensity, short duration storms occurring on steep gradient streams. Flash floods can be more dangerous than other floods because of their suddenness, the velocity of the water, and the large amount of debris carried by the flood waters.

Big Thompson Canyon, Colorado, following flash flood, July 1976.

Examples of Recent Flash Floods Causing Serious Loss of Life

February 1972, Buffalo Creek, West Virginia—125 killed and hundreds of homes washed away when a dam made of coal mine waste material gave way after heavy rains.

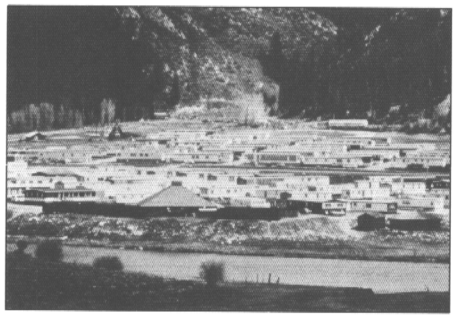
June 1972, Rapid City, South Dakota and adjacent areas—236 dead and $100 million in property damage after a large, slow-moving thunderstorm unleashed heavy rain on the slopes of the Black Hills.

July 1976, Big Thompson Canyon, Colorado—139 killed and millions of dollars in property damage after a thunderstorm inundated the western third of the canyon with 12 inches of rain in less than six hours.

July 1977, Johnstown, Pennsylvania—77 dead and more than $200 million in property damage when violent thunderstorms produced 11 inches of rain over a seven-county area in nine hours. Several dams failed, compounding the stream flooding and causing 40 of the deaths.

September 1977, Kansas City, Missouri, and adjacent areas—25 killed and $90 million in property damage when thunderstorms turned several streams into raging torrents, including "gentle" Brush Creek, which flows through the heart of Kansas City.

Source: Federal Emergency Management Agency



Alluvial fan flooding at the mouth of ravines or the foot of mountains occurs throughout the United States, but is most prevalent and poses the greatest hazard in the arid West. Mobile home park, Colorado river, near Parker, Arizona.

- *Alluvial fan flooding* can cause great damage because of the high velocities, large amounts of sediment and debris, and wide area covered by the flood waters. Alluvial fans occur mostly along the base of mountains in the western states. An estimated 15-25% of the arid West, including Los Angeles and Las Vegas, is covered by alluvial fans.
- *Unstable and meandering stream channels* are also frequently flooded. Many of them are the product of several decades of human activities, particularly in the arid and semi-arid West. Overgrazing, mining, forestry, urbanization, gravel and sand extraction, and the construction of railroads,

Storm drainage is a significant problem in many large urban areas, particularly if development has been rapid and not well planned. Drainage systems must be designed to handle infrequent, but potentially catastrophic, events.

Concrete-lined artificial channel carrying flood waters, Baton Rouge, Louisiana.

highways, dams, and irrigation facilities all have changed the vegetative cover, altered surface water patterns, changed the movement of sediments, and lowered water tables. These changes have made water movement during floods difficult to predict.

- *Ice jams,* which affect 35 states, cause a rapid rise of water both at the point of the jam and upstream; when the jam breaks, sudden downstream flooding results. Because the waters are higher and their velocities greater, damages usually exceed those that would have occurred without the jam. Additional damage can be caused by the force of the ice, as it builds in volume and expands overbank during the jam and then crashes downstream when the jam breaks.

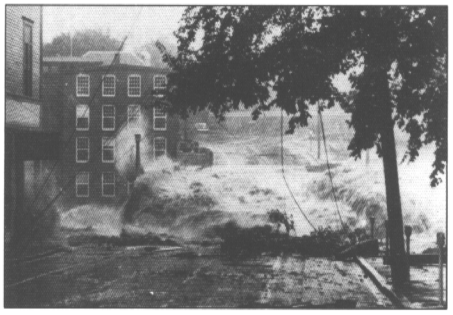
Flooding from Surface Runoff

The runoff from heavy precipitation can overtax inadequate local drainage systems and result in flooding outside of normal floodplains. These kinds of flooding problems generally intensify as areas become more urbanized. Frozen ground and heavy accumulations of snow can exacerbate the problem.

Coastal Flooding and Erosion

Coastal flooding and erosion result from storm surge (the rise in the water surface due to barometric pressure and the piling up of water as a result of wind) and wave action (the combination of wave set-up and wave runup). The frequency and magnitude of flooding and erosion vary considerably across the country.

- From 1899 to 1989 a total of 148 *hurricanes* and 135 *tropical storms* crossed or passed adjacent to the U.S. mainland.
- *Northeasters*—extratropical storms accompanied by strong winds—cause flooding along the north Atlantic coast.
- *Tsunamis* are sea waves generated by undersea earthquakes of over R6.5; they are very long-period, are of low height at sea, and can travel over 500 mph. The entire Pacific coast of the United States, including Alaska and Hawaii, is subject to tsunamis.
- *Shoreline erosion* occurs either when storm surge and wave action move sediment offshore or when the alongshore flow of sediment is interrupted by natural forces or human activities. Natural erosion may be accelerated by partial or inadequate structural or nonstructural measures intended to protect short reaches of eroding shoreline—such as beach nourishment, artificial dunes, breakwaters, seawalls, bulkheads, revetments, groins, and jetties.



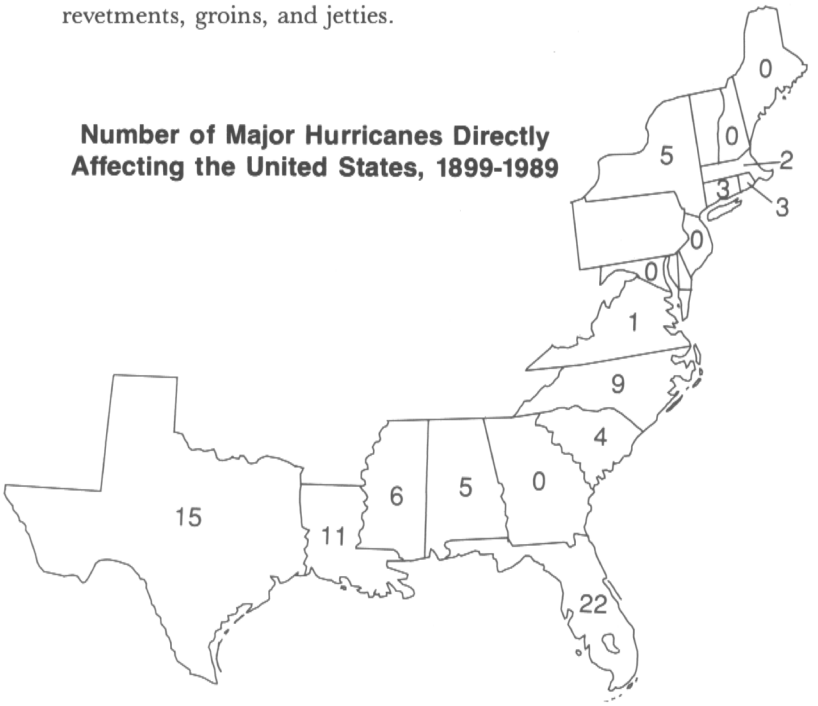
Hurricanes can result in flooding of various kinds, from flash flooding and slow-rise riverine flooding due to heavy precipitation, to coastal flooding due to storm surge.

Quinebaug River, Putnam, Connecticut, 1955, following Hurricane Diane.

Hurricanes can cause severe damage due to the combined effects of several agents—high winds, increased wave action, heavy precipitation, storm surge, and other types of flooding.

Damage near Charleston, South Carolina, following Hurricane Hugo, September, 1989.

Number of Major Hurricanes Directly Affecting the United States, 1899-1989



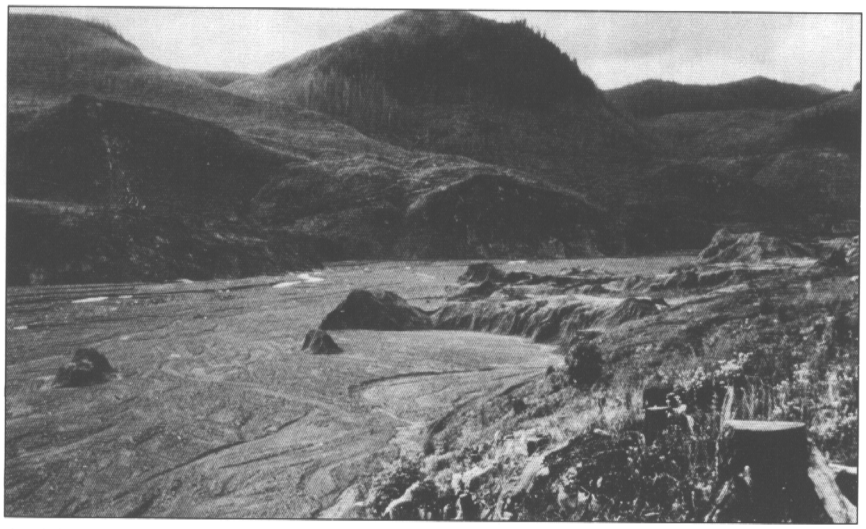
Source: National Hurricane Center, National Weather Service

Ground Failure

Areas subject to ground failure often suffer from *mud flows* and *mud floods*, two forms of landslides. Urban development alters hillslope configurations and upsets established equilibrium, triggering the natural instability of many slopes and sometimes reactivating old landslides. Mud and debris may fill drainage channels and sediment basins, causing flood waters to suddenly inundate areas outside the floodplain. Mud flows and mud floods may cause more severe damage than other flooding because of the force of the debris-filled water and the combination of debris and sediment.

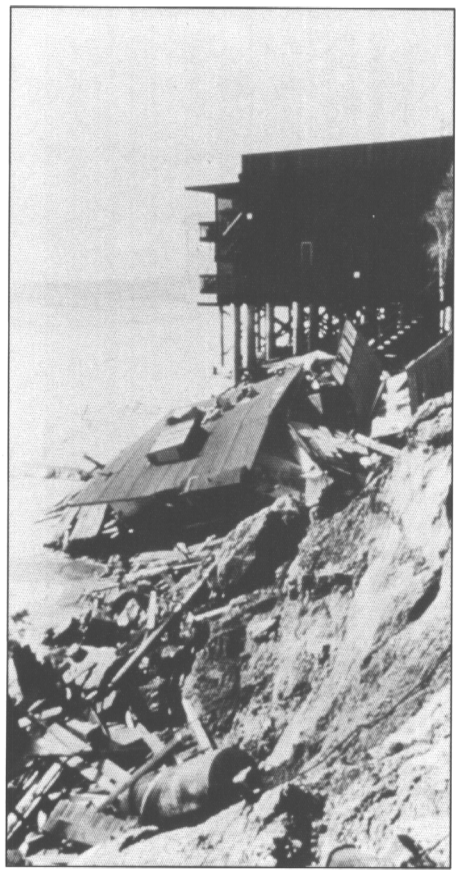
Both natural and human-induced *subsidence* can increase flood damage in areas of high groundwater, tides, storm surges, or overbank stream flow. It can also block or otherwise alter drainage patterns, leading to deeper or unexpected flooding. Subsidence occurs in at least 38 states.

Liquefaction is a type of ground failure triggered by seismic waves passing through unconsolidated and saturated soil. Depending on the character of the soil, the amount of water, and the drainage potential, the soils may sink or become liquid. This can result in serious flooding of structures built on fill or saturated soils—as in parts of San Francisco and Anchorage.



Mud flows and mud floods are two types of landslides that can be aggravated by human development. Additionally, they can result from other natural hazards, such as earthquakes and volcanic eruptions.

Toutle River, Washington State, following the eruption of Mt. St. Helens, May 1980.



Natural coastal erosion can be greatly accelerated by wave action during storms and hurricanes. Combined with inappropriate construction in coastal areas, this natural process can result in disaster.

Big Rock Beach, Malibu, California, following Pacific winter storm, 1983.

Fluctuating Lake Levels

Closed-basin lakes are susceptible to dramatic (5- to 15-foot), long-term fluctuations in their water levels as a result of variations in precipitation, runoff, and evapotranspiration. Flooding associated with this situation can last for years; examples of such lakes are the Salton Sea, the Great Salt Lake, and the Great Lakes. Short-term fluctuations can be triggered by sustained strong winds and by sharp changes in barometric pressure. Human activities, such as dredging, diversions, water consumption, and regulation by structural works, can also affect lake levels.

Changes in Water Levels in the Great Lakes, 1900—1986

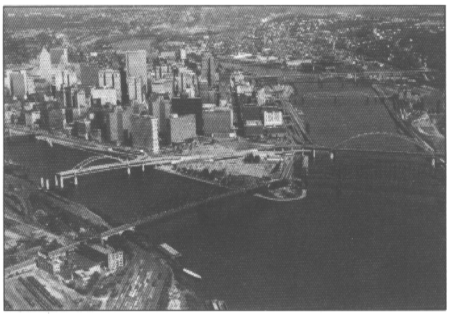
(Lake Surface Elevation, in Feet)

Lake	Monthly Mean 1900–1986			Range (winter low to summer high monthly means)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Superior	600.61	602.24	598.23	1.2	2.1	0.4
Michigan-Huron	578.33	581.62	575.35	1.2	2.1	0.4
St. Clair	573.40	576.69	569.86	1.7	3.3	0.4
Erie	570.50	573.70	567.49	1.6	2.8	0.9
Ontario	244.73	248.06	241.45	2.0	3.6	0.7

Levels are referenced to International Great Lakes Datum 1955.

Source: U.S. Army Corps of Engineers

Floodplain Losses



Historically, the development of the United States has proceeded along the principal waterways of the nation, where cities have been developed and redeveloped over the decades.

Pittsburgh, Pennsylvania, early 1960s.
(Compare this photograph with those on page 24.)

Throughout the history of the United States, the prevailing view has been that humans should use and modify the natural environment, including floodplains, to meet their needs. For centuries people have been settling on the banks of the country's rivers, streams, and oceans, taking advantage of the water supply, transportation, energy source, wildlife habitat, and other benefits floodplains provide. Unfortunately, human development on floodplains usually results in flood damages. In the United States the result of this widespread damage was a second wave of activity, during which individuals and governments enthusiastically engaged in the construction of dams and reservoirs, levees, floodwalls, and stream channelization projects in efforts to prevent or limit damages to development that was either knowingly or inadvertently placed within the floodplain. Thousands of water supply projects, particularly in the arid West, dramatically changed the natural resources of riparian areas. Millions of acres of inland and tidal wetlands were filled or drained, causing loss of natural flood storage areas, a lowered capacity for filtration of pollutants and groundwater recharge, and reduction or elimination of some wildlife species.

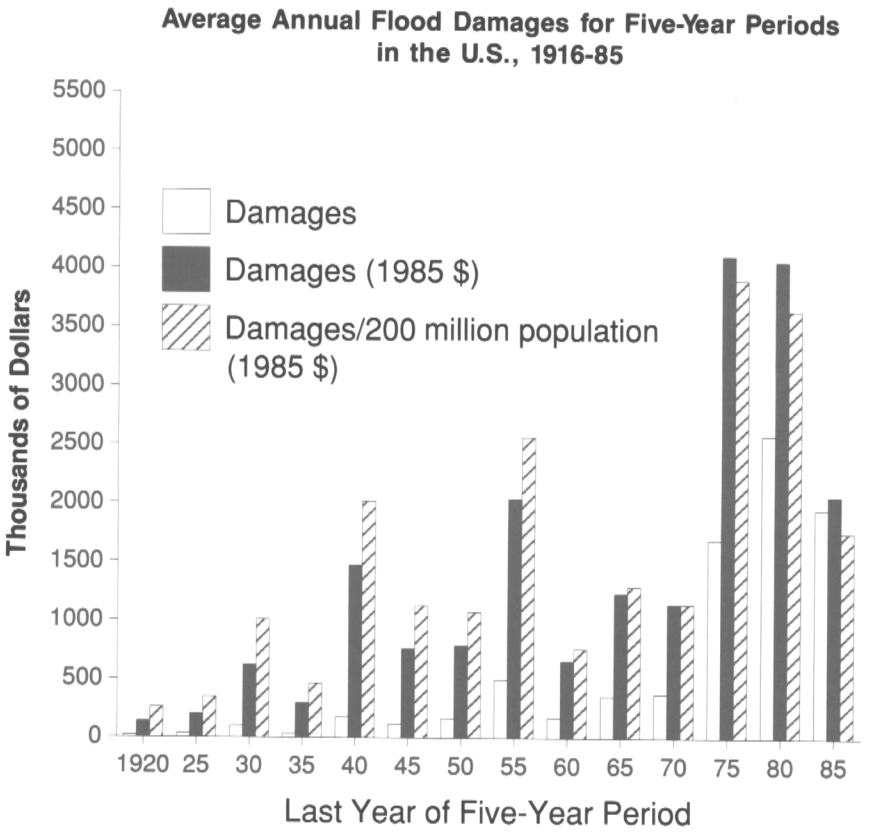
By the late 1970s it was estimated that from 3.5 to 5.5 million acres of floodplain land had been developed for urban use, including more than 6,000 communities with populations of 2,500 or more. Annual growth in these floodplain areas was between 1.5% and 2.5% during the 1970s, roughly twice that of the country as a whole. The coastlines of the United States have been attracting people and their accompanying property and infrastructure in ever-increasing numbers for several decades. The 1980 U.S. Census units within 50 miles of the Atlantic and Gulf coastlines increased in population from 34.1 million in 1940 to 63.3 million in 1980—an increase of 85%, compared with 70% for the nation as a whole. The population of Gulf Coast counties increased by 200%.

In 1991 the floodplain lands in 17,466 examined communities occupied a total of 146,600 square miles (93.8 million acres), including about 9.6 million

households and $390 billion in property. Florida was the state with the highest composite risk, followed by California, Texas, Louisiana, and New Jersey.

This large-scale development and modification of riverine and coastal floodplains has resulted in a major increase in the land area of the United States that may be economically developed and used, but at a high price extracted annually in deaths, personal injury and suffering, economic loss, and damage to or destruction of natural and cultural resources. There are two main kinds of floodplain losses: loss of life and property, and loss of natural and cultural resources. Both types continue to occur even with increased awareness of the value of floodplains and of the risks of floodplain occupancy. The actual and relative amounts of these losses are not well quantified.

It has been estimated that 3.5 to 5.5 million acres of floodplain land had been developed for urban use by the late 1970s. In many cases, this change has resulted in greatly altered river corridors and adjacent lands. Channel modification, Sioux City, Iowa.



Source: National Weather Service

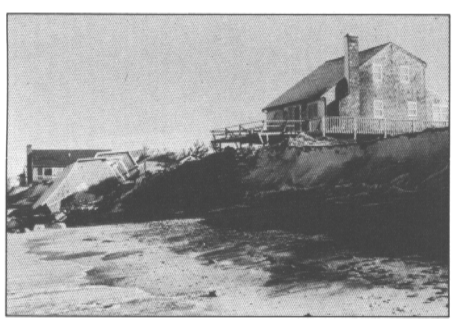
Although there is no uniform measure of flood losses, flooding clearly constitutes the most pervasive and costly hazard facing the nation. From 1965 to 1989, total assistance payments for Presidentially declared disasters amounted to almost $6.8 billion. Of that, $5.2 billion was allocated for flood- and hurricane-related damage. Flooding, Prairie du Chien, Wisconsin, 1975.

Although less dramatic than urban or coastal flooding, rural flooding and consequent agricultural losses account for almost 50% of flood damages in the United States.

Flooding along the Snohomish River, Washington State, November 1986.

Damages to infrastructure may account for as much as 25% of the total damages incurred during flooding.

Bridge damaged by flooding, Jefferson Island, Louisiana, 1979.



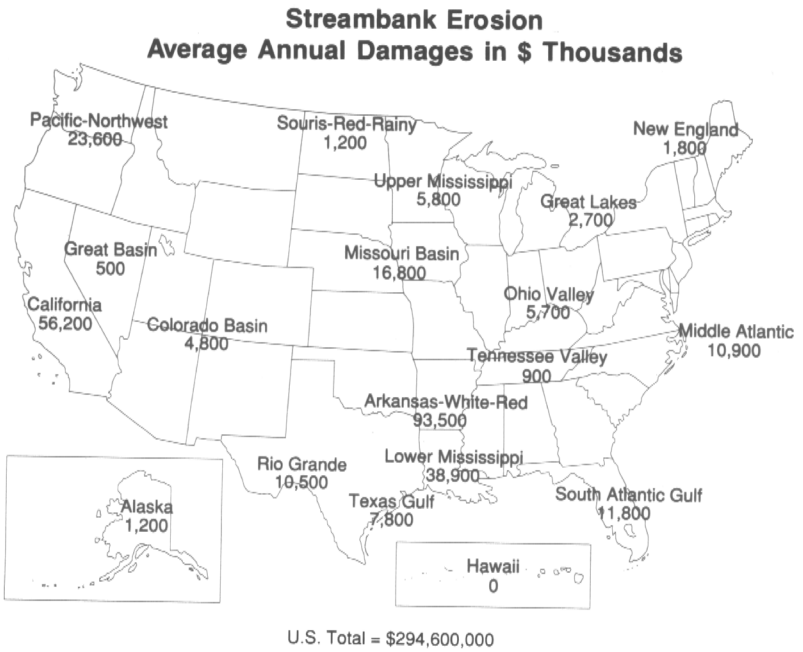
In a 1971 study, the Corps found that approximately 24% of the nation's shoreline was significantly eroding. Two-thirds of this land was privately owned.

Dune erosion and house collapse, Sandwich, Massachusetts.

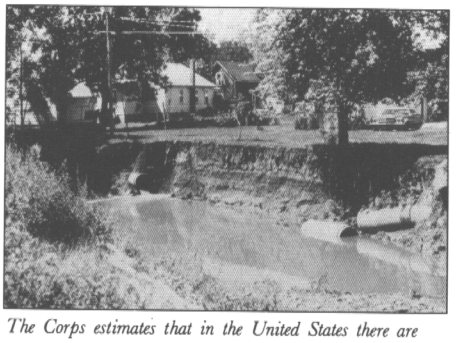
Loss of Life and Property

Between 1916 and 1985 there were, on average, 101 flood-related deaths annually; there is no indication that deaths are increasing or decreasing on a per capita basis. On the other hand, there definitely was an increase in flood damages over that 70-year period. Per capita flood damages were almost 2.5 times as great from 1951 to 1985 as from 1916 through 1950, after adjusting for inflation. Property losses from floods appear to have been fairly constant in relation to the overall national economy. For example, flood losses in 1937 in the Ohio and lower Mississippi River basins ($440 million) amounted to .0049% of the GNP for that year. Flood damages in 1983 ($4 billion) amounted to only .0012% of GNP. Consistent, reliable data on historic flood deaths and damages are still not being collected. Information on the financial aid given by many federal and state agencies is not available in a form that separates flood-related damages from other types of natural and technological disasters. Nevertheless, there are numerous figures available to help establish the type and extent of damages suffered.

- Floods account for more losses than any other natural disaster in the United States (with the exception of drought losses during certain years or long-term periods). In most years flood damages constitute the bulk of federal financial aid for disasters.
- From 1981 to 1985, about 23% of all Presidentially declared disasters involved coastal flooding, and about 49% of federal disaster aid obligations were attributable to coastal damage.
- A total of $2.6 billion in flood insurance claims were paid out by the National Flood Insurance Program from 1978 to 1987. Over 31% were for flooding in areas outside the 100-year floodplain—the result of rapid urbanization that exceeds the capacity of managers to remap and regulate, or to manage stormwater.
- The Federal Highway Administration provided $442.3 million in emergency relief from 1986 through 1989.
- About half of the nation's annual flood damages are agricultural losses.
- The Small Business Administration issued $78.7 million in economic injury disaster loans and $67.9 million in physical disaster loans in fiscal year 1989.
- On irrigated cropland, flooding can damage irrigation facilities, such as ditches, pipelines, and sprinklers. Sediment deposited by flood waters can reduce long-term yield by covering fertile land with infertile deposits and can damage existing crops by interfering with their growth. These losses range from $150 to $500 million annually.
- A review of eight disasters from the 1950s and 1960s found that damages to infrastructure accounted for about 25% of the total damages. Other estimates put that figure at 10–19%.
- Over three-fourths of all Presidentially declared disasters involve flash flooding; flash floods have been the cause of most weather-related deaths in the United States.
- A study of streambank erosion estimated $295 million in average annual damages. Neither the damages from nor costs of coastal erosion have been estimated.
- Total national losses from lake level fluctuations exceeded $250 million from 1981–1986.
- The overall damages and cleanup costs from the 1980 eruption of Mt. St. Helens, which caused catastrophic flooding and mudflows, were estimated at $1.2 billion; over $875 million was needed to restore land, clean up rivers, and provide flood protection to area communities.
- Three tsunamis have resulted in losses in recent times: 173 deaths in Hawaii in 1946; 61 deaths in Hawaii in 1960; and 107 deaths in Alaska, 4 in Oregon, and 11 in California in 1964, plus $100 million damage on the West Coast.



Source: U.S. Army Corps of Engineers



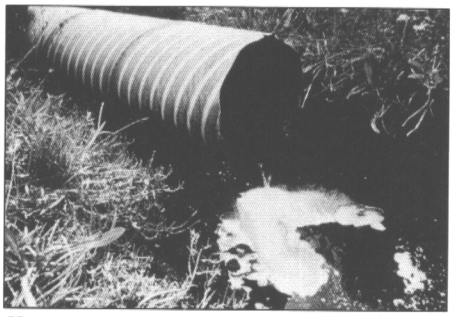
The Corps estimates that in the United States there are 574,500 miles of stream bank with erosion problems—142,100 with serious problems. About 78% of all stream bank erosion takes place west of the main stem of the Mississippi River.

Loss of Natural and Cultural Resources

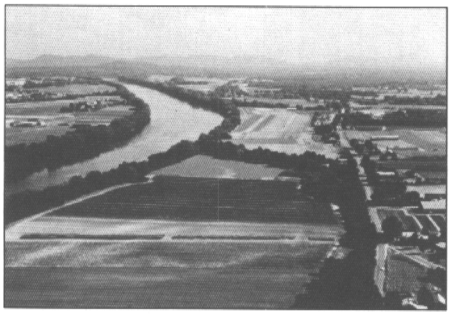
All three types of floodplain resources—water, living, and cultural—are threatened by human use of the floodplain, whether for urban development or seemingly benign agriculture or forestry. Furthermore, because floodplains are integrated natural systems, tampering with any one of the component natural processes may often lead to trouble. Increased runoff resulting from widespread clearing of vegetation, destruction of wetlands, dune removal, paving, roofing, and other activities can increase flood peaks, stream erosion, and sediment transfer. Blocking runoff or interrupting the movement of groundwater can raise flood profiles, increase pollution, and interfere with groundwater balances and the distribution of sediment. Fertilizers, septic systems, chemical and petroleum spills, and leached materials from waste disposal areas can degrade the surface and groundwater resources of floodplains. Recreational and commercial river traffic often seriously contributes to streambank erosion. Increased sediment can bury food sources and spawning areas and pollution can poison plants, animals, and other living things. Development can remove shelter and food, and prevent fish and other wildlife from moving through their habitat. Erosion of coastal wetlands and filling of wetlands destroys habitat. In many cases, developed floodplains do not have the aesthetic and recreational attributes of natural ones. Improper agricultural and forestry practices can be just as destructive of natural floodplain values as poorly planned urban development.

The nature of the value of natural floodplains makes the damage to them difficult to quantify, but the losses have been assessed even if no economic value has been assigned.

- Over 90% of the United States' coastal barriers are subject to flooding and erosion because of their seaward exposure, inherent instability, and relatively low-lying topography. In spite of these risks, 14% of the area of coastal barriers is urbanized (compared to only 3% of the entire mainland), including Atlantic City, Ocean City, Virginia Beach, and Miami. This development also interferes with the natural ability of the barriers to absorb storm energies, thereby reducing protection for mainland populations and development as well.



Human occupation and use of a floodplain threatens its natural resources in many ways. Significant among these is the potential for increased pollution due to improper waste disposal, spills, and various forms of nonpoint source pollution.

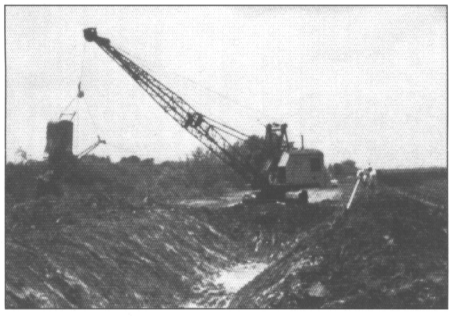


Just as urban development of floodplains must be carefully planned, the effects of agricultural and forestry uses must also be analyzed and understood before changes in a floodplain are made.

Connecticut River near Deerfield, Massachusetts.

Development in a floodplain may 1) increase runoff, 2) block runoff and interrupt groundwater movement, and 3) increase pollution. It can affect living resources and habitat in numerous, sometimes unpredictable, ways.

Development in coastal marshland of Louisiana.

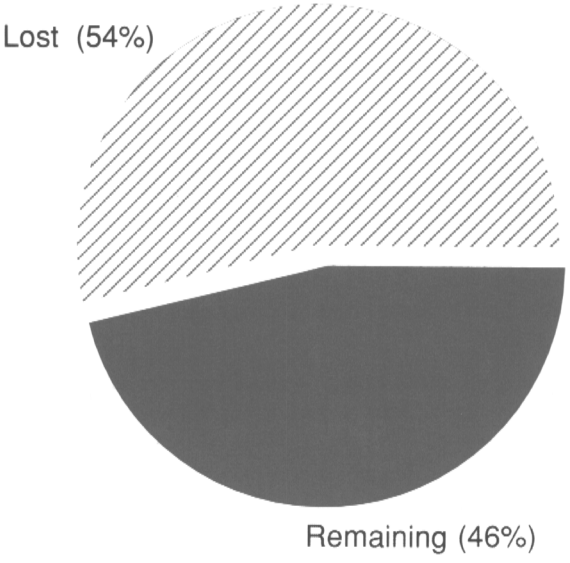


Over the years, the conversion of wetlands to other uses has resulted in more than half of all U.S. wetlands being lost.

Dredging near Amelia, Louisiana.

- Human activities have already profoundly affected floodplains and the nature of flooding throughout the arid and semi-arid Southwest, where rapid development is expected to continue. Many changes that began 450 years ago with the introduction of cattle are still affecting the basic hydrologic cycle and geomorphology of the region. Plant and animal associations that evolved for 10,000 years have been irreversibly altered, and the effects of this are still only vaguely understood and generally unmanaged.
- About 54% of the original 215 million acres of wetlands in the nation have been lost since European settlement. A recent U.S. Fish and Wildlife Service study estimates that there are about 100 million acres, or about 5% of the land mass, left in the continental United States, and the U.S. Office of Technology Assessment estimates that there are about 200 million acres, or about 60%, in Alaska. Historically, the greatest portion of this loss by far was the result of draining wetlands

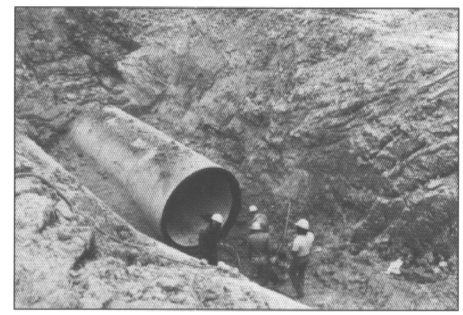
Original and Remaining Acreages of Wetlands in the Lower 48 States



Source: Fish and Wildlife Service, U.S. Department of the Interior

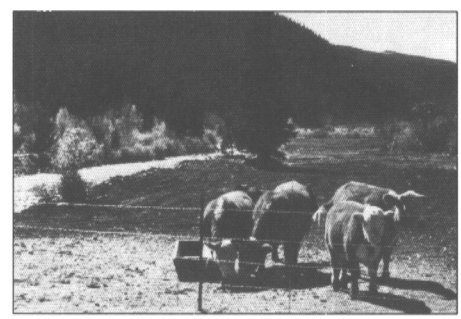
for conversion to agriculture. Major areas of bottomland hardwood forests have been cleared, drained, or converted to agriculture. Agricultural uses were estimated to account for 54% of the 300,000 acres lost annually from the mid-1970s to the mid-1980s.

- Riparian ecosystems are being degraded and destroyed throughout the United States. The lower 48 states originally contained 75–100 million acres of indigenous, woody riparian habitat, but today only 35 million remain in nearly natural condition. The rest have been inundated by reservoirs, channelized, dammed, riprapped, converted to agricultural use, overgrazed, paved, or altered by a combination of factors that have impeded their ability to stabilize and maintain the biological diversity of their own watersheds. Riparian habitats have been lost in every region of the country.
- Channelization and other flood control projects can destroy riparian habitat by clearing vegetation; eliminating sandbars, islands, and productive backwater areas; and accelerating bank erosion. Between 1940 and 1971 the U.S. Army Corps of Engineers assisted in navigation and flood control projects to alter 11,000 miles of streams. The Soil Conservation Service has installed 10,700 miles of channel modifications.
- Dams can alter riparian habitat in many ways, such as drowning it under reservoirs, desiccating it by downstream dewatering, or rendering it non-regenerative by interrupting the natural flood cycle. The nation's 68,153 nonfederal dams have altered or destroyed tens or hundreds of thousands of miles of riparian habitat. Impoundments by the federal government have transformed major river systems, including the Columbia, Colorado, Missouri, and Tennessee, into a series of artificial lakes, severely decreasing the diversity of habitats available to wildlife but creating other habitats and environments.
- By overgrazing, trampling vegetation, compacting the soil, and breaking down streambanks, livestock have seriously damaged watersheds and riparian zones. These impacts have led to increased soil erosion, higher nutrient load in streams, bank erosion, and lowering of water tables. Inadequate livestock management has been responsible for the serious lack of riparian habitat regeneration on federal rangelands in the West.
- Lowering of the water table in arid and semi-arid regions causes a drastic and often permanent degradation of the floodplain. In many areas, a high water table and accompanying pools and springs are the only sources of moisture for riparian vegetation and native animals. Introduction of non-native plants has also significantly contributed to alteration of floodplain habitat. Salt cedar, for example, which was imported to North America during the 19th century, has become the predominant riparian tree species on the lower Colorado, the lower Rio Grande, and Pecos rivers. It covers some 500 square miles in those basins alone, and makes the riparian areas less suitable to many native birds.



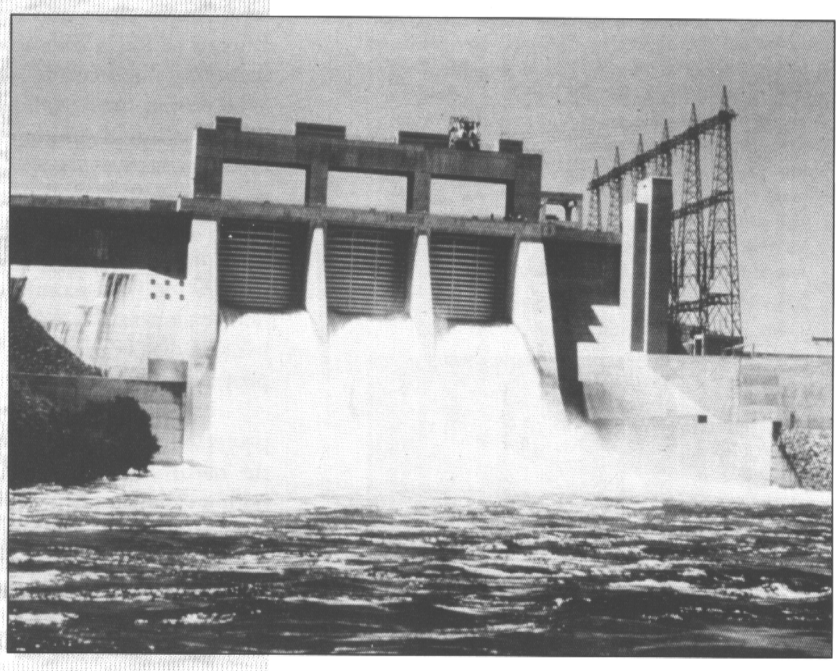
Alteration is widely used to control flooding by increasing the carrying capacity of a stream channel. Techniques include straightening, deepening, widening, or paving the channel; removing debris; raising or enlarging bridges and culverts; removing dams and other obstructions; and installing underground conduits. However, unless carefully planned and executed, such channel modification can significantly affect riparian habitat.

Artificial channel (buried conduit) under construction, LaPlace, Louisiana.



The introduction of cattle to the American West has had a fundamental effect on the nation's landscape—in particular, on riparian lands in semi-arid environments. In many cases the result has been soil compaction, loss of vegetation, increased erosion, and the consequent deterioration of floodplains, river banks, and river water quality.

Part II
Managing Floodplains to Reduce Losses



The History of Floodplain Management

Before 1965, government action to reduce floodplain losses was primarily a response to significant loss of life or property damage. Most of these efforts sought to control flooding through structural measures. During the mid-1960s, federal policy began to broaden to include nonstructural means. The last 25 years have witnessed a major expansion in floodplain management, incorporating better ways for analyzing and predicting flooding, paying appropriate attention to the natural resources of floodplains, and adjusting the roles of federal, state, and local governments and the private sector.

1900-1960: The Structural, Federal Era

During the 1800s and early 1900s, flood control efforts were undertaken by levee districts, conservancy districts, other local and quasi-public groups, and individual landowners. Federal involvement was sporadic and concerned mainly with flood impacts on navigation, forestry, or agriculture. After the Civil War, Congress authorized federal agencies to begin stream gaging as a start toward flood forecasting and warning, but federal involvement still was limited.

After two decades of major flooding along the Mississippi, Ohio, Potomac, Susquehanna, and various New England rivers, Congress committed the federal government to flood control of all navigable rivers in the nation in the Flood Control Acts of 1917, 1928, 1936, and 1938. The combined effect of these acts was the federal government's assumption of the full cost of building and maintaining reservoirs and channel modifications, and the placement of most of the responsibility for efforts to control floods in the hands of the Corps. These laws did mention other measures for reducing flood damages, such as evacuation, watershed improvement, and reconciliation of needs of upstream and downstream users, but the emphasis was on controlling flooding with such structures as dams, levees, and channel modifications.

Twenty-five years later the Corps' authorized flood control program encompassed 220 reservoirs (90 million acre feet of flood control capacity), over 9,000 miles of levees and floodwalls, and 7,400 miles of channel modifications—a total of 900 projects with an estimated federal cost of $9 billion. Other federal agencies also became involved in flood control. The Tennessee Valley Authority's regional program of resource development included construction of dams and reservoirs for flood control and other purposes. The Bureau of Reclamation and the U.S. Department of Agriculture began including flood control with other project considerations. During the 1930–1950 period the U.S. Forest Service established research watersheds to study water yield and timing of flows from forest and range watersheds. The Coweeta Hydrologic Laboratory in North Carolina was established in 1934 as the first of these watersheds. The Soil Conservation Service began helping individual landowners in 2,600 soil conservation districts to use conservation measures, including flood prevention.

Along with federal involvement in flood control came federal relief for flood victims. The Federal Disaster Act of 1950 was the nation's first comprehensive disaster relief act, and Small Business Administration disaster relief programs were also begun in the 1950s.

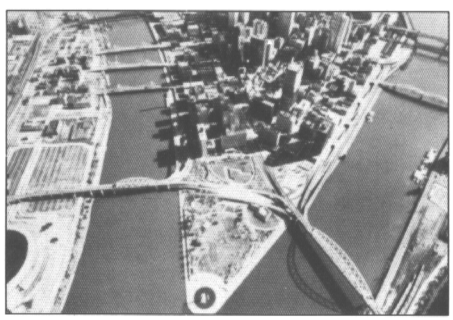
Before the 1960s a number of single-purpose federal laws and programs protected various specific natural resources and thus indirectly helped protect the natural resources of some floodplains. For example, the creation of national parks and federal forest reserves resulted in the protection of significant areas of natural floodplains. Other laws protected wildlife habitat and preserved open space for conservation and recreation, thus ensuring that some floodplain areas would be left in their natural states.

1960s: A Time of Change

Despite the billions of dollars in federal investments in structural projects, and the demonstrated effectiveness of these measures, flood losses and disaster relief costs continued to rise because of unwise occupancy and use of the nation's floodplains. Thus, broader approaches were studied and

In the latter part of this century, the scope of floodplain management broadened to encompass a wide range of techniques. The "Point Area" of Pittsburgh, Pennsylvania, at the confluence of the Allegheny and Monongahela Rivers, demonstrates these advances. For example, the transportation corridor in the foreground has been replaced by an open space park, highways have been elevated, and prominent structures have been floodproofed. These physical changes, along with a comprehensive system of upstream flood control, land use controls, and a coordinated flood warning and preparedness program, have significantly reduced the flood hazard in downtown Pittsburgh.

Above: Pittsburgh, Pennsylvania, Point Area 1948.
Below: Pittsburgh, Pennsylvania, Point Area 1982.



Previous page: Davis Dam, Colorado River, near Bullhead City, Arizona.

applied, including zoning and other land use regulation, flood forecasting, federal flood insurance, relocation of property, and alternative water storage techniques. Major steps were taken to redefine federal policy. Section 206 of the Flood Control Act of 1960 authorized the Corps to provide technical services and planning assistance to communities for wise use of the floodplain and for ameliorating the flood hazard. The Corps began producing maps and floodplain information reports describing a community's flood hazard from a broader perspective. The President's water policy statement of 1962 established policies and procedures for comprehensive river basin plans. The Water Resources Planning Act of 1965 created the U.S. Water Resources Council and authorized federal-state river basin commissions for comprehensive basin planning.

House Document 465, the report of a Bureau of the Budget Task Force on Federal Flood Control Policy, advocated a broader perspective on flood control within the context of floodplain development and use. Executive Order 11296, Flood Hazard Evaluation, directed all federal agencies to evaluate the flood hazard before undertaking federally financed or supported actions and to play a lead role in preventing uneconomic use and development of floodplains. Fifteen states, most notably Wisconsin and Minnesota, adopted floodplain management programs, some of them providing for strict regulation. Local governments also began trying to deal with the hazard in a more comprehensive way, usually with assistance from a state or federal agency such as the Tennessee Valley Authority.

HISTORY OF A UNIFIED NATIONAL PROGRAM FOR FLOODPLAIN MANAGEMENT

House Document 465, *A Unified National Program for Managing Flood Losses,* was submitted to Congress by President Lyndon Johnson in August 1966. It had been prepared by the Task Force on Flood Control Policy at the administration's request in an attempt to slow the mounting national toll of flood losses, unchecked by over $7 billion in national investments in flood control projects since 1936. House Document 465 recognized the need for a unified approach and for new planning measures, and made 16 recommendations for federal agency action to begin implementation of a program—including new legislation, specific studies, and new programs for collecting and disseminating flood-related information.

A Unified National Program, 1976

In response to a 1968 Bureau of the Budget request for a report pursuant to a directive in Section 1302(c) of the National Flood Insurance Act, and to a 1975 U.S. General Accounting Office report criticizing House Document 465 and Executive Order 11296, the U.S. Water Resources Council submitted to the President the *Unified National Program for Floodplain Management* in 1976. This revision, whose title change reflected a significant recognition that more than flood losses were involved, established a more detailed framework for the program, described the greatly changed context in which it would be implemented (numerous changes in flood-related federal programs had taken place), and added management strategies and tools for federal, state, and local decisionmakers to use. The report focused on the need for improved coordination, which was cited as the "weakest component of current management efforts."

1979 Revisions to a Unified National Program

Although the 1976 Unified National Program made a significant step forward in floodplain management, its very effectiveness made it quickly dated. Several executive level actions—President Carter's floodplain management policy articulated in 1977, Executive Orders 11988 and 11990, and the President's 1978 water policy initiatives—were soon taken, making the 1976 version obsolete. The Federal Interagency Floodplain Management Task Force updated and refined the Unified National Program in a report submitted by the Water Resources Council to the President in 1979. This revision incorporated federal concern with the "natural and beneficial values" of floodplains, responded to the President's policy directives, expanded the strategies (adding two: restoration of natural values and preservation of natural values), tools, and conceptual framework accordingly, and emphasized the insufficient awareness of alternative strategies due to "lack of adequate technical and procedural information to guide floodplain decision-makers."

1986 Revisions to a Unified National Program

In 1982, the Office of Management and the Budget assigned responsibility for the Unified National Program to the Federal Emergency Management Agency, which assumed chair of the Interagency Task Force. The Task Force submitted an updated Unified National Program in 1986, noting that the 1979 report had become "dated by the relative success and changes in federal programs and by the strengthening of floodplain management capability at the state and local levels." These changes included the use of federal interagency hazard mitigation teams, passage of the 1982 Coastal Barrier Resources Act restricting federal expenditures that might encourage development of coastal barriers along the Atlantic and Gulf coasts, and completion of two major National Science Foundation studies on flood hazard mitigation. The report included more explicit recommendations for the federal role in supporting state and local initiatives.

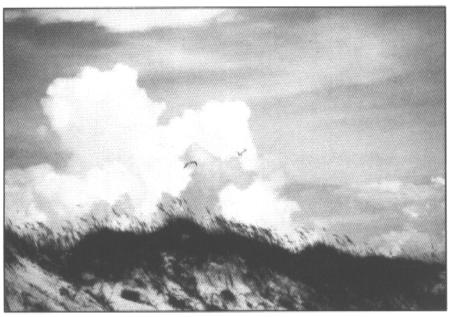
Two major pieces of legislation rounded out the change in federal policy. In 1969 the National Environmental Policy Act provided for consideration of environmental values in all federal and federally supported actions, making it possible to recognize the multiple values of floodplains. The National Flood Insurance Act of 1968 made federally subsidized flood insurance available to participating communities, contingent upon their implementing nonstructural flood loss reduction measures embodied in local floodplain management regulations.

1970s: The Environmental Decade

During the 1970s numerous state and federal environmental laws and programs and water resources initiatives began to decentralize water management and bring about a much broader perspective on floodplains. Numerous federal programs took shape for water quality management, pollution and erosion control, watershed management, and protection of groundwater, aquifers, inland and coastal wetlands, barrier islands, and specific habitats. Complementary legislation was passed by many states, requiring environmental quality review and impact assessments at state and local levels.

During this decade, changes were made in the National Flood Insurance Program; a proposal for a Unified National Program for Floodplain Management was issued and later updated; and executive orders on floodplain management and protection of wetlands were issued, making disaster relief contingent upon mitigation action and requiring the consideration of nonstructural measures in federal flood control projects.

State and local involvement in floodplain management increased with the appointment of National Flood Insurance Program coordinators in all states, the adoption by more states of regulatory programs, increases in state budgets for floodplain management, and the adoption of resource conservation legislation. About 17,000 communities adopted floodplain management regulations, and many adopted regulations to manage other local resources, such as wetlands and coastal areas.



Coastal management in the United States is shaped by the federal Coastal Zone Management Act of 1972 and the Coastal Barrier Resources Act of 1982. The former authorized federal grants to states for development and implementation of coastal management programs for water and land resources in coastal zones. As amended, the Act incorporates both flood loss reduction and protection of natural resources into program goals. The latter legislation established a system of largely undeveloped coastal barriers along the Atlantic and Gulf coasts in which federally subsidized development is restricted.

Sand dunes, Santa Rosa Island, Florida.

1980s: Continuing Evolution

More attention was given to implementing policies and programs for managing floodplains during the 1980s. The federal government took the role of coordinator and provider of technical assistance, while state and local governments gradually fashioned floodplain management strategies appropriate to their own jurisdictions. Interagency agreements were crafted to establish common policy on nonstructural measures and to evaluate floodplain management options after disasters. The Coastal Barrier Resources Act of 1982 established a policy of nondevelopment and avoidance of high hazard areas by prohibiting new federal expenditures on certain undeveloped coastal barriers.

The natural and cultural resources of floodplains received more protection through multipurpose, often federally supported projects for open space, recreation, urban renewal, greenbelt, and waterfront redevelopment.

State and local officials became even more involved in hazard mitigation planning with the implementation of requirements for planning after all Presidentially declared disasters and with participation in interagency hazard mitigation teams.

The Management Framework

Like any activity, floodplain management is carried out within a structure of legislative, administrative, economic, and judicial opportunities and constraints. The way in which floodplain lands and waters are handled, decisions are made and actions taken—whether by the U.S. Congress or by a single homeowner in a floodprone area—depends upon the relevant law, the policies and programs of government agencies, funding, public interest and opinion, and the availability of needed information. The framework for floodplain management has been strengthened significantly since the 1960s. Before then, flood loss reduction was largely dependent upon flood control works and federal actions; at the same time, a number of single-purpose federal laws and programs protected various natural resources, only indirectly addressing pro-

Strategies and Tools for Floodplain Management

Strategy A. Modify Susceptibility to Flood Damage and Disruption

1. Floodplain Regulations
   a) State regulations for flood hazard areas
   b) Local regulations for flood hazard areas
      1) Zoning
      2) Subdivision regulations
      3) Building codes
      4) Housing codes
      5) Sanitary and well codes
      6) Other regulatory tools
2. Development and Redevelopment Policies
   a) Design and location of services and utilities
   b) Land rights, acquisition, and open space use
   c) Redevelopment
   d) Permanent evacuation
3. Disaster Preparedness
4. Disaster Assistance
5. Floodproofing
6. Flood Forecasting and Warning Systems and Emergency Plans

Strategy B. Modify Flooding

1. Dams and Reservoirs
2. Dikes, Levees, and Floodwalls
3. Channel Alterations
4. High Flow Diversions
5. Land Treatment Measures
6. On-site Detention Measures

Strategy C. Modify the Impact of Flooding on Individuals and the Community

1. Information and Education
2. Flood Insurance
3. Tax Adjustments
4. Flood Emergency Measures
5. Postflood Recovery

Strategy D. Restore and Preserve the Natural and Cultural Resources of Floodplains

1. Floodplain, Wetland, Coastal Barrier Resources Regulations
   a) Federal regulations
   b) State regulations
   c) Local regulations
      (1) Zoning
      (2) Subdivision regulations
      (3) Building codes
      (4) Housing codes
      (5) Sanitary and well codes
      (6) Other regulations
2. Development and Redevelopment Policies
   a) Design and location of services and utilities
   b) Land rights, acquisition, and open space
   c) Redevelopment
   d) Permanent evacuation
3. Information and Education
4. Tax Adjustments
5. Administrative Measures

GENERAL PRINCIPLES FOR FLOODPLAIN MANAGEMENT

- *The federal government has a fundamental interest in how the nation's floodplains are managed, but the basic responsibility for regulating floodplains lies with the state and local governments.*
- *Floodplains must be considered in the context of total community, regional, and national planning and management.*
- *Flood loss reduction should be viewed in the larger context of floodplain management, rather than as an objective in itself.*
- *Sound floodplain management embodies several aspects:*
  - *goals (wise use, conservation, and development of resources);*
  - *objectives (economic efficiency, environmental quality, and social well-being);*
  - *consideration of future needs and the role of the floodplain;*
  - *evaluation of alternative strategies for alleviating flood losses;*
  - *accounting for benefits and costs and interrelated impacts of floodplain management actions;*
  - *motivation of decisionmakers;*
  - *coordination of agencies at all levels for all aspects of floodplain management; and*
  - *evaluation through continuous monitoring and reporting to the public.*

Source: A Unified National Program for Floodplain Management, 1976

tection of the natural and cultural resources of floodplain. Today's floodplain management framework is a product of planned initiatives, evolved methods, and fortuitous circumstances. Many aspects of the framework developed independently and then were incorporated for the common purpose. Many were intended at the outset to complement each other. Many apply to floodplains only incidentally but nevertheless serve an important function.

The idea of a unified national program for reducing flood losses was first set out in House Document 465 and has been refined and expanded since to produce *A Unified National Program for Floodplain Management*. It establishes as a basic national goal the wise use of floodplains; sets forth the conceptual framework of a multiobjective approach to use of the nation's floodplains, including flood loss reduction and natural values protection; identifies implementing strategies and tools; and recognizes the respective roles of each level of government and the private sector in the decisionmaking process.

There are four main strategies for reducing floodplain losses. They are described in detail in the Unified National Program documents. Each strategy can be carried out by using one or more specified "tools"—activities undertaken by governments, individuals, or the private sector that have an impact on floodplain management:

- Modify susceptibility to flood damage and disruption.
- Modify flooding.
- Modify the impact of flooding on individuals and the community.
- Restore and preserve the natural and cultural resources of floodplains.

At all levels of government and within the private sector, the tools and strategies for floodplain management take various forms, including components of broader initiatives, legislation, and policy directives in water resources management, emergency management, environmental protection, and projects for community development and redevelopment. Federal, state, and local programs and private efforts to manage the natural and cultural resources of floodplains are usually focused on the particular resource or activity that happens to occur on the floodplain rather than on the floodplain itself.

The Federal Government

At the federal level, flood loss reduction is accomplished through a network of laws, executive orders and directives, administrative regulations, interagency actions, and agency policies and programs. These components of the framework address various aspects of floodplain management, including insurance, land use, disaster preparedness and relief, information and education, warning systems, and structural flood control. At least 25 subdivisions of 12 departments and agencies have significant responsibility for some aspect of floodplain management.

The water resources values of floodplains are managed through programs for water quality, pollution control, watershed management, erosion control, and groundwater and aquifer protection. Restoration and preservation of the living resources of floodplains have been addressed in multiobjective federal programs or activities aimed at protecting inland or coastal wetlands or barrier islands. Other federal programs have been specifically directed at protecting habitat. Cultural resources have been protected through a variety of federally supported programs for open space, recreation, urban renewal, waterfront redevelopment, and historic preservation.

State Government

State activities for floodplain management have responded to and often paralleled federal activities. States administer locally adopted and enforced floodplain management regulations pursuant to the National Flood Insurance Program. All coastal states have some type of permitting program for development activities below mean high water and most coastal and Great Lakes states have federally approved coastal management programs. Every state has a multihazard emergency operations plan that covers floods. All coastal states and some inland states have wetland protection programs of some sort which include mapping, permitting, and protection.

SOME COMPONENTS OF THE FEDERAL FRAMEWORK FOR FLOODPLAIN MANAGEMENT

The Clean Water Act of 1972 • Coastal Barrier Resources Act (1982) • Coastal Zone Management Act of 1972 • The Dam Safety Act (1986) • The Disaster Relief Act of 1974 • The Disaster Relief and Emergency Assistance Amendments of 1988 • The Emergency Wetlands Resources Act of 1986 • The Endangered Species Act of 1973 • Executive Order 12127 (1979) • Executive Order 12148 (1977) • Executive Order 11296 (1966) • Executive Order 11988 (1977) • Executive Order 11990, Protection of Wetlands • The Federal Crop Insurance Act (1980) • The Federal Insecticide, Fungicide, and Rodenticide Act • Federal Interagency Floodplain Management Task Force established 1975 • The Federal Land Policy and Management Act of 1976 • Fish and Wildlife Coordination Act of 1958 • The Flood Disaster Protection Act of 1973 • The Food Security Act of 1985 • House Document 465, *A Unified National Program for Managing Flood Losses* • The Housing Act of 1961 • The Housing and Urban Development Act of 1969 • The Housing and Community Development Act of 1977 • The Housing and Community Development Act of 1987 • The Land and Water Conservation Fund Act (1964) • The National Dam Inspection Act of 1972 • The National Environmental Policy Act (1969) • The National Flood Insurance Act (1968) • The National Forest Management Act of 1976 • The National Historic Preservation Act (1966) • The North American Waterfowl Management Plan (1986) • OMB Memorandum, "Nonstructural Flood Protection Measures and Flood Disaster Recovery" (1980) • The Omnibus Budget Reconciliation Act of 1981 • The Reservoir Salvage Act of 1960 • The Safe Drinking Water Act of 1974 • The Soil and Water Resources Conservation Act of 1977 • The Tax Reform Act of 1986 • United States-Mexico Boundary Treaty of November 23, 1970 • The Water Bank Act (1970) • Water Pollution Control Act Amendments of 1972 • The Water Quality Act of 1987 • The Water Resources Development Act of 1974 • The Water Resources Development Act of 1986 • The Water Resources Development Act of 1990 • Water Resources Planning Act of 1965 • The Watershed Protection and Flood Prevention Act of 1954 • The Wild and Scenic Rivers Act of 1968 • Flood Control Act of 1917 • Rivers and Harbors Act of 1930 • Flood Control Act of 1936

Several states have adopted their own statewide floodplain management regulations, and in some states executive orders compel state agencies to consider flood hazards before carrying out their activities. Several states have adopted environmental policy acts that require analysis of the impacts of proposed state and local actions on natural resources, including those of the floodplain. Every state has an agency involved in planning, funding, or sponsoring structural flood control projects. Floodplain management is further accomplished through state-level regulatory and nonregulatory programs directed at wetlands, dune protection, restoration and protection of living resources and natural areas, mapping, flood conveyance and storage, dam safety, pollution control, natural crops, groundwater supply, wildlife habitat, historic preservation, recreation, and shoreline management.

Local Government

The adoption and enforcement of local floodplain regulations is now widespread because of the National Flood Insurance Program. Many local zoning and subdivision regulations protect the natural and cultural resources of floodplains through shoreline setbacks, density limits, historic preservation guidelines, or specification of compatible uses. Local governments are almost exclusively responsible for local drainage and stormwater management. Many localities participate as cosponsors of structural projects, providing a small financial contribution to the cost of the works. Some localities have coastal management programs within a state framework, and some states provide for local application of state controls, usually established under legislation geared toward multiple goals like protection of wildlife and sensitive shoreland areas, or erosion control. Some communities have developed multihazard emergency preparedness or operations plans.

Regional Entities

Regional entities can be extremely effective in managing floodplains, whose boundaries typically do not conform to traditional governmental jurisdictions. Special districts are the most numerous and fastest-growing type of governmental entity in the country; nearly one-quarter of them have natural resource functions—soil and water conservation, drainage and flood control, and sewerage. The nation's 3,000 counties also have floodplain management functions, including storm drainage, land acquisition, flash flood warning, emergency response, land use planning, and building regulation (usually of unincorporated areas). Nearly 3,000 conservation districts exist, covering more

THE IDNDR

In 1987 the United Nations General Assembly declared 1990 to 2000 AD as the International Decade for Natural Disaster Reduction (IDNDR). It is anticipated that this assessment will provide useful input to the United States program for the Decade.

SELECTED PROFESSIONAL AND NONPROFIT ORGANIZATIONS ACTIVE IN FLOODPLAIN MANAGEMENT

American Institute of Architects
American Land Resource Association
American Littoral Society
American Planning Association
American Rivers Conservation Council
American Society of Civil Engineers
American Water Resources Association
Association of Conservation Engineers
Association of State Dam Safety Officials
Association of State Floodplain Managers
Association of State River Managers
Association of State Wetland Managers
The Coastal Society
Coastal Conservation Association
Coastal States Organization
Connecticut River Watershed Council
The Conservation Foundation
Conservation Law Foundation of New England
Council of State Governments
Environmental Defense Fund
The Environmental Law Institute
Environmental Policy Institute
Freshwater Foundation
Friends of the Earth
Friends of the River
Land Trust Alliance
League of Conservation Voters
National Association of Conservation Districts
National Association of Counties
National Association of Home Builders
National Association of State Recreation Planners
National Association of Urban Flood Management Agencies
National Audubon Society
National Center for Urban Environmental Studies
National Emergency Management Association
National Fish and Wildlife Foundation
National League of Cities
National Organization for River Sports
National Recreation and Parks Association
National Trails Coalition
National Trust for Historic Preservation
National Water Resources Association
National Waterways Conference
National Wetlands Technical Council
National Wildlife Federation
The Natural Areas Association
Natural Resources Defense Council
New England Natural Resources Center
North American Lake Management Society
The Oceanic Society
The River Conservation Fund
Save the Dunes Council
Sierra Club
Society for Range Management
Soil and Water Conservation Society
The Sounds Conservancy
The Trust for Public Land
Urban Land Institute
Wetlands for Wildlife
The Wilderness Society
Wildlife Management Institute

than 97% of the country. They provide planning and technical assistance to individual landowners for controlling soil erosion and water pollution, and they implement swampbuster, wetland restoration, and erosion reduction portions of the Food, Agricultural, Conservation, and Trade Act of 1990.

The Private Sector

Besides undertaking basic and applied research on floodplain management, academic institutions also provide education in the field, although so far no university offers a program of study specializing in floodplain management. Many states have Water Resources Research Institutes, as authorized by the Water Resources Act of 1964.

Over 700 national and local land trusts exist throughout the nation. Most are nonprofit organizations that receive land, either through donations or purchase, and manage it as open space or for historic purposes.

There are a large number of professional and nonprofit organizations involved in floodplain management. Most are national in scope and accomplish their objectives through meetings, publications, lobbying, and fostering professional communication. The number of private conservation and watershed organizations is even larger. Usually nonprofit with a broad public membership, they are typically directly involved in environmental issues with flood loss reduction as an indirect goal or benefit. These citizen-based groups serve a tremendous public education function, are largely unaffected by partisan politics, and can usually respond to an issue more rapidly than government agencies.

Individuals and for-profit corporations have become more involved in floodplain management since the 1960s, helping develop floodproofing techniques and materials, automated flood warning systems, geographic information systems, remote sensing techniques, and computerized information management.

Modifying Susceptibility to Damages and Disruption

Modifying susceptibility to flood damage and disruption is the floodplain management strategy of avoiding dangerous, uneconomic, undesirable, or unwise use of the floodplain. The tools used to implement this strategy are regulations; development and redevelopment policies; disaster preparedness; floodproofing and elevation; and flood forecasting, warning systems, and emergency plans.

Regulations

Regulations have a potentially greater impact on flood loss reduction than any other single floodplain management tool and have been widely used over the last 15–20 years. Development that conforms to regulations is less prone to flood damage than pre-existing development.

Regulation is largely a local government responsibility, but throughout much of the country there is still widespread resistance to any type of land use regulation and concern among jurisdictions that it will be ruled an unconstitutional "taking" of private property. Effective enforcement often requires more training, personnel, and financial resources than many communities can provide. Regulations cannot provide full protection; they have a limited impact on existing buildings and infrastructure already subject to flooding, and they do not prevent development in floodplains. In addition, most floodplain regulations do little to protect the natural resources of floodplains. In fact, to the extent that floodplain regulations allow development in floodplains—even though it may not be subject to damage—they can contribute to the loss of natural and cultural resources. On the other hand, current regulations do provide a de facto prohibition on development in wetlands.

Academic Institutions Engaged in Natural Hazards and Emergency Management Research and Education

Arizona State University, Office of Hazard Studies • Charleston Southern University, Earthquake Education Center • Brown University, Alan Shawn Feinstein World Hunger Program • Clark University, Center for Technology, Environment, and Development • Colorado State University, Hazards Assessment Laboratory • Cornell University, Cornell Institute for Social and Economic Research/Program in Urban and Regional Studies • Memphis State University, Center for Earthquake Research and Information • New York Medical College, Center for Psychological Response in Disaster Emergencies • New York University, Industrial Crisis Institute • State University of New York at Buffalo, National Center for Earthquake Engineering Research • Texas A&M University, Hazard Reduction and Recovery Center • Texas Tech University, Institute for Disaster Research, Wind Engineering Research Center • University of Arizona, Office of Arid Lands Studies and Arid Lands Information Center • University of California, National Information Service for Earthquake Engineering • University of California, California Earthquake Education Project and Chemical Education for Public Understanding Project • University of Central Florida, Florida Sinkhole Research Institute • University of Colorado, Natural Hazards Research and Applications Information Center • University of Colorado, U.S. World Data Center for Glaciology, National Snow and Ice Data Center • University of Delaware, Disaster Research Center • University of Hawaii, Pacific Islands Development Program, Disaster Preparedness and Rehabilitation Project • University of Maryland-Baltimore County, Emergency Health Services Program • University of Massachusetts, Land and Water Policy Center • University of North Carolina, Center for Urban and Regional Studies • University of North Texas, Emergency Administration and Planning Degree Program • University of Pennsylvania, The Wharton School, Risk and Decision Processes Center • University of Pittsburgh, Center for Social and Urban Research • University of Wisconsin Extension, Disaster Management Center

Source: Natural Hazards Research and Applications Information Center

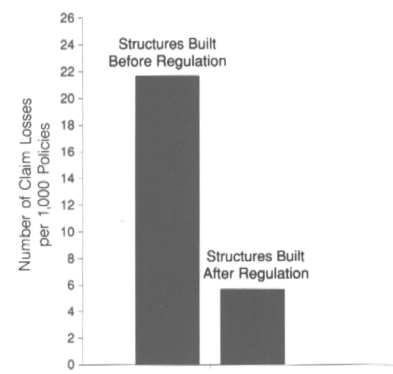
The most widespread floodplain regulations are the minimum requirements of the National Flood Insurance Program, which must be enacted and enforced by communities participating in the program. The minimum regulations vary depending upon the risk studies and mapping that have been done in the community, but include

- permitting for all proposed new development;
- reviewing subdivision proposals to assure that they will minimize flood damage;
- anchoring and floodproofing structures to be built in known floodprone areas;
- safeguarding new water and sewage systems and utility lines from flooding; and
- enforcing risk zone, base flood elevation, and floodway requirements after the flood insurance map for the area becomes effective.

There are numerous performance and prescribed standards applicable to each of the zones on flood insurance maps. The Federal Insurance Administration has several programs to help states and communities adopt and comply with the regulations. Other federal agencies provide technical and planning assistance and support.

Since the 1960s the number of state and local governments exercising regulatory authority over floodplain uses has increased markedly, and the variety of regulatory approaches has expanded. A given state may directly regulate the flood hazard area, set standards for local application, or regulate the flood hazard area as part of a broader resource protection and management program. To meet these requirements, local governments adopt specific floodplain management or stormwater management ordinances and incorporate floodplain management provisions into zoning and subdivision regulations, housing and building codes, and resource protection regulations. The number of communities with regulatory requirements more stringent than those of the National Flood Insurance Program is unknown, but clearly is in the thousands.

Average Losses per 1,000 Flood Insurance Policies on Unregulated versus Regulated Structures, 1978-88



Source: FEMA/FIA

ENFORCING LAND USE REGULATIONS IN MAINE

In 1983 the Maine legislature enacted "Rule 80K" to allow less expensive and faster enforcement of local land use regulations. Once local code enforcement officials are trained, they can take a violation directly to the district court without an attorney. Procedures are followed that are less formal than usual but do not sacrifice the defendant's due process rights. The court can levy a fine and order abatement of the violation.

THE SOUTH CAROLINA BEACHFRONT MANAGEMENT ACT

The South Carolina Beachfront Management Act establishes a "no construction" zone beginning at the crest of the actual or theoretical dune line and extending landward 20 feet or 40 times the average annual rate of erosion, whichever is greater. The legislature anticipated that the Act would result in the gradual elimination of structures built too close to the ocean and hence subject to damage or destruction from hurricanes and other coastal storms.

Development and Redevelopment Policies

Federal, state, and local governments all have established programs, policies, and directives to avoid inappropriate development and redevelopment of the floodplain.

Federal policies relating to the design and location of services and utilities (roads, bridges, and sewer lines, etc.) in floodprone areas include the National Environmental Policy Act, Executive Order 11988, and the Coastal Barrier Resources Act. All of these either restrict federal participation in development in floodprone areas or require careful review of the impacts on the floodplain of proposed federal or federally supported activities.

Several states have issued executive orders or other directives comparable to the federal ones, and every state now has a statute or executive order to govern construction of state projects, such as prisons and universities, that are exempt from local regulations. All coastal states have policies on development in coastal flood hazard areas. Some states have more stringent flood loss reduction standards for roads and bridges than those of the federal aid system.

In some cases, the only way to preclude future uses incompatible with the flood risk is to permanently evacuate a portion of a floodplain and to obtain full title or easements on its development rights. Although this process (called "acquisition") is expensive, the long-term benefits in reduced floodplain losses, protection of natural resources, and public use of the land, may make it worthwhile.

Most redevelopment relating to flood loss reduction occurs after one or more major floods. Usually a control structure is built to protect what development remains, and a temporary moratorium is imposed to allow evaluation and planning. Unfortunately, legislative and regulatory requirements often encourage a quick return to the preflood status quo, wasting opportunities to mitigate and revitalize the area.

Disaster Preparedness

Disaster preparedness encompasses plans for mitigation, warning, and emergency operations; training; public information activities; exercises to test disaster preparedness plans; readiness evaluations; research; review and coordination of disaster preparedness plans and programs; and postdisaster evaluations. Individual preparedness is important but severely underutilized. Preparedness plans often are developed in concert with flood forecast, warning, and emergency plans. There are several federal programs for disaster preparedness, and every state has an integrated emergency management plan and an agency responsible for preparing for floods. Each Gulf and Atlantic

SOME FEDERAL PROGRAMS FOR DISASTER PREPAREDNESS

- Under the authority of Section 201(d) of the Disaster Relief Act of 1974, the Federal Emergency Management Agency provides up to 50% matching grants to help states develop and improve state and local plans for preparedness and mitigation. Interagency flood hazard mitigation teams are formed after each Presidentially declared flood disaster to offer technical assistance to communities and states and to identify mitigation measures that may be implemented in the affected areas.
- Under Section 409 of the Act, any jurisdiction receiving federal disaster assistance must prepare a hazard mitigation plan within 180 days of the declaration; future federal assistance may be curtailed if such a plan is not filed.
- The Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the National Weather Service have formed a program of comprehensive hurricane evacuation planning in association with Gulf and Atlantic states. The NWS develops the SLOSH (Sea, Lake, and Overland Surge from Hurricanes) model for each coastal basin, and FEMA funds the running of the models by the NWS's National Hurricane Center to predict storm directions, speeds, and intensities. Evacuation plans are prepared from the studies. Their value was proved during Hurricane Hugo in 1989, when hundreds of thousands of people were evacuated and loss of life was kept to a minimum.
- The Federal Emergency Management Agency provides grants to states to conduct hazard mitigation projects.
- The Federal Energy Regulatory Commission requires emergency action plans at its licensed projects and periodically holds in-depth exercises to test the plans and the licensee's coordination of responsibilities with the appropriate state and local disaster agencies.
- The Soil Conservation Service has done flood audits of structures in the floodplain of the Yantic River in Norwich, and the Quinnipiac River in Southington, Connecticut, to complement the response to flood warnings.
- The U.S. Army Corps of Engineers conducts technical evaluations to determine what types of warning systems and preparedness plans are appropriate for certain areas.

coast state has a hurricane preparedness plan completed or underway. Many localities also have emergency management plans, but relatively few have detailed plans specifically for floods, and even fewer have plans for mitigation after a flood. This is probably due to lack of expertise and funding to develop such plans, the hope that the flood problems will be taken care of through some structural measures, and the expectation of receiving federal disaster assistance when the flood does occur.

Flood Forecasting, Warning, and Emergency Plans

Warning systems and accompanying emergency response have long been recognized as effective ways to save lives and reduce flood damages in both riverine and coastal floodprone areas. The joint hurricane evacuation study is a good example of this. As the cost of the required equipment continues to decrease, more and more state and local governments are funding the development of flood warning systems and emergency plans.

The National Weather Service conducts research, provides specific flood forecast and warning services to over 3,100 communities, and works with many of the 900 communities that have local warning systems. The Corps, the Tennessee Valley Authority, and the Bureau of Reclamation collect hydrometeorological data and prepare operational forecasts, often in cooperation with the National Weather Service, for their flood control structures. The U.S. Geological Survey collects streamflow and other data that can be used for flood forecasting.

About half of the states are involved in flood warning, including cooperation in IFLOWS (the Integrated Flood Observing and Warning System) in Appalachia and installation of automated data collection equipment. Some large urban communities have included forecasting and preparedness planning in their operations for years, participated in regional warning systems, or have developed their own systems.

University and private research has contributed substantially to the knowledge about and design of warning systems, disaster response, and system effectiveness. The private sector is vital to the design, installation, operation, maintenance, and modification of local flood warning systems. In many instances, industries have cooperated in the installation and operation of flood warning systems and reduced their own flood losses.

Floodproofing and Elevation

Floodproofing is the use of permanent, contingent, or emergency techniques to either prevent flood waters from entering buildings or to minimize the damages from water that does get in. Some of the techniques involve using water-tight seals, closures or barriers; using water-resistant materials; and temporarily relocating the contents of a building. Elevating a structure means raising it on fill, piers, or pilings so that it is above expected flood levels. Most new floodplain structures are now designed to incorporate floodproofing and/or elevation, primarily because it is required by the regulations of all National Flood Insurance Program communities. There are millions of existing floodprone homes to which floodproofing could be applied retroactively ("retrofitted"), but this technique is not yet routinely used. One obstacle has been that flood insurance rates stay the same when a residence is retrofitted; the new Community Rating System of the National Flood Insurance Program should help remove that disincentive.

Floodproofing is probably the tool most widely used by the private sector with only limited government assistance. Many of the early floodproofing techniques were developed by architects, engineers, and building contractors as they worked with individual property owners, especially on small commercial buildings and industrial facilities. The American Institute of Architects, the National Association of Homebuilders, university researchers, and private engineering firms have conducted considerable research on and developed technical information about floodproofing. The private sector is also the source of many floodproofing products, such as vinyl sheathing, devices to prevent sewer backflow, substitutes for sand bags, equipment for filling sand bags, and flood shields to temporarily seal windows, doors, and other openings.

LYCOMING COUNTY'S EARLY WARNING SYSTEM

Lycoming County, Pennsylvania, lies almost entirely within the drainage area of the West Branch of the Susquehanna River and contains close to 2,200 miles of streams. Most of the county's people live on or near the river. After major flooding from Hurricanes Agnes in 1972 and Eloise in 1975, a self-help early warning system was developed with an initial investment of $500. With the help of the National Weather Service, forecasting procedures were established for each watershed within the county, and the system was put into operation within three months. Over 100 volunteer observers were recruited and trained to observe and monitor stream gages and make reports to a stream coordinator. The coordinator assembles the data for a watershed and conveys it to a system coordinator. With the help of expert personnel, the data is evaluated and a determination of expected flooding and appropriate response is made.

Over the last 10 years improvements to the system have been made. To assure adequate backup for data transmission, the county provided National Oceanic and Atmospheric Administration weather radios to the volunteer observers, and NWS distributed base station radios to the stream coordinators. In addition, a system of 10 automated rain gages and 4 automated stream alarm devices was installed to supplement the manual data collection.

Examples of Retrofitting

Relocation: Moving a building to high ground, above flood levels.

Elevation: Raising a building so that flood waters will go under it.

Floodwalls: Building a wall of concrete or earth to keep flood waters from reaching a building.

Dry Floodproofing: Making building walls watertight and sealing openings so flood waters cannot enter.

Wet Floodproofing: Altering a building to minimize damage when flood waters enter.

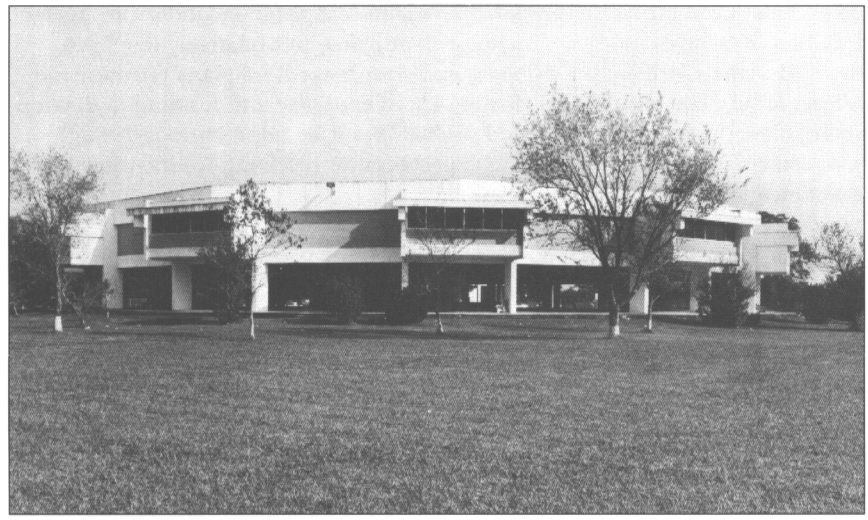
Source: Floodproof Retrofitting: Homeowner Self-Protective Behavior, Shirley Bradway Laska, 1991

FLOODPROOFING AND THE CORPS

In the early 1960s the Tennessee Valley Authority and the U.S. Army Corps of Engineers jointly produced the first comprehensive report on floodproofing. In 1972, after further review and evaluation of different techniques, the Corps released Floodproofing Regulations, *which has since been incorporated into or recommended by all the major regional building codes and many of the state and local codes. The Corps routinely evaluates the potential for using floodproofing in all its project feasibility studies. It also provides technical assistance to local communities and is involved in several projects to floodproof large numbers of homes in communities with chronic flood problems.*

FLOODPROOFING IN ILLINOIS

After floods in Illinois in 1982, 1985, 1986, and 1987, the state provided technical assistance on floodproofing to victims who visited the local Disaster Assistance Centers. Over half of the flood victims eventually altered their houses and/or yards to protect themselves from future flooding. The average homeowner implemented three different floodproofing measures. The median costs ranged from $42 for a standpipe or sewer drain plug to $2,350 for sewer backup valves; most cost between $200 and $600. Most of the floodproofing measures were installed within two months after the flood. Those who were flooded again in the 1987 floods found that their floodproofing measures were generally effective.



One floodproofing technique is to elevate a structure so that flood waters can pass beneath. Sebastien Roy Elementary School, Verret, Louisiana.

Most states distribute information about floodproofing and provide technical assistance to individuals and groups of property owners. Several states have promoted floodproofing by publishing technical manuals, helping localities obtain funding, holding seminars for industry and individual owners, establishing loan programs, and cooperating with disaster assistance centers so that victims can begin to retrofit immediately. Local governments have floodproofed individual structures. A few communities have provided their own funding for larger projects, and others have provided technical and financial assistance to local businesses and residences.

Modifying Flooding

Modifying flooding is a floodplain management strategy of using structural means to alter the flood itself. Structural measures—dams, reservoirs, dikes, levees, floodwalls, channel alterations, high flow diversions, spillways, land treatment measures, shoreline protection works, and stormwater management facilities—permit deliberate changes in the volume of runoff, peak stage of the flood, time of rise and duration of flood waters, location of flooding, extent of area flooded, and velocity and depth of flood waters. The effectiveness of these measures for protecting property and saving lives has been well demonstrated. Flood control projects have saved billions of dollars in property damage and protected hundreds of thousands of people from anxiety, injury, and death.

Throughout the second half of this century, the number and size of structural flood control projects have been decreasing. High construction costs coupled with increased cost-sharing requirements for nonfederal sponsors of projects have made some structures unaffordable. Structural measures also have been criticized for destroying riparian habitat, scenic values, and water quality; creating a false sense of security; resulting in eventual loss of flood storage capacity due to sedimentation; and inducing development in floodplains. These criticisms have been coupled with greater recognition that humans should attempt to adjust to floods and not just try to control them.

It appears likely that the rate of construction of new flood control projects may hold steady or decrease slightly and that relatively few large flood control structures will be built in the future. Local and private construction of smaller flood control projects is certain to continue and may even increase.

One issue that the nation must face in the coming decades is how to deal with the aging inventory of existing flood control structures. Many dams and reservoirs are nearing or even past their design lives, and the flood control capacity of many reservoirs has been reduced by sedimentation. The financial

Structural measures to directly control floodwaters have been used on virtually all scales—from modifying a major river course, such as that of the Colorado, Missouri, or Tennessee, to controlling the flow of (usually) insignificant tributaries.

Concrete channel and retaining wall, Silver Creek, Leyden Township, Illinois.

resources are not available to undertake all required remedial actions. One option being actively considered and already used on a limited basis by the Soil Conservation Service and others is breaching small dams that are no longer functional.

Investment in Flood Control

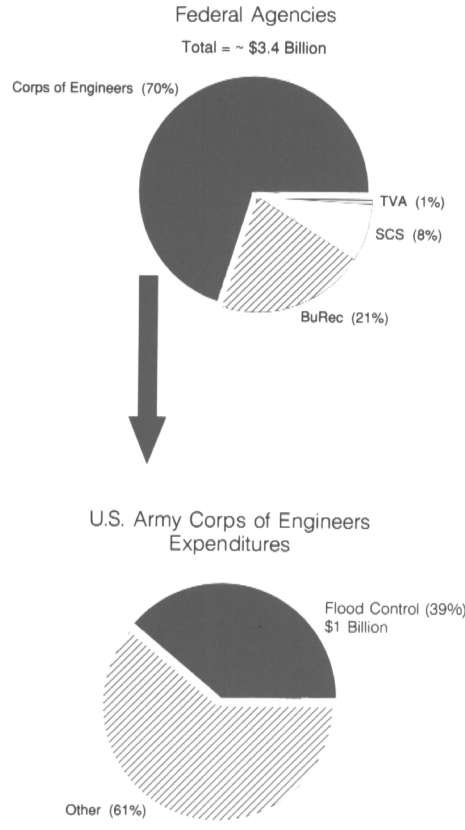
The Flood Control Act of 1936 established the federal interest in controlling floods on the nation's navigable waters and their tributaries. Under this Act, $310 million was authorized for carrying out flood control projects, with the Corps receiving major responsibilities for mainstem and downstream projects. The Soil Conservation Service was later assigned responsibility for flood protection on upstream watersheds. This act established the condition that federal involvement in flood control would be appropriate "if the benefits to whomsoever they may accrue are in excess of the estimated costs and if the lives and social security of the people are otherwise adversely affected." For 50 years this phrase has been the basis of efforts to analyze the benefits and costs of water resources projects.

In addition to the Corps and the Soil Conservation Service, the Bureau of Reclamation and the Tennessee Valley Authority are involved in the construction of flood damage reduction structures. The Bureau of Reclamation has planned and constructed many large irrigation and hydropower reservoir projects in the western United States that also provide flood control, including Grand Coulee Dam, the Central Valley Project, and Hoover Dam. The Tennessee Valley Authority has played a role in flood control since its creation in 1933; two of its statutory purposes are "to improve navigation in the Tennessee River and to control destructive flood waters in the Tennessee River and Mississippi River Basin."

Between 1936 and 1975 the federal government spent about $13 billion for dams and other structures. A few of the first flood control projects were financed 100% by the federal government, although most required the contribution of land, easements, and rights of way by state and local governments and maintenance of the project after it was completed. Today, however, state and local governments and private sponsors are required to share the costs of practically all flood control projects.

State and local governments play two major roles in funding water resources development: constructing and operating their own projects, and financing their share of and maintaining the projects built for them by the federal government. Tremendous variations exist in the extent of state and local involvement in each role. As of 1988, 23 states provided technical assistance to communities for flood control; many more states are directly involved in local structural flood projects in other ways.

Expenditures by Federal Water Resource Agencies, 1986



WATER RESOURCES DEVELOPMENT BY THE STATES

- *Florida has created Water Management Districts that are authorized to levy ad valorem taxes to finance local water projects.*
- *In Montana, a water development fund was created in 1981 to make loans and grants for all water development purposes.*
- *Louisiana, Maryland, and Minnesota have recently created programs to provide financial assistance to communities that develop flood control plans.*
- *Washington provides grants to communities to help maintain levees and other flood protection projects.*

DAMS AND THE FEDERAL GOVERNMENT

- The U.S. Army Corps of Engineers has some responsibility for five categories of dams: dams planned, designed, constructed, and operated by the Corps; dams designed and constructed by the Corps but operated and maintained by others; dams owned by other agencies in which flood control storage has been provided at federal expense; dams for which the Corps issues permits under its regulatory authority; and dams that the Corps inventoried and inspected under the National Dam Inspection Act of 1972 and the Dam Safety Act of 1986.
- Upon its creation in 1979, the Federal Emergency Management Agency was given responsibility for coordinating dam safety. The agency coordinates the national dam safety programs and reports progress to the President; chairs the Interagency Committee on Dam Safety; encourages the development and use of uniform guidelines and standards; coordinates dam safety research; coordinates the development and funding of training materials; facilitates information exchange among federal and state officials; encourages the use of model state legislation and programs; and fosters preparedness, warning, and evacuation programs.
- The Bureau of Reclamation is the coordinating agency for dam safety within the Department of the Interior. In addition to responsibility for the safety of its own dams, it provides standards and guidelines for the safety of dams owned or operated by seven other Interior agencies.
- The Tennessee Valley Authority has complete responsibility for the planning, design, construction, operation, and maintenance of its dams. The TVA's situation is unique in that it constructs its dams with its own resources, and all except one of its dams are located in a single river basin and operated and maintained for the unified development and regulation of the Tennessee River system.
- The U.S. Department of Agriculture, in fulfilling assigned responsibilities to American agriculture, is a permitter, owner, manager, planner, designer, constructor, financier, and grantor of dams. Most of the dams are small, but a few range up to 200 feet high.
- The Soil Conservation Service has provided technical and/or financial assistance for the installation of over 25,000 dams.
- The U.S. Forest Service owns 1,316 dams and administers permits for an additional 2,366. Most of the owned dams are designed and constructed by the Forest Service in conjunction with the management of national forests and grasslands.
- The Farmers Home Administration, Rural Electrification Administration, and the Agricultural Research Service also serve on the U.S. Department of Agriculture's Dam Safety Committee and have some involvement with dams, but generally depend on the Soil Conservation Service for technical assistance.
- The Federal Energy Regulatory Commission regulates and licenses nonfederal hydropower projects. The commission is presently responsible for the safety of about 2,000 nonfederal hydropower dams and the Department of Energy (DOE) has asked FERC to be responsible for dam safety review on 20 DOE dams.

THE DAMAGE PREVENTED BY FLOOD CONTROL DAMS

No accurate number is available of the actual number of people protected by flood control dams. Between 1960 and 1985, Corps projects prevented an estimated $245 billion (1985 dollars) in potential flood damages. Since its inception, the Tennessee Valley Authority multipurpose dam and reservoir system has prevented flood damages that would have amounted to nearly $3.03 billion. These calculations are based on the assumption that floodplains would have been just as intensively or sparsely developed if there were no structural protection. Although this is not necessarily the case, there is no way to account for the development that may have been encouraged by the presence of the dam. Likewise, it is possible that losses could be greater without dams because development would have taken place in the reservoir area if the dam had not been built.

Dams and Reservoirs

Storing flood water in reservoirs can modify floods by reducing the speed at which the water flows, limiting the area flooded, and reducing and altering the timing of peak flows. However, misconceptions about or lack of understanding of dams can create an exaggerated sense of security. Reservoir sedimentation can significantly reduce flood control capacity. Competing uses of the reservoir can impair flood control because those relying on the dam for recreation and water supply (irrigators, manufacturers and residential users) often press for continued high pool levels, resulting in less storage space in the reservoir for flood waters. In addition, most dams are designed for purposes other than flood control, although they do have the temporary effect of flood reduction through storage. The availability of water, power, or recreational opportunities associated with dams therefore often attracts new development regardless of the flood risk or the ability of the dam to provide flood protection. Over time, without adequate land use regulations, encroachment onto the floodplain downstream of dams can prevent proper operation of the structure and increase exposure to flooding. Once signs of dam failure become visible, breaching often occurs within minutes or a few hours, leaving little or no time for evacuation. The massive volume of water and its high velocity will cause severe damage.

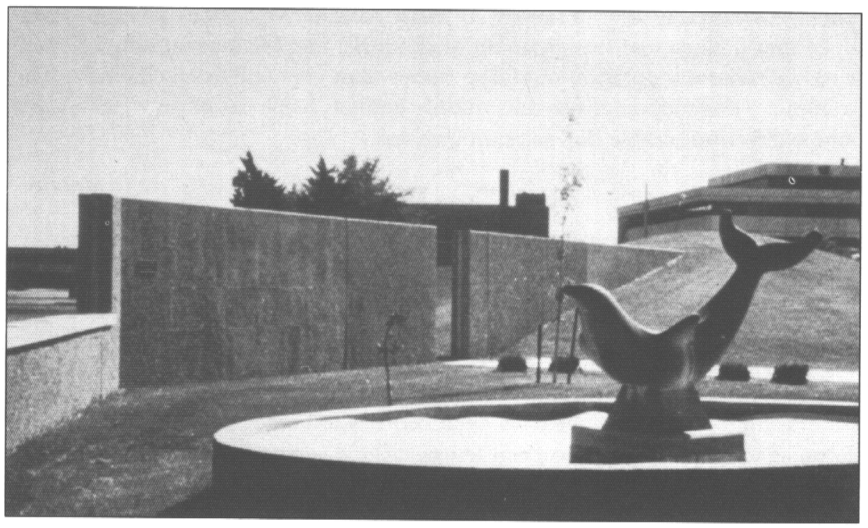
More than 20 federal agencies and four independent offices and commissions own about 4,000 dams, have regulatory authority over 6,000 others, and have various other responsibilities for additional tens of thousands of nonfederal dams. The number of dams of all types and sizes in the United States is unknown, but when small dams (such as for farm ponds) are included, the total could be as high as several million.

State regulation of dams is generally considered to have started in California after the failure of the St. Francis Dam in 1928. The California law

has been strengthened at least twice since then after other major dam failures or near failures, and has been used as model state legislation for the review, inspection, certification, and maintenance of nonfederal dams. As of 1989, 31 states had statutory authority to perform all of these functions, and only two had no statutory authority at all. The states had a collective 1989 budget for dam safety of $17,668,552. The Association of State Dam Safety Officials, which was organized in 1984, has become a major influence in improving state regulation of dams.

Dikes, Levees, and Floodwalls

Dikes, including levees and floodwalls, can be thought of as dams built roughly parallel to a stream rather than across its channel, or parallel to the shorelines of lakes, oceans, and other water bodies. Levees are generally constructed of earth, floodwalls of masonry or steel. Levees were probably the first structures built for flood control by European immigrants to North America. The first levee in the Mississippi Valley was constructed at New Orleans in 1717. Levees are the most common type of flood control works. Although they can be effective in reducing flood losses, a large percentage of private or locally built levees and floodwalls provide a low level of protection suitable only for agricultural purposes or are poorly designed and maintained. Levee or floodwall overtopping or failure is involved in approximately one-third of all flood disasters.



An estimated 25,000 miles of levees and floodwalls have been built nationwide. They can be very effective in reducing flood losses, although areas behind levees and floodwalls may risk greater than normal flood damage. Floodwall, Waterloo, Iowa.

Areas behind levees and floodwalls may be at risk of greater than normal flood damage for several reasons. Many floodplain residents in those areas believe that they are protected from floods and do not think it necessary to take proper precautions. Development may also continue or accelerate based on expected flood protection. A levee breach or floodwall failure, like a dam break, can release a large wave of flood waters with high velocity. After a breach, the downstream portion of the levee system may also act like a dam, catching and prolonging flooding of the once-protected area.

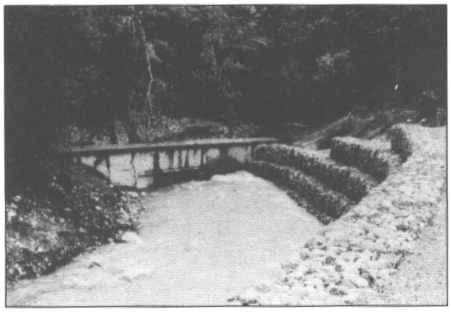
The Corps has designed and constructed about 10,500 miles of levees and floodwalls, most of which have been assigned to nonfederal sponsors for operation and maintenance after construction. The Federal Emergency Management Agency has established minimum design, operation, and maintenance standards for levees that, for insurance purposes, must be met in order to be credited with providing protection against a 1% annual probability flood. The Tennessee Valley Authority owns and inspects 37 saddle dams and levees and treats them with the same criteria as regular dams, including inspections, instrumentation, and maintenance. Thirteen states have special regulations governing the construction of levees.

THE CLASSIFICATION OF DAM FAILURE RISK

Classification of the risk of potential dam failure is based on the severity of potential impact rather than the structural safety of a dam. Dams may be of very sound construction but classified as "high hazard" if their failure, however unlikely, could result in catastrophic loss of life. Lower risk classifications include dams that pose a "significant hazard" for which failure is estimated to result in large property loss; and those that are "low hazard," for which failure is expected to result in minimal property loss. The failure of several dams during the 1970s led to the evaluation and repair of numerous unsafe dams in the United States.

LEVEES IN THE UNITED STATES

About 1,000 communities (5.5% of floodprone communities) have levees that protect from 1% annual probability floods; the length of these structures is about 9,000 miles and they protect about 5,000 square miles of land.



Structural techniques to modify channels and control stream flow include the construction of diversionary walls and gabions—prefabricated baskets of rock within wire cages used to stabilize banks.

City Creek Canyon, Salt Lake City, Utah.

AN ALTERNATIVE APPROACH TO STORMWATER MANAGEMENT

The cost to communities of damages caused by stormwater flooding and investment in costly channelization and other conduits can sometimes be reduced through different approaches to stormwater management. In Arizona, for example, the larger, rapidly urbanizing communities all have some form of stormwater management requirements for new development. All of the larger communities in the state's two urban counties, which include 77% of the state's population, regulate the development of watersheds.

ON-SITE DETENTION: A MULTIPURPOSE TOOL

Principal on-site detention measures include restricting land clearing, creating impervious areas, and providing for temporary storage of some or all of the runoff from a property. Many urban communities have begun to recognize that areas devoted to stormwater management represent a significant portion of their open space land and opportunities for urban recreation and wildlife protection. Shallow grass-covered basins can be used as athletic fields, parking lots, or for other purposes during dry periods and as detention basins after storms. Equipping roofs or parking lots for temporarily storing at least a part of the water that falls on them, designing streets in hilly areas to prevent rapid runoff, incorporating small retention basins into landscaping, using rock-filled pits to catch gutter runoff, and using pavements that let water seep through into the ground below all slow runoff.

Channel Alterations

Channel alterations increase the flow-carrying capacity of a stream's channel and thereby reduce the height of a flood. The various types of alterations include straightening, deepening, or widening the channel, removing debris, paving the channel, raising or enlarging bridges and culverts, and removing dams and other obstructions.

Channel alteration is widely practiced by state and local governments to control flooding by rapidly conveying storm runoff through populated locales to downstream areas. The Corps and the Soil Conservation Service also undertake channel alterations. The Corps projects typically lie on larger streams and rivers, while Soil Conservation Service works mostly in smaller streams on the upper portions of watersheds. The Soil Conservation Service has provided assistance in the construction of 10,700 miles of open channels.

The use of channel modifications has decreased primarily because of the potentially adverse environmental impacts. Alternative designs are now developed that include less straightening of channels, employ more gradual slopes, and use natural vegetation or riprap rather than concrete-lined channels. This minimizes destruction of fish and wildlife habitat, helps maintain water quality, and avoids undesirable downstream impacts.

High Flow Diversions

Diversions intercept flood waters upstream of a damage-prone or constricted area and convey them around it through an artificial channel or a designated flow-way. Diversions may either completely reroute a stream or collect and transport only excessive or potentially damaging flows. A negative aspect of such diversions is the false sense of security that may prevail in the protected areas along with a lack of awareness that the floodway actually exists. Several high flow diversions have been constructed along the Mississippi River. Excess water has also been temporarily diverted from the Great Salt Lake to an evaporation basin to prevent lakeshore flooding.

Stormwater Management

Stormwater management is the removal of water that falls directly onto properties as opposed to flood water that flows onto the property from upstream sources or an ocean surge. Stormwater networks have historically been constructed in urban and agricultural areas to remove these waters. Generally, the stormwater system removes the excess rainfall over a period of days and the temporary ponding floods only low-lying buildings and roads. A significant problem occurs when an agricultural zone with an adequate stormwater system is urbanized. Large areas are paved with roofs, roads, and parking, contributing to additional runoff. Often, shopping centers and other developments are placed on natural drainageways. The pre-existing stormwater network becomes inadequate for its new urban use. Localized flooding then occurs.

In an alternative approach often used in new developments today, runoff may be retained on the site, within a regional system, and total runoff within a watershed may be managed so that discharges from different units reach the main channel at different times to reduce peak flows downstream. Natural drainage systems may be used instead of concrete-lined channels or enclosed pipes. Many local ordinances now require a zero-increment runoff for new development, making such on-site detention a necessity.

Shoreline Protection

Quasi-natural methods such as beach nourishment or artificial sand-dune building are often used to attempt to restore an eroding beach as well as protect development. Long reaches of shore can be protected by artificial nourishment at a relatively low cost per linear foot. In addition, nourishment can widen a beach and increase its recreational value. A well-known beach nourishment project is the 10.5 miles of beach restoration in Dade County, Florida, which includes Miami Beach. However, these methods provide only temporary solutions to chronic long-term erosion caused by the diminishing supply of sediment in the littoral system. They also require periodic renourish-

ing during their 15- to 50-year life span. Even so, they are more cost-effective than large structures, such as groin fields or segmented offshore breakwaters. These structures can also build or increase beach width as well as provide protection, but erosion can occur downdrift if they are not properly designed.

Structures like seawalls, bulkheads, and revetments protect development, but are not intended to renourish or widen the beach. Erosion can occur in front of them because the natural movement of the shoreline has been affected. Such structures as breakwaters and jetties, which are designed to protect harbors and navigation channels from wave action or to stabilize inlets, can also cause erosion on the downdrift side if they do not include a sand-bypassing system.

Because of their high cost, few shoreline protection projects have been built without federal assistance, although most coastal states and many communities have participated in various ways. Some states, notably North Carolina, have adopted policies against new structural shoreline protection projects, opting to allow the shoreline to retreat naturally. Others, such as Connecticut, discourage construction of new structural projects, but do not specifically prohibit them. Still others, such as New Jersey, have active structural protection programs. Some states have empowered localities to establish beach protection districts with the authority to collect taxes to fund long-term maintenance programs. Private landowners also use various techniques to forestall erosion and reduce damages. These measures are necessarily low-cost and small-scale: vegetation plantings, beach fill, breakwaters, groins, revetments, bulkheads, and seawalls.

Land Treatment Measures

Land treatment measures reduce overland runoff from agricultural lands to streams or other waters by improving infiltration of rainfall into the soil, slowing and minimizing runoff, and reducing the sedimentation that can clog stream channels or storage reservoirs. These techniques are most commonly used in agricultural areas. They include maintaining trees, shrubbery, and vegetative cover; terracing; slope stabilization; using grass waterways; contour plowing; conservation tillage; and strip farming. Some measures involve building structures to retain or redirect runoff. Several land treatment measures involve little additional cost to the farmer, and some, such as no till or minimum tillage, actually reduce costs. Technical and financial assistance for the more expensive techniques is often provided through public sources, particularly programs of the U.S. Department of Agriculture. Although the impact of an individual measure is limited, extensive land treatment programs can effectively reduce flooding in small headwater areas.

ADJUSTING TO A RETREATING SHORELINE

Where relative sea level rise is accelerating, coastal flooding and erosion will also accelerate, placing billions of dollars worth of additional coastal property at risk. The nation will thus have the options of retreating from the shoreline, armoring it with protective measures, or providing beach nourishment. The National Park Service's policy is to allow natural forces to act on the shoreline rather than trying to prevent erosion with structural devices. The state of North Carolina has taken a similar stance. Some federal agencies have limited the use of structural measures on federal lands, but when it is economically justifiable and environmentally acceptable, they will still construct projects to protect existing coastal development. Likewise, many states limit structures in undeveloped or lightly developed coastal areas, but continue to permit structural projects to protect existing development. The Coastal Barrier Resources Act excluded the use of federal funds in "undeveloped" coastal regions.

Restoration of beach vegetation is one means of slowing beach erosion and transport.

Beach grass planting by volunteers to preserve sand dunes, Newburyport, Massachusetts.

Modifying the Impacts of Flooding

Despite efforts to control flooding and to reduce susceptibility to it, floods do occur, with adverse consequences on individuals and communities. A third strategy for mitigating floodplain losses is to help individuals and communities prepare for and recover from floods. This can be done through information dissemination and education, spreading the costs of the loss over time, and transferring some of the individual losses to the community.

It is not clear whether the present combination of flood insurance, disaster assistance, tax adjustments, and postflood recovery practices designed to implement this strategy is producing an equitable sharing of the capital and operating costs of floodplain occupancy among its beneficiaries, or shifting the costs from the individual to the public and government agencies. Neither has there been a clear statement of how much, if any, of the cost of floodplain development should properly be borne by the general public. Some argue that all costs should be borne by those occupying the floodplain; others that development of the floodplain provides economic benefits and, therefore, the general public should shoulder them.

Information and Education

Information and education activities for floodplain management have expanded dramatically since the 1960s, as illustrated by the number of publications, technical manuals, brochures, conferences, workshops, organizations, and media presentations now in existence. The effectiveness of this activity is difficult to assess. It is clear that many local officials and property owners still do not thoroughly understand concepts of probability, cumulative impacts, off-site impacts, and functional values—all of which are important for successful floodplain management. It is also clear that little of the material that has been generated and released adequately integrates the flood loss reduction and natural resources protection aspects of floodplain management.

Much of the basic information about floodplain management was developed or sponsored by federal agencies, and includes technical design and application manuals, research reports, computerized databases, and public awareness materials. Federal and state agencies train their own personnel in floodplain management programs and activities. Both levels of government have actively provided financial and technical support to hundreds of conferences, seminars, and workshops on every aspect of floodplain management for professionals at all levels of government and the private sector, and for floodplain residents.

In addition, states respond to individual inquiries from local officials, insurance agents, lenders, property owners, and the general public, and publish information tailored to the particular legal, administrative, and geographic situations of each state. Numerous nonprofit and professional organizations with concern for floodplain management have been formed in the last two decades. These organizations conduct research, produce publications, hold conferences and workshops, and provide a network through which professionals can exchange information.

Flood Insurance

Insurance is a mechanism for spreading the cost of losses both over time and over a relatively large number of similarly exposed risks. Until 1969, insurance against flood losses was generally unavailable. Under the National Flood Insurance Program, initiated in 1968 and significantly expanded in 1973, the federal government made flood insurance available for existing property in flood hazard areas in return for enactment and enforcement of floodplain management regulations designed to reduce future flood losses.

Although participation in the program is voluntary, of 21,926 communities in the nation identified as floodprone, 18,023 (82%) had joined the program as of November 30, 1990. At the end of calendar year 1990, there were 2.39 million policies in force with $201 billion of coverage. From 1978 through 1989, over 384,000 claims were paid totalling over $3.1 billion. Net receipts from policy premiums versus claims payments varies substantially from year to year. From 1978 to 1989 the net operating deficit or surplus ranged from a

Much information on floodplain management and flood hazard mitigation has been published in illustrated, clearly written manuals directed toward both private property owners and public officials.

STATE INITIATIVES TO EDUCATE THE PUBLIC

- *Texas holds workshops on the National Flood Insurance Program tailored to the host county's flood situation, and invites lenders, insurance agents, real estate agents, and others.*
- *In Tennessee, a community planner will visit a floodprone site upon request, recommend actions, and direct the owner to more information or assistance.*
- *Wisconsin state law requires real estate agents to advise prospective purchasers if a property is shown as floodprone on NFIP maps.*
- *The Maryland Department of Natural Resources created "Farley Floodhound," a cartoon character who appears in a coloring book and helps "flood pups" learn flood safety tips.*
- *Arizona is preparing a short course to be presented at local real estate schools.*
- *The Oklahoma legislature passed a law in 1986 that reads, "If the premises to be rented have been flooded within the past five years and such fact is known to the landlord, the landlord shall include such information prominently and in writing as part of any written rental agreements."*

deficit of $261 per policy in 1979 to a surplus of $98 per policy in 1987. A surplus was realized in fiscal years 1986, 1987, and 1988. As of October 1, 1988, the flood insurance fund was operating with a net surplus of $450 million, the result of a combination of rate increases and relatively low flood losses during those years. The accumulated surplus provides a reserve for years with catastrophic losses.

In 1983, the Federal Insurance Administration initiated its "Write-Your-Own" program whereby private insurance companies, under special arrangements, are permitted to sell and service flood insurance under their own names. The success of this program is evidenced by the fact that 80% of all flood insurance is presently sold by the participating WYO insurance companies.

Insurance premiums are based on the location of a structure within the floodplain and are determined primarily by the height of the structure's lowest floor in relation to the height of water during a base flood. Higher rates apply to structures subject to fast-moving waters. New and substantially improved structures in the floodplain that are not properly elevated to the base flood level are subject to higher rates than structures already in the floodplain at the time a community joined the program. Since 1974, flood insurance rates have increased several times in order to reduce the amount of the federal subsidy and bring the cost of flood insurance closer to true actuarial rates. In early 1988 the administrator of the Federal Insurance Administration announced success in "making the National Flood Insurance Program self-supporting for the historical average loss year." Even so, the existing premium base is not large enough to permit the National Flood Insurance Program to operate on a fully actuarial basis. But because only 15% to 30% of the nation's floodprone structures are insured, there is plenty of room for increased market penetration. Several strategies for increasing the number of insured structures have been suggested, including requiring more stringent enforcement by lenders of the mandatory purchase requirements, increasing public awareness of the flood hazard, imposing disclosure requirements on real estate agents, offering special insurance coverage and policy riders, and maintaining premiums at more affordable levels.

Concern has been expressed that flood insurance premium costs have increased to a level so high that many people do not purchase flood insurance unless they are required to do so by a mortgage lender or unless they have experienced flooding. Many of those who do purchase insurance allow it to lapse later. The net result appears to be that only those individuals with the greatest risk actually purchase and maintain flood insurance. To maintain actuarial rates for this group, insurance rates may be forced even higher.

Many of the claims paid out each year are on structures that have previously incurred damage. The Federal Emergency Management Agency defines these as repetitive loss structures—those for which two or more losses of more than $1,000 (building and contents combined) have been paid during the most recent 10-year period. From January 1980 through December 1989, 27.5% of the total losses and 32.5% of the amount paid on them were repetitive losses. Most repetitive losses are suffered by structures built before regulations and are for relatively small amounts; the building damage is usually a low percentage of the building value (53.2% of repetitive losses are for 10% or less of the building value). A high proportion of the repetitive loss claims payments are for contents.

Repetitive losses tend to be concentrated in a small number of National Flood Insurance Program communities, and many occur outside the designated floodplain. Six repetitive loss communities have had 29.7% of all the repetitive losses; 20 communities have had 44.3% of the losses. Although 12 of the top 20 repetitive loss communities are coastal, only two have significant numbers of policies in coastal areas. Only 22 of the top 100 repetitive loss communities are primarily subject to tidal flooding. Because of this it is believed that the repetitive loss problem is more related to riverine or stormwater flooding than to tidal flooding.

The Federal Insurance Administration has implemented a Community Rating System to encourage communities to go beyond the required standards. The incentive will be a reduction in flood insurance premiums for policyholders within communities that take approved actions to reduce flood losses.

NFIP Flood Claims Paid 1978-1987

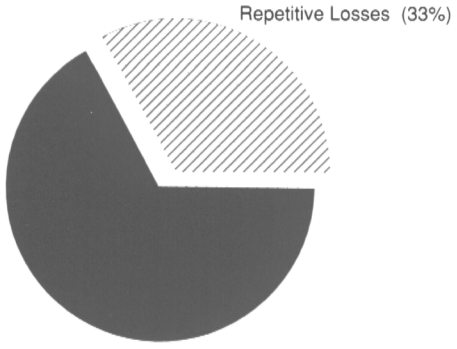
State[1]	Amount of Claims Paid
Alabama	$ 87,805,791
Alaska	332,839
Arizona	14,064,010
Arkansas	10,800,307
California	108,846,266
Colorado	3,223,467
Connecticut	34,906,126
Delaware	1,929,167
District of Columbia	101,518
Florida	165,125,349
Georgia	8,455,396
Guam	17,492
Hawaii	10,354,101
Idaho	499,193
Illinois	81,307,867
Indiana	13,289,339
Iowa	3,101,421
Kansas	12,957,557
Kentucky	48,913,951
Louisiana	502,019,965
Maine	15,921,597
Maryland	21,859,402
Massachusetts	40,890,955
Michigan	23,999,710
Minnesota	16,518,655
Mississippi	108,496,982
Missouri	113,043,717
Montana	1,943,610
Nebraska	9,460,795
Nevada	1,891,589
New Hampshire	3,729,914
New Jersey	117,979,379
New Mexico	490,587
New York	105,271,504
North Carolina	15,495,792
North Dakota	9,786,873
Ohio	29,549,982
Oklahoma	60,986,298
Oregon	2,404,346
Pennsylvania	61,971,275
Puerto Rico	32,200,608
Rhode Island	7,828,172
South Carolina	10,324,333
South Dakota	1,403,419
Tennessee	8,482,208
Texas	575,588,046
Utah	4,439,661
Vermont	1,140,338
Virgin Islands	2,332,664
Virginia	59,077,329
Washington	13,196,518
West Virginia	67,738,531
Wisconsin	3,295,144
Wyoming	1,038,852
Totals	$ 2,657,819,907

Source: Flood Insurance Producers National Committee

1. "State," as defined by FEMA program regulations, means any state, the District of Columbia, the territories and possessions of the United States, the Commonwealth of Puerto Rico and the Trust Territory of the Pacific Islands.

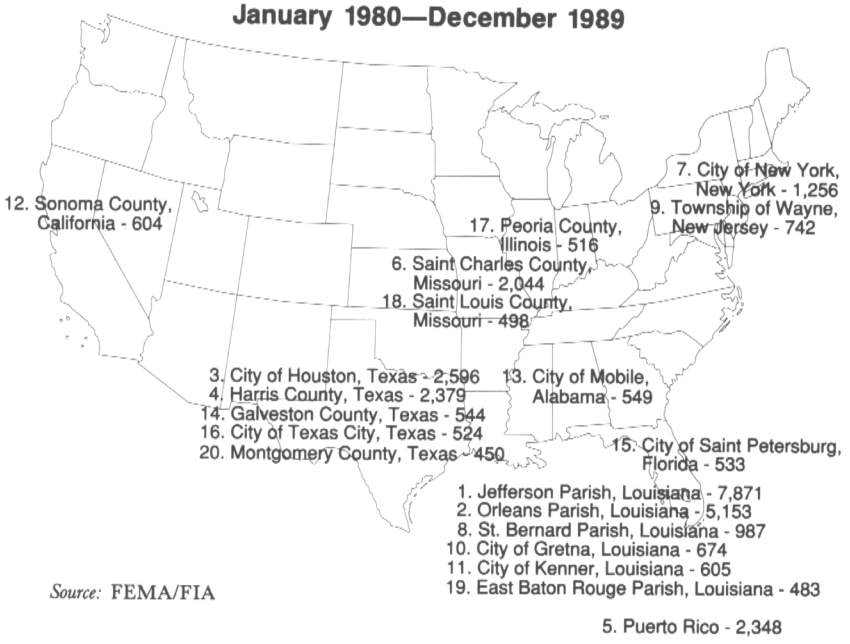
Amount Paid for NFIP Losses, 1980-1989

Total Paid = $2.27 Billion



Source: FEMA/FIA

Top 20 Repetitive Loss Communities by Number of Losses January 1980—December 1989



Source: FEMA/FIA

ACCEPTING THE NFIP

During the first 15 years of the National Flood Insurance Program, communities often challenged it and resisted adopting the required regulations. Now, because communities have seen the regulations supported in the courts, because there has been intensive media coverage of flood disasters, and because concerns about local liability for flood damages have been heightened, there is increased awareness of the program's benefits. As a result, NFIP regulations and other floodplain management activities have become institutionalized and generally accepted as a community responsibility.

TAX POLICIES TO MODIFY THE IMPACTS OF FLOODING

- *In 1987, Des Plaines, Illinois, began a permit surcharge of $200 for floodplain development projects to help finance city flood protection activities.*
- *The city of Stamford, Connecticut, has required developers of certain projects constructed in the floodplain to contribute funds for the operation and maintenance of their automated flood warning system.*
- *After disastrous flooding in 1982, the state of Connecticut enacted special flood relief legislation that included a provision for tax abatements for those whose property was damaged more than 10% of its value. Towns were authorized to abate up to one-third of the taxes due, and the state would reimburse them for 90% of the taxes lost. Eighteen towns offered some tax abatement to property owners, and the state reimbursed the towns a total of $49,504.*

Today, flood insurance is largely unavailable except under the National Flood Insurance Program. An exception is a Lloyds of London-based policy which has as many policyholders in Utah as does the National Flood Insurance Program. Some private policies or riders are available for basement flooding; these were initiated after the National Flood Insurance Program limited its coverage for basements and subsurface flows. Flood insurance is included as part of a comprehensive flood insurance policy for some large businesses with offices and land holdings in many locations, in and out of the floodplain. Crop insurance available under the U.S. Department of Agriculture's Federal Crop Insurance Corporation provides protection to agricultural producers from losses caused by insects, disease, fire, hail, drought, floods, freeze, and wind.

Tax Adjustments

Most provisions of federal, state, and local tax codes are designed to encourage development without regard to whether it might take place in a floodprone area, while relatively few provisions provide incentives to leave land in its natural state. Some tax-based incentives for development are reductions in property taxes, abatement or deferral of taxes to entice or retain businesses in an area, and the establishment of enterprise zones or other special business zones to promote development and employment in economically depressed areas. These make locating businesses, homes, and other development in some floodprone areas financially feasible and even attractive. On top of this, the federal Internal Revenue Code and many state codes also provide casualty loss deductions on income taxes to those suffering flood losses. After disastrous floods, many states and localities provide additional types of tax relief, reducing or temporarily suspending real estate taxes or business taxes for those affected by flooding, for example.

Still, more integration of tax policies and floodplain management is occurring. The Tax Reform Act of 1986, for example, made major changes in the Internal Revenue Code, some of which have an impact on floodplain management. Individual casualty loss deductions under $100 are now prohibited, and the deduction is limited to the portion of the loss that exceeds 10% of the adjusted gross income. The new rule does not apply to business property. The Act also eliminated or restricted many of the tax deductions and credits that had been used as incentives to build in floodplains, on barrier islands, and at other hazardous locations.

Flood Emergency Measures

Flood emergency measures are typically carried out by local civil defense, police and fire departments, public works agencies, and public health personnel, supplemented as necessary by assistance from state and federal agencies. Emergency activities during and immediately after a flood may include removing people and property from areas about to be flooded; sandbagging around individual structures and constructing emergency dikes to direct water away from vulnerable areas; search and rescue; and steps to protect the health and safety of residents.

To be successful, flood emergency measures must have the thorough involvement of the private sector, from individuals who evacuate and take household-level emergency precautions, to the organized group efforts like those of the American Red Cross local chapters. Private contractors work for communities and individuals to remove debris and repair homes, roads, bridges, and other property damaged from floods. Some states have standing contracts with private businesses to provide emergency services in disasters. The 1983 floods in Utah showed what literally thousands of volunteers, acting individually and in groups, can accomplish during flood emergencies.

The Corps is the federal agency most commonly involved in flood emergencies, under authority of P.L. 84-99, which authorizes it to help in flood fighting, repair and restoration of flood control works, provision of emergency water supplies, implementation of advance protective measures, and the performance of other hazard mitigation activities. The support may take the form of technical assistance, materials, equipment, or services. The Soil Conservation Service may also become involved with emergency efforts. The Federal Energy Regulatory Commission requires emergency action plans for all its licensed dams. The Federal Emergency Management Agency helps state and local governments assess the extent and severity of damage in order to seek disaster assistance. State emergency services agencies generally coordinate state resources and activities during flood emergencies, and the state police and transportation or public works departments, the state national guard, and the agencies responsible for dam safety and water resources also play major roles.

Disaster Assistance

Disaster assistance is provided by federal, state, and local governments, and the private sector. It may take the form of financial relief, or of help to repair, replace, or restore facilities damaged or destroyed by a disaster. The system is most often efficient and adequate to provide the necessary financial relief to individuals and communities.

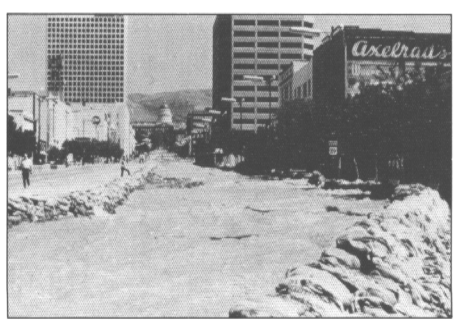
The greatest source of federal disaster assistance is provided under the Disaster Relief Act of 1974 and takes the form of grants to the states from the President's Disaster Relief Fund after Presidentially declared disasters. The assistance is administered by the Federal Emergency Management Agency, which also directs and coordinates the disaster assistance functions of all federal agencies. The Small Business Administration issues its own disaster declarations and makes low-interest loans available directly to eligible individuals and businesses to replace or repair damaged real estate, inventory, or other business property. The Federal Highway Administration provides funding assistance for damaged highway facilities that were constructed with federal aid. Under the Emergency Watershed Protection Program, the Soil Conservation Service may directly undertake emergency work such as clearing debris from channels and stabilizing streambanks. As mentioned above, the Corps has authority to provide assistance for disaster the Corps has authority to provide assistance for disaster preparedness, advance protective measures, rehabilitation of flood control works damaged or destroyed by flood, protection or repair of federally authorized shoreline protection works threatened or damaged by coastal storms, and provision of emergency drinking water. The Farmers Home Administration State Director may make emergency loans to farmers, ranchers, and oyster planters. Under the Emergency Conservation Program, an Agricultural Stabilization and Conservation Service State Director may designate areas eligible for cost-sharing grants of up to 64% to rehabilitate farm lands damaged by natural disasters.

Emergency response to flooding is usually the responsibility of local agencies, with supplemental assistance from state and federal agencies. However, private citizens are typically the first to respond and provide assistance to others.

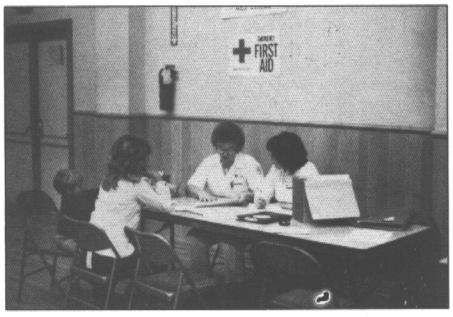
FIGHTING FLOODS IN UTAH

In early May 1983 Salt Lake County, Utah, began 24-hour monitoring of critical streams in anticipation of severe flooding as a result of a large snowpack and unusually cold spring. The most vulnerable flooding location was identified as 13th South, where three streams came together. City forces, with assistance from volunteers, built temporary dikes along the street so it could be used as a channel. After a sudden thaw on May 26, the county and city declared an emergency and flood control plans were activated. Two days later another creek reached a flood discharge nearly double its previous record and went out of control. Volunteers were called in to sandbag 1.5 miles of State Street through the city; flood waters were successfully controlled in this temporary river.

During the extended period of flooding and subsequent cleanup in Utah in 1983, volunteers put in an estimated 50,000 days of work in Salt Lake City, and about 100,000 days in the rest of the county. The value of the volunteer work has been estimated at over $18 million.



State Street, Salt Lake City, Utah, May 1983. (Street was used as a temporary water conveyance path.)



Most federal disaster assistance is provided through FEMA, although the Small Business Administration, Federal Highway Administration, Soil Conservation Service, Army Corps of Engineers, Farmers Home Administration, and Agricultural Stabilization and Conservation Service also administer programs. State and local governments, as well as private, nonprofit organizations such as the Red Cross, are also centrally involved in providing aid following flooding.

Disaster Assistance Center, DeRidder, Louisiana, 1983.

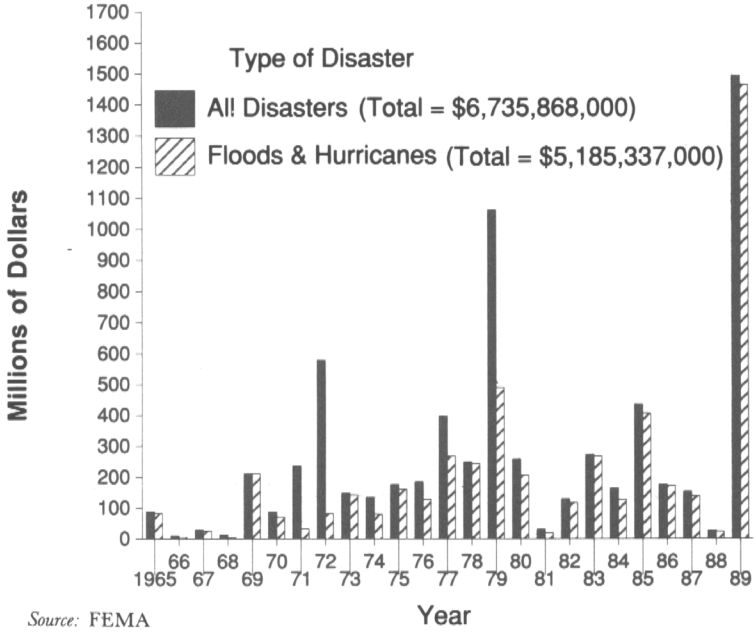
THE "AVERAGE" DISASTER

A 1990 preliminary report by the U.S. General Accounting Office noted that in an "average" disaster about 2,000 individuals and families seek federal disaster assistance and the Federal Emergency Management Agency spends about $10 million.

Although all state and most local governments have programs to coordinate and provide assistance during an emergency, few have special funds for financial assistance to victims. Most states limit their own disaster assistance funding to local governments, rather than extending it to businesses or individuals. All states now contribute some of the nonfederal share of assistance for Presidentially declared disasters. States may also declare their own emergencies or disasters; 28 states then provide assistance to localities out of a governor's emergency fund.

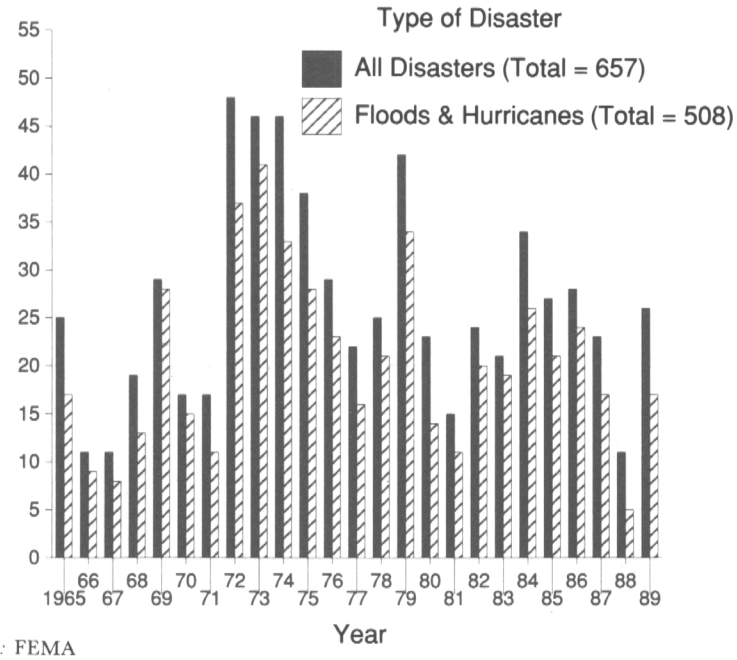
Local governments may provide disaster assistance to their residents and business community, most commonly through some form of tax break. Many localities have joined mutual aid agreements with nearby communities to pro-

Dollars Paid for Disaster Assistance, 1965-89
All Disasters versus Floods and Hurricanes



Source: FEMA

Number of Presidentially Declared Disasters, 1965-89
All Disasters versus Floods and Hurricanes



Source: FEMA

vide equipment, personnel, and other disaster assistance. Research has shown that local governments have the capacity to assume a much higher proportion of losses than they usually do within the existing framework of federal and state programs.

A number of national voluntary organizations provide disaster relief services, primarily emergency shelter, food, clothing, and medical aid. Some also provide longer-term assistance, such as rebuilding homes or job placement. A committee known as the National Voluntary Organizations Active in Disaster coordinates 11 private relief groups. Three of these organizations, the American National Red Cross, the Salvation Army, and the Mennonite Disaster Service, were formally recognized in the Disaster Relief Act of 1974 and have signed memoranda of agreement with the Federal Emergency Management Agency formalizing the provision of their disaster assistance. In addition to national organizations, local churches and other voluntary groups often provide significant assistance during and after disasters.

Postflood Recovery

Postflood recovery work, aided by many types of disaster assistance, has been largely effective at restoring flood-damaged communities and individual properties to their preflood condition. Unfortunately, this has not always been the wisest course of action, because returning to the status quo leaves the door open for a repeat of the disaster. Numerous recommendations have been made over the years to alter recovery procedures to take advantage of the opportunities presented immediately after a flood, when outside expertise and money flows into a community, damaged or destroyed facilities are waiting to be repaired or replaced, and local attitudes toward mitigation are more flexible than before. It was thought that this would be the best time to identify mitigation actions that might easily be taken and to delay reconstruction until wise decisions about the vulnerability of future development could be made. Gradually federal agency policies began to change so that over the past two decades individuals and communities have had to meet certain conditions in order to receive disaster assistance. These include protecting the environment, implementing floodplain management measures, purchasing flood insurance, and taking action to mitigate hazards. Passage of the Disaster Relief and Emergency Assistance Act in 1988, which allows federal disaster assistance funds to be spent on mitigation activities and not just to rebuild to the predisaster condition, signalled a new approach to postflood recovery.

Restoring and Preserving the Natural and Cultural Resources of Floodplains

The strategies of preserving and restoring the water resources, living resources, and cultural resources of floodplains are generally intertwined. The best way to protect these floodplain resources is to avoid development within floodplains. It has been suggested that stronger federal support of programs to set aside floodplains from development is needed, and that federal policies and procedures actually do not encourage and sometimes even obstruct innovative approaches to preserving natural floodplains. Several federal policies, for example, limit the features of water resources projects to those that have quantifiable economic benefits. Because many natural and cultural resources are difficult to quantify, or add only incremental benefits, the cumulative effect of eliminating these features may not be taken into account.

Limited preservation and restoration can be accomplished indirectly through flood loss reduction activities. Numerous programs at all levels of government establish policies that encourage, but generally do not require, protecting floodplain resources. Natural resources management itself is usually not focused on floodplains but instead addresses a particular resource throughout its natural range.

NAGS HEAD PLANS ITS RECOVERY FROM A FUTURE FLOOD

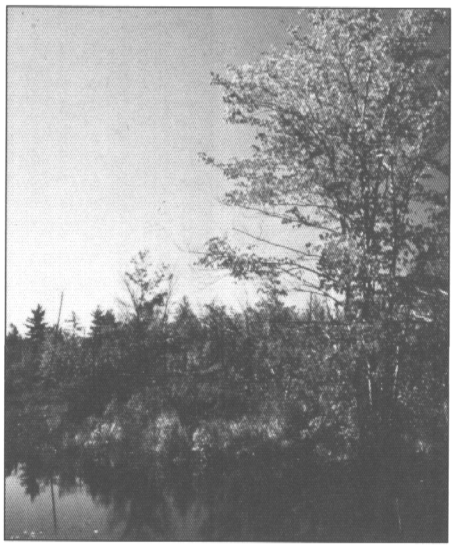
The Town of Nags Head, formerly a quaint village of seaside cottages on the Outer Banks of North Carolina, is now a resort community facing substantial growth and development. One of its main concerns is protecting the quality of its natural resources and preparing its residents and thousands of visitors for hurricanes and coastal storms. With guidance from the state's Coastal Area Management Act Program, Nags Head began preparing a local land use plan that would incorporate a prestorm mitigation program, warning and preparedness plans, and post-storm reconstruction policy.

In developing its plan, Nags Head surveyed all its properties at risk, finding that 84% of the town's 2,500 buildings lay in the 100-year floodplain and 44% in the high hazard areas. There were also four public buildings, 27 miles of streets, and 32 miles of public water mains within the floodplain.

After a series of meetings and workshops, the Board of Commissioners adopted policies and actions "to reduce, to the extent possible, future damage from hurricanes and severe coastal storms." There are 12 mitigation policies, including using the capital improvements program to encourage growth away from high hazard land into public open space, and opposing construction of finger canals and other projects that destroy the protection provided by natural features.

The poststorm reconstruction policies are designed to take advantage of the natural land clearance provided by severe storms. When it begins to redevelop the cleared areas, the town will limit reconstruction of substantially damaged buildings and public utilities, will rebuild public structures strong enough to be used as shelters, and will not permit oceanfront reconstruction until the state reestablishes the setback line.

(Adapted from ASFPM News & Views, *1988)*



It has been difficult to quantify the value of the natural and cultural resources of floodplains and therefore difficult to justify government expenditures to preserve floodplains in their natural state. However, there is a growing desire among the public to make sure that the natural benefits of the riparian environment are safeguarded.

Regulations

Regulatory measures are among the most widely used and most effective means of helping to protect the natural and cultural resources of floodplains; they are employed at all levels of government. There are several drawbacks to using them, however. Restrictions on the use of private land in order to protect natural resources are generally viewed less favorably by the public and the courts than are restrictions to protect human lives or property. Because of this, regulations must be well designed to avoid being ruled unconstitutional takings. Finally, protective regulations sometimes conflict with flood loss reduction measures, especially with structural works.

Many federal environmental regulatory programs directly or indirectly protect floodplain natural resources. These include programs established to implement the Clean Water Act; the Safe Drinking Water Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Solid Waste Disposal Act; the Endangered Species Act; the Natural Historic Preservation Act; and others.

Statewide floodplain, wetland protection, or similar regulations may be applied directly by a state or, as is more often the case, by local communities according to state-established standards. Any alteration of the natural topography or habitat, or any damage to flora or fauna requires a permit in some states. Cumulative impacts are considered during the permit review process in a few states, and mitigation of the loss of natural resources is often a condition for permit issuance. Several states specifically protect wetlands with programs that outline minimal criteria for permit issuance and prohibit all other development.

Local regulations, such as zoning and subdivision regulations, building codes, housing codes, and sanitary and well codes, may directly or indirectly manage natural resources by including provisions for protecting habitat, water quality, and open space. Relevant provisions include setbacks from the shore, limited density in coastal areas, restrictions or prohibitions on certain kinds of development in such sensitive areas as barrier beaches and sand dunes, and specification of uses that will not degrade the natural resources of the site.

THE WILD AND SCENIC RIVERS ACT

The Wild and Scenic Rivers Act of 1968 establishes as national policy the protection of certain selected rivers (or segments of them) with particular natural and cultural value. The National Park Service maintains a list of rivers that are potential additions to the designated system. The Act prohibits the Federal Energy Regulatory Commission from licensing any dam or other work on or directly affecting any river of the system and likewise prohibits other federal agencies from activities that would have a direct and adverse effect on the values incorporated into the Act. Further, all federal agencies are required, as part of their normal planning and environmental review processes, to avoid or mitigate adverse effects on rivers being considered for wild and scenic designation.

FEDERAL REGULATIONS AND THE NATURAL RESOURCES OF FLOODPLAINS

- The Section 404 program under the Clean Water Act helps protect the natural resources of floodplains by regulating the discharge of dredged or fill material into waters of the United States, including adjacent wetlands. Permit applications are subject to a public interest review that includes consideration of floodplain values and flood hazards, and compliance with the Environmental Protection Agency's section 404(b)(1) guidelines, which incorporate extensive environmental criteria to prevent the loss of aquatic resources and minimize adverse environmental impacts. One aspect of the guidelines provides for the mitigation of adverse impacts at one site by restoring alternative degraded sites; it has been responsible for a number of experiments in rehabilitating degraded wetlands and creating new ones.
- One of the most significant developments in protecting rare plant and animal species, many of which live in floodplain habitats, was the Endangered Species Act of 1973, which authorizes the designation of habitats critical to the survival of threatened and endangered species. It directs federal agencies not to authorize, fund, or carry out actions that may jeopardize their existence or modify their habitats. Many states have developed their own programs of identifying and protecting rare and endangered species.
- The National Historic Preservation Act of 1966 was passed, in part, because Congress recognized that federal projects, such as highways, dams, and urban renewal, had damaged or destroyed thousands of historic properties during the 1950s and 1960s. The National Historic Preservation Program has operated as a working partnership between federal, state, and local governments, private citizens, the Advisory Council on Historic Preservation, and the National Trust for Historic Preservation. The federal government provides guidelines, technical assistance, and grants in aid for state and local historic preservation efforts, and monitors its own activities so that they do not unnecessarily harm historic properties. State historic preservation officers coordinate the program, assist local governments and the public and give them advice on preservation matters, and carry out other aspects of the national program on behalf of the federal government. Preservation work at historic sites is done by local governments, nonprofit organizations and institutions, corporations, and individuals.

Development and Redevelopment Policies

Important federal policies and programs affecting the design and location of services and utilities in the nation's floodplains have been established in the executive orders on floodplains and wetlands and in accord with the Wild and Scenic Rivers Act and the Coastal Barrier Resources Act. The executive orders require federal agencies to evaluate their proposed actions in light of, among other considerations, the proposed impact on the natural resources of floodplains. Some states have executive orders to control placement of public facilities on floodplains, while others directly regulate these uses through statutes. A number of federal laws and programs provide funding and other assistance for acquiring and protecting floodplain land.

States protect natural and cultural resources with open space and recreation programs that are occasionally linked to floodplain management. Most states have at least one program through which wetlands are brought into public ownership, although that usually was not its specific intent; frequently wetlands are acquired because of their habitat, open space, or other value. Most states have now enacted legislation to protect wetlands; many of these states have found that the incremental loss of small wetland areas still results in an unacceptable cumulative loss. In response, they are acting to tighten existing wetland protection programs. A related measure is mitigation banking programs, which provide for the creation or enhancement of wetlands at one site as compensation for damage that has or will occur to wetlands as a result of development at another site. At least 10 mitigation banks were functioning in the United States as of 1986. Mitigation banking is only appropriate in certain situations and requires a great deal of administrative and planning effort, financial support, and commitment.

Several thousand communities have acquired a portion of their floodplains for parks, parkways, wildlife areas, conservation, agriculture, or other environmental or social uses. Some local jurisdictions have moved toward programs to combine other community objectives with floodplain management, including open space, hiking, cycling, water quality, aquifer protection, wetlands protection, and the provision of fish and wildlife habitat. These multiobjective programs typically take two forms: greenway or river corridor projects and community redevelopment projects. The State and Local River Conservation Assistance Program, administered by the National Park Service, is the principal federal program for providing information, technical assistance, and limited funding for such river planning.

Charles River natural flood water storage area near Dedham, Massachusetts.

PROTECTION OF FLOODPLAINS AND WETLANDS THROUGH REGULATION

- *Many Michigan communities have adopted combined floodplain and wild and scenic river regulations to preserve the natural resources of these areas.*
- *Besides floodplain regulations that require permits for filling, grading, or construction, Virginia Beach, Virginia, has adopted coastal wetland and sand dune protection regulations that require building setbacks.*
- *A zoning ordinance in Clearwater, Florida, includes special regulations for environmentally sensitive areas, including mangrove and freshwater swamps, barrier islands, coastal beaches, natural drainageways, and aquifer recharge areas.*
- *In order to reduce bank erosion, increase groundwater infiltration, and provide wildlife habitat, several California communities have adopted ordinances regulating the removal of riparian cover along watercourses.*
- *In Northampton, Massachusetts, 1,500 acres of floodplain along the Connecticut River have been placed in an exclusive agricultural use district.*
- *In East Hampton, New York, floodplain regulations are supplemented by a beach grass protection ordinance, tidal and inland wetland regulations, a dune setback regulation, and scenic easements to protect wetlands, dunes, and other areas.*

PROTECTION OF FLOODPLAINS AND WETLANDS THROUGH DEVELOPMENT POLICY

- *A Glastonbury, Connecticut, floodplain regulation includes a density transfer mechanism under which development rights may be shifted from one place to another.*
- *In the largest federally funded watershed management project in history, the U.S. Army Corps of Engineers purchased 8,500 acres of wetlands in the Charles River watershed upstream from Boston, Massachusetts. These wetlands provide 50,000 acre-feet of flood water storage, eliminating the need for a flood control dam or other structure and constituting significant areas of habitat and open space.*
- *New Jersey used funds from the U.S. Fish and Wildlife Service's Federal Aid to Wildlife Fund to acquire additions to the 4,400-acre Cape May Wetlands, which the state maintains as a wildlife refuge. An adjacent 315-acre salt marsh was purchased, and the owner of the property donated 25% of the land to the state, providing the state's required matching funds.*

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PROTECTION OF FLOODPLAINS AND WETLANDS THROUGH DEVELOPMENT POLICY

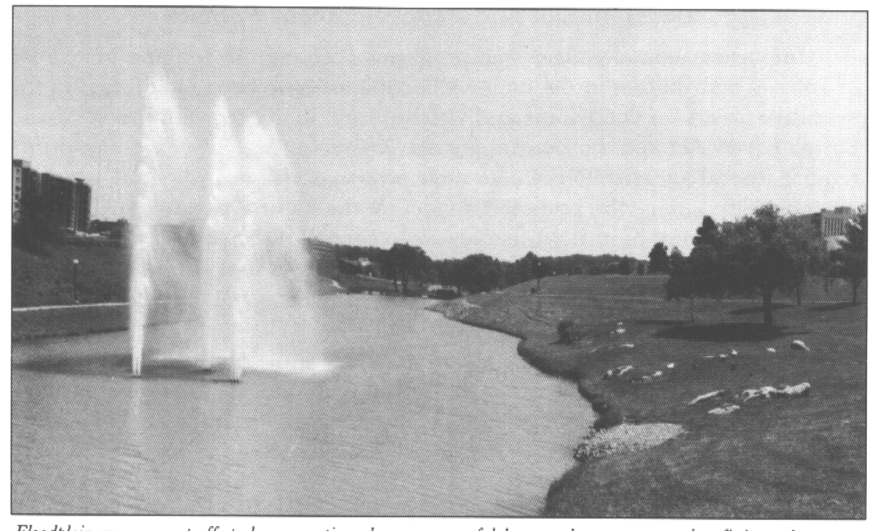
Continued from previous page

- *When the Wynoochee Dam was constructed in Washington State, a portion of wildlife habitat was lost under the lake and a number of elk and deer were left homeless. To mitigate the loss, the U.S. Army Corps of Engineers acquired 1,034 acres of land to provide replacement winter rangeland. Within each area, cultivated fields supply winter forage, while the remaining area serves as buffer and as habitat.*
- *Florida's Save our Rivers Program is one of several that have protected substantial acreage for habitat, water quality, watershed protection, and recreation. Land has been purchased to restore channelized or impounded rivers that feed the Everglades, to restore the Kissimmee River to its original channels, to conduct a pilot project on marsh habitat renewal, and to preserve parts of the Green Swamp.*
- *The Mecklenberg County, North Carolina, Greenway Master Plan provides for the preservation of floodplains along more than 20 creeks for passive recreation, habitat protection, and reduction of flood damages. A network of greenways is planned that will include 4,000 acres and 60 miles of trails. As of 1986, over 1,000 acres had been acquired through donations, local park bonds, and dedications.*

PROTECTION OF FLOODPLAINS AND WETLANDS THROUGH TAX ADJUSTMENTS

At least 43 states offer real estate tax incentives to leave land in agriculture, forestry, and certain other open space uses; undeveloped floodplains qualify under some of these statutes.

- *A Florida program earmarks for the Water Management Lands Trust Fund the revenues from a documentary tax of $.075 per $100.00 on all real estate transactions. The money is used to purchase and manage floodplains and wetlands. Revenues over the next 30 years are expected to approach $1 billion.*
- *Minnesota's Tax Exemption and Credit Program has two main components. Under the first, eligible wetlands are exempt from property taxes. Under the second, landowners who agree not to drain wetlands in a given year receive a tax credit. Excess credits for wetland property may be applied to the landowner's tax liability for contiguous property. The state reimburses counties for revenues lost due to the exemptions and for the value of the tax credits.*



Floodplain management efforts have sometimes been unsuccessful because they are seen as benefitting only select groups at the expense of an entire community. Therefore, some jurisdictions have developed programs that combine other community objectives—the development of open space and recreation facilities, or the protection of wetlands and water quality, for example—with floodplain management.
Greenbelt park, Maryville, Tennessee.

The private sector, operating largely through private, nonprofit organizations, is heavily involved in acquiring land to protect it for open space and habitat, and much of that land is wetlands or floodplain land. As of 1989 the Nature Conservancy was responsible for the protection of 3,643,352 acres in 50 states, Canada, Latin America, and the Caribbean. The Audubon Society and Ducks Unlimited have active programs to help preserve wetlands.

Information and Education

Information, education, and technical assistance are becoming more important as natural resource managers and interest groups realize the benefits of a public that is well-informed about natural systems and about the consequences of decisions that affect them. Technical information and public education about the natural and cultural resources of floodplains is provided by the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Office of Coastal Resources Management, and other federal agencies through press releases, newsletters, magazines, and television programs. Most states have active programs within their natural resources, environmental protection, and parks and recreation departments that prepare and distribute literature, films, and other materials. Many offer instructional courses to staff and officials of local communities. Natural resource inventories and mapping are major components of many state programs. Hundreds or thousands of private organizations exist across the country to inform and educate the public about natural resources, including those on floodplains. Environmental values are widely taught in schools at all levels, and popular television programs reach a wide audience. Research is an important predecessor to education and technical assistance, and the information base on natural resources is being broadened continually.

Improved documentation and quantification (including dollar values) of the value of natural floodplains are needed to improve public understanding and acceptance of the need for protection. For example, few developers seem to realize that floodplains and wetlands have great aesthetic appeal, that in their natural state they can simultaneously enhance property values and continue to fulfill their normal natural and cultural functions.

Tax Adjustments

Positive incentives for the preservation and restoration of floodplain resources can be provided through several kinds of tax adjustments, although this technique has not been widely used. Federal income and estate tax benefits, which are available to individuals and organizations who donate land and provide easements to governments and eligible nonprofit organizations, have

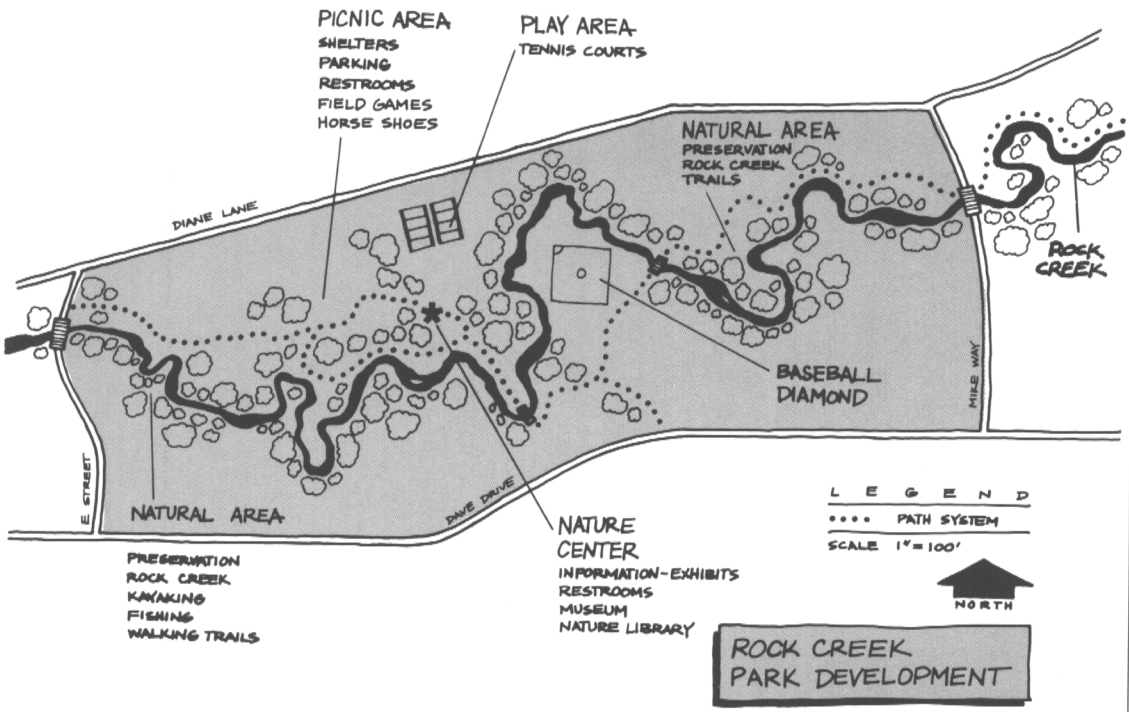
been a major factor in facilitating private donations of property with valuable wildlife and habitat functions or historical significance. Most conservation organizations are tax exempt, and many of them are active in protecting the natural and cultural resources of wetlands. Almost all states offer tax incentives for open space uses.

Administrative Measures

Many different administrative measures can be used specifically to preserve and restore the natural and cultural resources of floodplains, including restrictions or conditions on contracts, grants, loans, permits, and licenses; encumbrances during land conveyance; delegation of responsibility for floodplain activities to a specific authority; comprehensive planning; systematic review of agency programs to identify opportunities for preservation and restoration; and coordination among federal, state, local, and private agencies to implement unified efforts. Some of the most important administrative measures address the inventory, classification, and mapping of wetlands, wildlife, aquifers, and other natural resources. It is necessary to know what natural resources exist in the floodplain and what their individual and collective value is before making land use decisions that will sustain those values and functions.

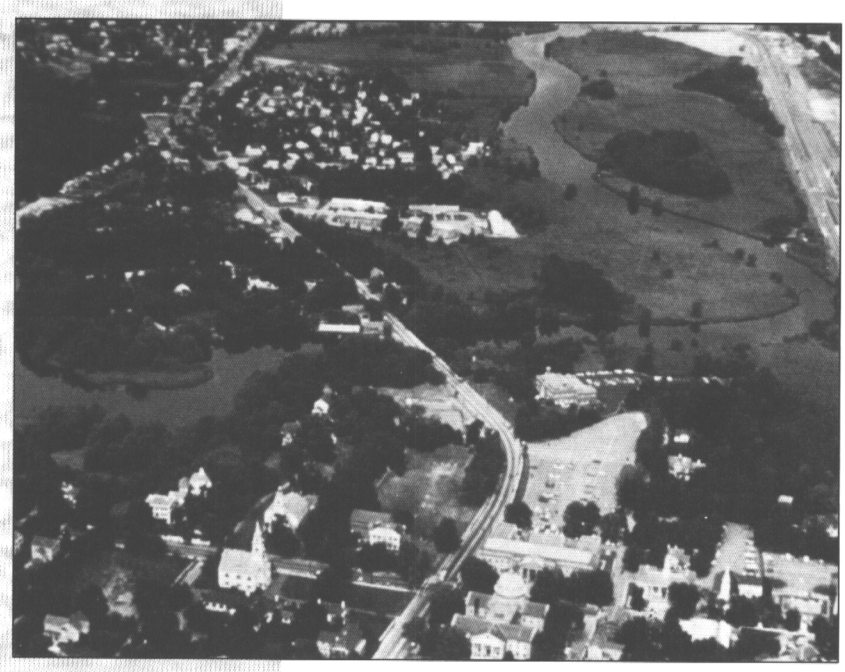
Planning historically has been used by governments for many kinds of activities besides natural resources management. Comprehensive planning provides an opportunity for taking a holistic view of floodplain resources while also meeting other local needs, such as water supply, agricultural erosion control, recreation, and economic development. This sort of planning is getting increasing attention at the state and local level, and typically incorporates several of the tools discussed above.

Multiple Use Planning for a Floodplain



Part III

The Effectiveness of Floodplain Management



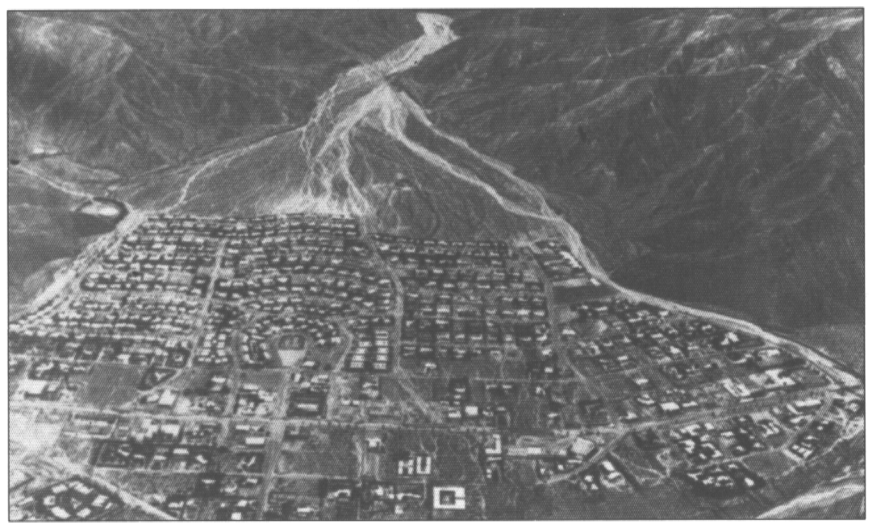
Perception and Awareness of Floodplain Losses

Both individual and institutional perception and awareness of flood risk and vulnerability affect floodplain management. Although substantial progress has been made in increasing institutional awareness and response, individual perception and awareness generally falls far short of what is needed. This shortfall makes itself unpleasantly felt in the unwise development of flood hazard areas and in disregard for the value of natural floodplains.

Recognition of Risk

Local perception of flood hazards—by both governments and floodplain residents—is related to previous experience with flooding; the extent to which the floodplain is developed; the existence of structural control measures; the seriousness of the flooding in relation to other community problems; and attitudes about land use, water resources management, and regulations. In general, the threat of damage from coastal flooding seems to be taken more seriously by communities than is damage from riverine flooding. Because most people discount the probability of loss from infrequently occurring events, such as large floods, individual and community experience with flooding results in both heightened perception of risk and increased attention to solving flood problems. The perceived seriousness of the flood problem is directly associated with the extent of floodplain development and existence of intensive land uses in the hazardous area; increasing development may result in greater awareness of flood problems. The presence of structural flood control measures has varying effects on perception of risk and subsequent responses; structural measures may contribute to a sense of complacency, as though the problem were "solved."

Private citizen perception of risk may be quite different from that of local officials. Even if the risk is acknowledged, the advantages of a floodplain location to the individual property owner may seem to outweigh the disadvantages. Homeowners also may be more concerned with the effect of floodplain regulations on resale value than with the effect of a potential flood on the house or property itself. Some studies have found that even after a control structure is built, local governments remain concerned about a flood problem, while the citizens themselves tend to forget about the threat. Both individual and community perception of risk may be tempered by other considerations, such as apprehension about the potential secondary effects of land use management—reduction in property values, slowed economic growth and development, reduction in the tax base, and increased construction costs.



Although public knowledge concerning flood risks has increased significantly in the last 30 years, development in hazardous areas is still occurring.

Flooding and alluvial fan, Magnolia Spring Canyon, Rancho Mirage, California, July 1979.

FLOODPLAIN MANAGEMENT TERMINOLOGY

Some misperceptions about floodplain management are the result of simple lack of understanding. For example, probably the most misunderstood concept is the "100-year flood." The term is often taken literally, causing individuals to believe, incorrectly, that if they or their community have experienced a 100-year flood, a similar one cannot occur for another century. The terms "1% annual chance flood" and "national base flood standard" have been suggested as less-misleading substitutes.

Use of the term "floodproofing" also can give a false sense of security about susceptibility to flood damage. The techniques involved in floodproofing do not make a structure completely safe from flooding. The term "flood-resistant construction" has been suggested as an alternative.

REGULATION AND PUBLIC AWARENESS

Many regulatory measures have been instituted by governments in an effort to force individual awareness of flood hazards and protective action. For example, the National Flood Insurance Program is voluntary, but changes have been made in the law since it was passed in 1968 in order to encourage greater participation. Primary among these was the Flood Disaster Protection Act of 1973, which prohibits nonparticipating floodprone communities from receiving disaster assistance after a flood. Another mechanism intended to promote awareness and compliance is the provision that federally insured banks and other financial institutions require purchasers of homes and other structures in the floodplain to take out flood insurance. This procedure has not been wholly effective because the institutions currently are not penalized if they fail to comply.

Previous page: Charles River watershed, Massachusetts.

Informing and educating the public about both flood risk and about the importance of the natural and cultural resources of floodplains is an ongoing effort. Much research has examined ways to provide information and to make people take action, and new techniques are being sought continually. Typical means of providing information to the public include distribution of pamphlets and other publications; use of radio, television, and newspapers; placement of warning signs; and many other more imaginative methods. A few jurisdictions require real estate agents to provide flood and other hazard information to prospective buyers of homes.

Awareness of the Value of Natural Floodplains

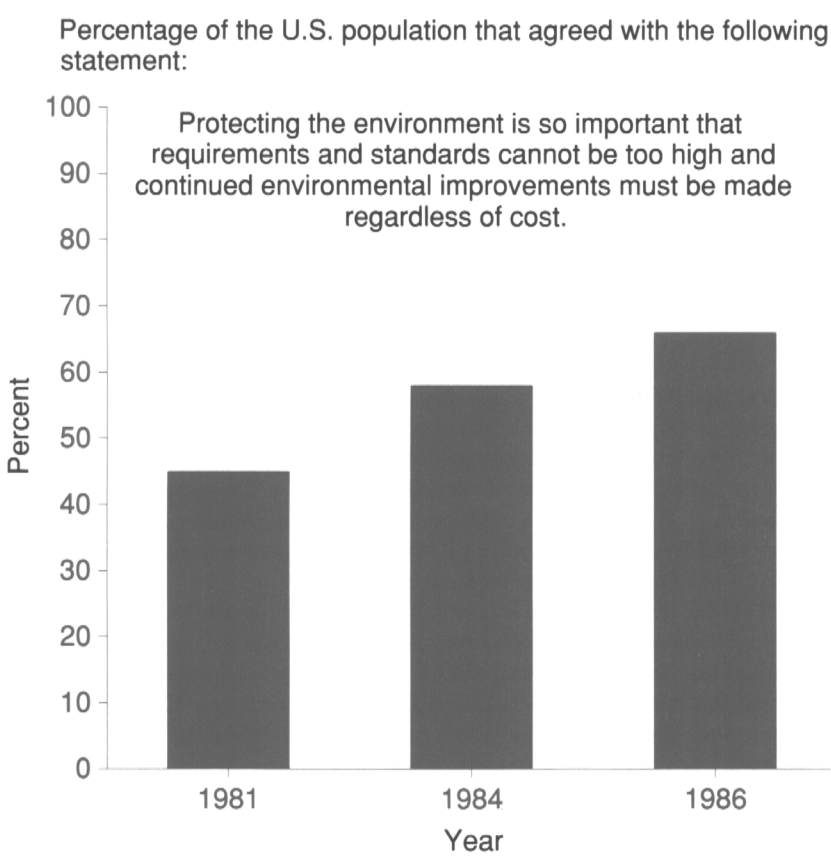
The protection of the natural and cultural resources of floodplains is beginning to emerge as a popularly expressed environmental objective; it is already encompassed in the broader environmental goals embraced throughout the nation. The general level of public environmental awareness and support for all types of protection programs has increased dramatically in the past 25 years, and the importance of preserving wetlands, protecting endangered species, and maintaining water quality is widely recognized.

This kind of awareness represents a potentially broad base of public support for floodplain management. Unfortunately, this voiced support does not necessarily translate into action, particularly when an individual's own property is involved. Any restriction on individual property rights may be strongly resisted, or the loss of natural values may seem inconsequential because of the small area affected.

PUBLIC SUPPORT FOR WETLANDS

Concern for the loss of wetlands and support for their protection appear to be increasing. A 1982 Harris poll found that 83% of respondents felt that it is "very important" to preserve the nation's remaining wetlands. A 1985 poll reaffirmed this broad support: 85% of those polled favored strict enforcement of the Clean Water Act and its wetlands protection requirements.

Protecting the Environment



METEOROLOGICAL DATA: THE NWS

The collection and analysis of weather data for floodplain management—precipitation intensity, extent, and duration; wind data; and temperature—is the responsibility of the National Weather Service. The NWS's data collection system extends throughout the 50 states, offshore, and across the Pacific Ocean, and now consists of about 230 staffed stations, 165 automated stations, and almost 400 stations under contract. In marine locations, automated moored and drifting data buoys are used. A network of automatic hydrological observing system stations is operated to provide near real-time data of river stages and rainfall. The NWS also operates 128 weather radar stations that provide information on areal coverage, height, intensity, and movement of storms for warning and forecasting and hydrological and climatological programs. Over 1,300 ships report data systematically, and 300 others report data whenever they are in waters covered by NWS forecasts.

HYDROLOGICAL DATA: THE USGS AND THE EPA

Water data have been published annually by the U.S. Geological Survey since 1890. Records are now published annually for each state and maintained on a computerized data base, the National Water Data Storage and Retrieval System. It includes data from USGS surface water records, with an index for the 320,000 water data storage sites; over 240 million daily parameters such as streamflow, groundwater levels, specific conductance, and water temperatures; 460,000 records of annual maximum streamflow and gage height values; 2.3 million analytical results describing biological, chemical, and physical water characteristics; and construction history, geohydrologic data, and one-time field measurements on 850,000 sites. The Environmental Protection Agency has a water quality data base of nationwide information on water quality, water quality standards, point-source pollution, fish kills, waste abatement needs, and other topics.

Knowledge, Standards, and Technology

Effective floodplain management requires a sound understanding of the physical, biological, and chemical processes that affect flood hazards and the natural resources of floodplains, as well as an appreciation of the social processes involved in human interaction with them. The last 25 years have witnessed a rapid expansion of the knowledge, information base, and technological expertise in floodplain management—products of the combined efforts of governments at all levels, academic institutions, and the private sector.

Climate Change and Weather Forecasting

One of the basic assumptions of hydrology and floodplain management has been that long-term climate is constant. Over the past few decades, however, new evidence has suggested that climatic changes can take place rather quickly (over a decade or so) and last for half a century or more. Therefore, the traditional 30-year averages of various climatic parameters—precipitation, for example—that have been the basis of past policy may be misleading for decisions involving long-term consequences.

During the 1970s and 1980s, indications of a global warming trend increased, and some scientists hypothesized that human use of fossil fuels was amplifying the greenhouse effect sufficiently to cause changes in global climate. The normal historical relative rise in sea level is expected to continue over the next century, and as a result of the human-induced climate changes, the rate of rise is anticipated to increase. The predicted rise in global mean sea level is about 20 cm by 2030, and 65 cm by the end of the next century, with significant regional variations. This could have profound flooding implications.

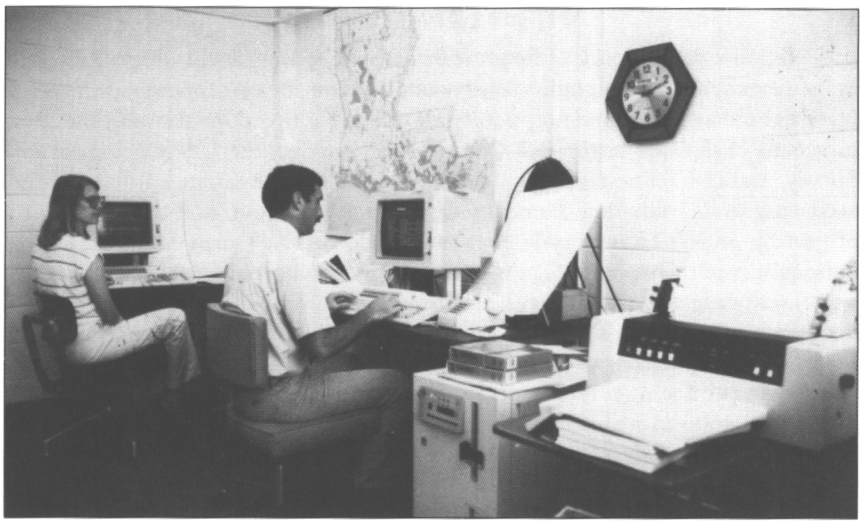
Streamflow Data

Over 90% of the 7,492 daily-record stream gages in the United States are operated by the U.S. Geological Survey in cooperation with a local sponsor. Since the first stream gage was established in 1889, the U.S. Geological Survey network expanded until 1980, but has declined since then, largely due to reductions in funding by local cooperators. This makes spatial and temporal consistency in gathering these data difficult. Even though information about runoff from small watersheds (between one and two square miles) is important for many purposes, including highway drainage design and urban drainage analysis, almost all of the nation's stream gages are located on larger watersheds. To partially fill this gap, the Agricultural Research Service has gaged hundreds of plot-sized watersheds to measure runoff for individual land uses and soils.

Hydrology and Hydraulics

Hydrologic parameters of importance to floodplain management are flood peak flows; flood volumes; time of concentration and travel; rate of rise; water velocities; sedimentation and degradation of flood channels and floodplains; flood elevations; the effect of geomorphology on floods and vice versa; the hydraulics of flood channels, floodplains, and human-made structures; and water quality as affected by floods. These characteristics and their interrelationships are generally modeled mathematically.

Inexpensive, easy-to-use computers have made it possible to apply accepted methods of hydrology and hydraulics analysis to many floodplain management activities. The susceptibility to flooding of small developments and even single structures now can be evaluated relatively quickly and inexpensively. Researchers and a few practitioners are using two- and three-dimensional analyses of flood flows to obtain more realistic and reliable results than those yielded by the step-backwater analysis. Several models and methods are available for mapping the 100-year flood in coastal areas, for determining stillwater flood elevation from hurricanes along the Atlantic and Gulf coasts, and for accounting for the effects of wave heights, wave runup, and marsh grass. Other models address flooding on the Great Lakes, flooding from tsunamis, and other special situations. Sediment transport models are being developed, calibrated, and applied in many areas. All these techniques, which



In recent years, microcomputers have made it possible for agencies and jurisdictions at all levels to use sophisticated hydrologic and hydraulic models to analyze potential flooding at virtually any scale.

Microcomputer workstation at the Floodplain Management Section, Louisiana Department of Transportation and Development.

only a decade ago were very expensive and hence infrequently applied, help evaluate the effects of future urbanization, structures, and other land use changes. Although the computer revolution has improved many aspects of flood hydrology and hydraulics, it has also made possible misuse of the standardized techniques by those not fully aware of the assumptions and limits inherent in the methods.

Flood Forecasting and Warning

Weather forecasting, and hence flood forecasting, is improving with remote sensing capabilities and the availability of more real-time data. New radar equipment, such as NEXRAD, and other tools promise better precipitation forecasts for small-scale storms and flood forecasting for small watersheds. The combination of new satellite data on snow pack and real-time data on precipitation and temperatures may be combined with established runoff models and recurrence interval techniques to produce seasonal flood forecasts.

There are a small number of automated flash flood warning systems throughout the country, notably in Arizona, California, Colorado, Connecticut, Maryland, Nevada, New York, Pennsylvania, and Texas. The performance of these systems has been uneven; most have not been tested under actual flooding situations to determine if they will indeed provide the anticipated level of warning. As the technology improves and operation and maintenance experience is gained, additional automated systems will come into use, significantly reducing the loss of life from flash floods.

Soil Identification and Mapping

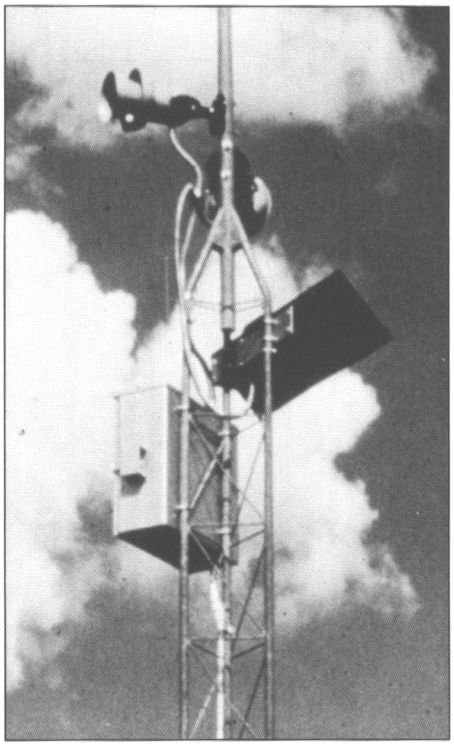
Soil maps and data have proven useful in identifying and classifying floodplains and wetlands. The modern soil survey, with improved techniques and standards, began in the mid-1950s. By 1983, the Soil Conservation Service had mapped and classified about two-thirds of the U.S. land area (except Alaska), or nearly 1.3 billion acres. The Soil Conservation Service expects to complete soil surveys for the entire country by 2000. The agency is beginning to digitize existing soil surveys, and most of the remaining soil survey maps may be prepared with digital methods at the outset. This should improve the level of detail of soil classifications, standardize the map scales, and provide additional supporting information.

COMPUTER MODELS FOR HYDROLOGY AND HYDRAULICS

Computer programs like the Soil Conservation Service's TR-20 and the U.S. Army Corps of Engineers' HEC-1 can be used to mathematically model hydrologic conditions based on such parameters as flood peaks, volumes, rate of rise, and velocity. Other programs in use today are the Soil Conservation Service's TR-55 for small urban drainages and the Environmental Protection Agency's SWMM for urban drainages where water quality is important.

To determine a water-surface elevation for a single point on a stream, the Manning equation is often used and can give good results where normal flow prevails and there are no downstream obstructions. However, when there are obstructions or other special conditions, a backwater analysis is used, and computer models have been developed to perform it as well. The most widely used backwater model is the Corps' HEC-2. A special dynamic routing model has been developed by the National Weather Service for flood routing and inundation from dam breaks.

The NWS also developed the first widely applied model, known as SPLASH, for early mapping of coastal flood zones under the National Flood Insurance Program. A more sophisticated model, SLOSH (Sea, Lake, and Overland Surge from Hurricanes), was developed in 1975 to model flood levels at the coastline for hurricanes of a particular magnitude, forward speed, and track. Today, the Coastal Flooding Hurricane Storm Surge Model is used by the Federal Emergency Management Agency to analyze coastal flood hazards.



Warning siren tied to flood sensors, Lavaca River, near Hallettsville, Texas.

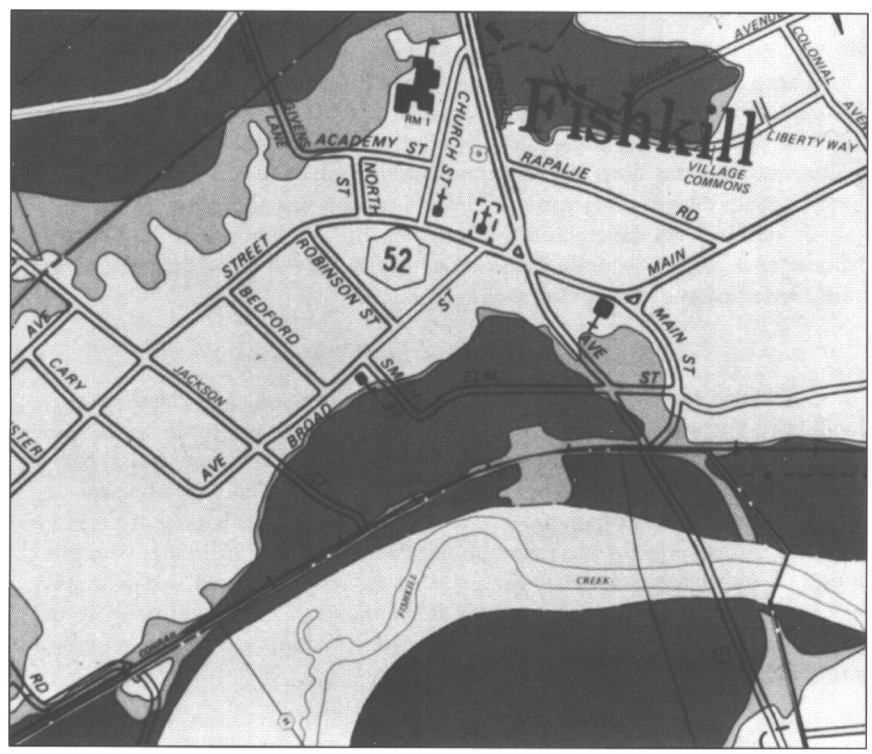
Mapping Flood Hazards

Nationwide mapping of floodprone areas may well be the single greatest achievement in floodplain management to date. Before enactment of the National Flood Insurance Act, floodplain mapping was done through the programs of the Corps, the Soil Conservation Service, the U.S. Geological Survey, and the Tennessee Valley Authority. Each agency mapped floodplains according to its individual authority and primary mission, and often on a project-by-project basis or only after major floods. The Corps compiled a national list of incorporated communities with flood problems and in 1962 began mapping and providing the information to individual communities in floodplain information reports. Mapping of floodplains for the National Flood Insurance Program began in 1968, when the Federal Insurance Administration began producing temporary maps to show approximate boundaries of floodprone areas in identified communities and entered into cooperative efforts with other federal agencies and contracts with private engineering firms to develop methods for preparing more detailed maps. By 1990 more than 12,000 new flood insurance map studies had been initiated and over 1,700 restudies undertaken at a cost of nearly $900 million. In addition to contracting with numerous private firms, the Federal Insurance Administration used the resources of the Corps, the U.S. Geological Survey, the Soil Conservation Service, the Tennessee Valley Authority, the Bureau of Reclamation, the National Oceanic and Atmospheric Administration, the Delaware River Basin Commission and the Susquehanna River Basin Commission, and some states to perform this work.

Twenty-three states fund and prepare their own floodplain maps to complement the National Flood Insurance Program—to provide greater detail or a better scale, to reflect changes in development or hydrology, to extend mapping beyond corporate limits, to meet special requirements, or to cover special natural values. In the past few years, communities themselves have become more involved in mapping, either because of unique floodplain problems or because comprehensive local programs require more specialized mapping. In addition, private consultants frequently perform hydrological or drainage studies for subdivisions and other developments. These studies form the basis for many amendments and revisions to original flood insurance maps.

THE COST OF FLOOD MAPS

The Federal Insurance Administration now spends about $36 million annually to keep published flood risk information updated and current and to provide detailed flood risk data where none existed before. Of this amount, about $4 million annually is spent to distribute about seven million maps to states, communities, lenders, agents, banks, consultants, and others.



The foundation of the National Flood Insurance Program is accurate maps of hazard areas in floodprone communities. The program has been producing such maps since its inception in 1968.

Flood Boundary and Floodway Map of the Fishkill, New York, area.

Understanding and Mapping Wetlands

Since the 1970s significant progress has been made in both scientific and public awareness of the value of wetlands. In 1986 the Environmental Protection Agency adopted a plan of research on ways to create, restore, and enhance wetlands and their functions. National wetlands mapping is being performed by the U.S. Fish and Wildlife Service. The detailed (scale 1:24,000) wetland maps are used by local, state, and federal agencies and private organizations for many purposes, including comprehensive resource management plans, environmental impact assessments, permit reviews, facility and corridor siting, oil and chemical spill contingency plans, natural resource inventories, and wildlife surveys. They show the location, shape, and characteristics of wetlands and deepwater habitats on a U.S. Geological Survey base. Wetlands are classified according to the Fish and Wildlife Service's wetland classification system. Maps have been done for 65% of the lower 48 states and 20% of Alaska. In addition, many states have developed their own wetlands mapping programs.

Understanding Natural and Cultural Resources

As discussed in Part II, the nation's floodplains contain some of its most important natural and cultural resources. A wide variety of data sources now provides information about these national assets. For example, the U.S. Environmental Protection Agency maintains several dozen water-quality-related data bases, and the U.S. Geological Survey compiles extensive natural resources data through its Water Data Storage and Retrieval System and the National Water Data Exchange. Additionally, the U.S. Fish and Wildlife Service, as part of its National Wetlands Inventory, is developing a computerized multidimensional wetlands mapping scheme for the entire country. The U.S. National Park Service has established the Nationwide Rivers Inventory of more than 1,500 river segments and maintains much other data on both natural and cultural resources. NOAA's National Ocean Service and National Marine and Fisheries Service maintain natural resources data in several data bases as part of NOAA's responsibilities as the nation's principal marine science agency. The Soil Conservation Service oversees the National Resources Inventory—a survey of land use and quality, based on 160-acre units across the United States—and the U.S. Forest Service similarly keeps extensive information on lands within the national forest system.

Beyond these federal resources, state agencies, private organizations, and universities also maintain comprehensive data describing many aspects of the nation's cultural and natural resources.

Remote Sensing Techniques

In the past 20 years the availability and analysis of high-altitude photography, satellite imagery, and other forms of remote sensing have increased tremendously. Systematic comparison of images from different times yields information on changes in land use, which can be used to help assess many natural resources and identify areas where future flood damages may occur. After the land uses and natural resources of an area are calibrated, most of the subsequent analysis can be automated. So far these techniques have had limited application in relatively small areas of the nation's floodplains, but technological advances in computer capabilities and data management systems should accelerate the use of remotely sensed data in the near future.

At least one Arizona community uses periodic aerial observations to look for floodplain violations. Aerial photography combined with floodplain maps has been used in some communities to count the number of structures within selected floodplains. Other communities have used or plan to use low-level aerial photography after floods to help determine the extent of flooding and damage. As digital mapping becomes more widespread, it will become easier and more inexpensive to monitor floodplain activities through remote sensing.

Geographic Information Systems

Many organizations now make routine use of geographic information systems (GIS)—computer systems that allow users to collect, manage, and analyze large volumes of spatially referenced and associated attribute data—

HENDERSON COUNTY'S GIS

The Henderson County, North Carolina Soil and Water Conservation District is one of the first in the nation to install a microcomputer-based geographic information system to provide better interpretative soils information. The county's published soil survey has been digitized and stored in the system, and the computer can capture, store, analyze, and retrieve soils maps and other geographic data. Funding for the demonstration project was provided by the Tennessee Valley Authority, supplemented by the Soil Conservation Service and the Henderson County Commissioners.

for a wide variety of purposes, including natural hazards and natural resource management. GIS-generated maps are easily manipulated and can be updated at a low cost. However, GISs have not yet become widely used, mostly because the initial cost of digitizing the needed information for input into a GIS system can be formidable. Another handicap is that the different systems now in use are not always compatible. Once these obstacles are overcome, GIS technology will allow planners and managers to more easily obtain and apply the information they need to make wise decisions about floodplains. The Federal Emergency Management Agency is developing a standard for digital flood insurance maps in public domain format and has committed to a program to digitize the maps for over 340 metropolitan counties with large amounts of property at risk from flooding.

Regulatory and Design Standards

Over the past 20 years numerous standards of terminology, procedure, performance, and quality have been developed in floodplain management. They include both prescriptive standards (clearly identified limits set by law, policy, or custom), and performance standards (requirements that a specified goal be reached by unspecified means). Some of these standards are freely adopted, others are met in response to an incentive, and still others are required by law. Many manuals and technical reference volumes have been developed to assist builders and regulators to meet the performance standards required by the National Flood Insurance Program. Having these standards has provided a uniform means of applying, reviewing, and evaluating the design, construction, and regulation carried out in support of floodplain management.

Not all aspects of floodplain management are amenable to nationwide standardization. There have been no national standards established for minimum setbacks from river channels, although there are some statewide standards for designated streams, lakes, and other water bodies. Lincoln Township, Michigan, for example, requires setbacks of 110 feet from dune and bluff areas on Lake Michigan, while Wisconsin requires a minimum setback of 75 feet from the ordinary high-water mark. There are no national standards for dam and reservoir construction; instead, each federal agency has its own set of criteria. Likewise, each of the three agencies (the Corps, the Soil Conservation Service, and the Bureau of Reclamation) that constructs federally funded levees has its own policies for construction and maintenance.

Judicial Support for Floodplain Management

Over the last few decades the types of lawsuits and the specific issues litigated in floodplain management have changed, reflecting the predominant techniques of the time and general status of the relevant law. Before 1968, most litigation challenged the power of governments to undertake flood control measures and to regulate floodprone lands. From 1968 to 1978 concepts of legal liability expanded and government defenses to it diminished. Constitutional challenges to regulations increased and shifted from broad constitutional attacks to specific challenges to the reasonableness of particular measures. Since then, courts have continued to hold governments liable for their actions that increase flood damages. The number of constitutional challenges to regulations has diminished, however, due to the widespread judicial support for regulations over the previous 20 years. Most recent cases have addressed relatively technical issues, such as the validity of nonconforming use provisions and setbacks.

Constitutionality of Regulations

Floodplain management regulations have been challenged as unconstitutional on two fronts: as violations of due process guarantees and as takings of private property. The due process claims, which were based on a general legal argument that the federal, state, and local governments had no legal authority to regulate activities on floodplain lands and waters, have almost disappeared over the years as the statutory authority to regulate was clarified and strengthened. With the exception of a few cases in which regulations prevented all

AVOIDING CONSTITUTIONAL CHALLENGES TO REGULATIONS

To reduce the chances of having their floodplain management regulations found unconstitutional, many jurisdictions have

- *adopted regulations with stringent performance standards rather than simply prohibiting all activities in hazard areas;*
- *mapped floodplains in more detail and more accurately than has the National Flood Insurance Program;*
- *provided real estate tax breaks for tightly controlled land to diminish the financial burden of owners whose use of their property is greatly restricted;*
- *improved their permitting and record-keeping procedures to include detailed statements of findings on denials in order to provide a better defense in court.*

economic use of floodplain property, courts likewise have upheld the general validity of floodplain regulations against claims that they take private property for public use without payment of just compensation, in violation of the Fifth Amendment to the U.S. Constitution. These rulings are consistent with a much larger body of law in which courts have upheld other land use regulations against claims of taking, despite the impact of the regulation upon property values. Floodplain management regulations have been supported for a number of reasons.

- The rights of private landowners to their water-oriented lands are subject to public trust and navigable servitude rights and interests.
- Courts give great weight to protection of public health and safety and have, without exception, sustained regulations needed to prevent nuisances (such as blockage of flood flows) and to prevent private actions that may threaten public or private safety on other property (such as construction of dams).
- Over the past 20 years courts have upheld performance standards such as the requirements that private landowners protect the floodway's conveyance capacity and elevate or otherwise protect structures to the 100-year flood elevation.
- Courts have supported technically based regulations adopted consistent with a federal, state, or local overall plan and standards (pollution controls or the National Flood Insurance Program, for example).

Liability for Flood Damages

In contrast with the small number of successful constitutional challenges to governmental floodplain management actions over the last 20 years, landowners have won thousands of damage suits against governmental units for causing or increasing flood damages. Most of these have been based on such common law grounds as nuisance or trespass.

There have been more successful liability suits in recent years because

- Large damage awards from juries (and subsequent payments of them by governments with "deep pockets") have made plaintiffs and lawyers more willing to litigate;
- Courts have recognized broadened concepts of public and private landowner responsibility to other landowners and the public;
- The "act of God" defense has diminished as a result of improved flood prediction capability and maps;
- Improved data on stream flow and better hazard modeling have made proof of causation of the damages easier;
- Improved technology, wider use of that technology, and adoption of regulations and guidelines have all raised the standard of "reasonable" actions on the part of government; and
- The "sovereign immunity" defense of states and local governments, and to a lesser extent the federal government, has been modified by statutes and case law, making the governments responsible for more actions and their consequences.

Avoiding Legal Problems

There is little doubt that performance-oriented floodplain regulations (building codes, subdivision regulations, zoning, etc.) will continue to be upheld in the courts despite restrictions that may affect private property owners in some instances. Likewise, carefully crafted flood loss reduction measures will reduce community and state liability in the long run. It is important, however, that governments take care when formulating and implementing these measures to reduce potential legal problems and lessen the risk of constitutional challenge.

AVOIDING LIABILITY FOR FLOOD DAMAGES

There are many actions that state and local governments can take to reduce their potential liability for flood damages:

- *obtaining legal advice before taking anticipated actions;*
- *adopting comprehensive flood hazard plans, because they can avoid liability if they avoid flood hazards;*
- *enrolling in the National Flood Insurance Program, because landowners are less likely to sue for damages if they are insured and thus quickly receive compensation for their losses;*
- *adopting drainage as well as flood hazard reduction plans and regulations (most suits against cities for flood problems are really for damages due to interference with natural drainage);*
- *operating flood loss reduction measures (structures, warning systems) with greater care to avoid claims of negligence;*
- *avoiding hazardprone locations for public facilities;*
- *designing public works—roads, sewers, bridges, and water treatment facilities—to comply with federal, state, and local floodplain guidelines and regulations so they do not block flood flows or cause drainage problems;*
- *undertaking remedial flood loss reduction measures for existing floodprone development, particularly where the problem has been partly the result of government action;*
- *purchasing liability insurance and establishing self-insurance pools.*

The Present and the Future

Overview

It is difficult to assess the effectiveness of floodplain management in the United States. The degree of accomlishment to date is impressive; at the same time, a considerable distance remains between the status quo and the ideal that can be envisioned. Two principal complications are that there are few clearly stated, measurable goals, and that there is not enough consistent, reliable data about program activities and their impacts to tell how much progress is being made in a given direction.

Between 1916 and 1985, there were an average of about 100 flood-related deaths annually; there is no indication that deaths are increasing or decreasing on a per capita basis.

Per capita flood damages were almost 2.5 times as great from 1951 to 1985 as they were from 1916 through 1950, after adjusting for inflation.

The natural and cultural resources of floodplains are being lost at unacceptable rates.

Overall Effectiveness

There is general agreement on three fronts:

- Floodplain management should reduce the number of flood-related deaths in the nation. This goal has been partially achieved. Average annual loss of life from flooding has been somewhat reduced from the level that prevailed early in this century and has remained relatively constant for many years.
- Floodplain management should result in an actual decline in the nation's flood losses, including public and private property damage, injuries, and disaster relief. This has not been achieved. In fact, there was a definite increase in flood damages from 1916 to 1985, although there is evidence that these losses have remained fairly constant over the last two decades when compared to broad economic indicators like the GNP.
- Floodplain management should reduce the loss of the natural and cultural resources of the nation's floodplains. The programs designed to do this have not yet arrested that deterioration.

Achievements to Date

Several significant achievements in floodplain management can be noted, even though all the goals have not yet been reached.

- There is now more widespread public recognition of flood hazards, the value of the cultural and natural resources of floodplains, and the close interrelationship of the hazards and the resources.
- There is an extensive body of judicial decisions supporting floodplain management activities, indicating a perception throughout society that floodplain losses can and should be managed.
- Numerous standards of terminology, procedures, performance, and quality have been developed, providing a uniform means of applying, reviewing, and evaluating the design, construction, and regulations needed for floodplain management, and also providing limited measures of effectiveness.
- In many locales, floodplain development has been prevented or reduced in high hazard areas as a result of mapping and the establishment and enforcement of regulations.
- New development that meets commonly accepted flood-loss reduction standards has experienced greatly reduced losses.
- The institutional framework for floodplain management has been improved through an expanded legislative base, new agencies, and supportive judicial interpretations. There has been a shift away from federal dominance toward a more equal partnership among federal, state, and local governments, and the private sector.
- A considerable amount of floodplain acreage, particularly wetlands, has been preserved by both the public and private sectors.

The Need for Specified Goals

No single piece of legislation or other authority outlines a comprehensive set of measurable goals and objectives for floodplain management in the United States. Floodplain management would benefit from a set of specified goals meant to be achieved by a certain date and whose success can be measured. Numerous national goals have been proposed by various government agencies and observers of floodplain management. Some examples of these suggestions are managing the natural resources of floodplains in conjunction with loss reduction efforts by the year 2000; moving people out of areas where they are continuously threatened by flooding; removing all residences and commercial establishments from the 20-year floodplain by the year 2020 and restoring these lands to their natural state; reducing losses to existing buildings and infrastructure by requiring all federal agencies to assess the vulnerability to flooding of existing federal facilities and those state and local facilities constructed with federal aid; and reducing losses to areas and structures outside regulated floodplains.

The Need for a Comprehensive Data Base

There is a considerable amount of information about floodplain management available, but most of it was not collected with evaluation in mind; thus it is not precise enough to support judgments about the effectiveness of various floodplain management activities. This not only inhibits evaluation, but also hinders legislators, regulators, and other professionals in their efforts to establish, overhaul, or fine-tune programs and strategies to make them more effective. A more complete data base will also give local government leaders a better opportunity to identify the public risks and costs associated with floodplain development.

The obstacles to developing and maintaining an adequate data base are substantial. Important determinations must be made about the type of data to be collected, how often it should be collected, by whom, and using what criteria. Adequate funding must be found.

Additional information should be developed on several important topics, including an examination of the full benefits and costs, both public and private, of floodplain occupancy; an evaluation of the monetary benefits of maintaining the natural uses of the floodplain; and a determination of the steps needed to reduce the potential losses in the areas of the nation with the highest risk of catastrophic impacts from flooding.

The Effectiveness of Management

Although a truly unified national program to manage floodplains is not yet in place, great strides have been made in that direction. The management framework has matured and expanded significantly since the 1960s. The growing recognition of the need for alternatives to federal investments in structural projects for flood loss reduction has been of particular importance. A major improvement was made in 1979, when protection of natural floodplain resources was formally embraced. But the conceptual approach presented in the current *Unified National Program for Floodplain Management* is still evolving. Further improvements could be made in the framework by developing a clear definition of floodplain management and a set of measurable goals. Management efforts in general would be more effective if there were more flexibility for different approaches, smoother coordination among government agencies, and ways to account for local conditions.

Allowing for Different Approaches

Many floodplain losses are of a sort that simply cannot be addressed through a by-the-book approach. For example, management techniques for such high risk flood problems as ice jams, flash floods, coastal flooding and erosion, mudslides, ground failure, alluvial fans, fluctuating lake levels, moveable stream beds, and areas behind unsafe levees or below unsafe dams, are not included in most local programs, which are designed to meet standardized National Flood Insurance Program minimum criteria. New methods for identifying, mapping, and regulating areas with these flood hazards have been developed in some states—particularly in the arid West—through special

GISs AND THE FLOODPLAIN MANAGEMENT DATA BASE

Recent advances in the development and application of geographic information systems can improve the floodplain management data base. With these systems, layers of information, such as that from flood insurance maps, cultural resource maps, and the TIGER data system of the U.S. Census Bureau, can be combined for display, analysis, and management applications.

cooperative efforts with the Federal Emergency Management Agency. This sort of flexible and innovative approach yields more effective management in the long run. Incentives for communities to map and regulate high risk hazard areas are now being provided through the Community Rating System of the National Flood Insurance Program.

Another reason that management flexibility is needed is that the conditions that cause floods do not recognize the political boundaries by which most floodplain management techniques are applied. Many professionals believe that comprehensive management based on hydrologic units must be made a higher priority, especially if natural resources are to be protected. The river basin commissions, the Environmental Protection Agency's National Estuarine Sanctuary Program, and the National Park Service's State and Local River Conservation Program are examples of this technique. To facilitate broader management, the states could enact legislation providing for regional or watershed management, for river corridor management, and for other regional efforts based on hydrologic and other natural boundaries rather than political jurisdictions.

AGENCY AND ORGANIZATION COORDINATION

Positive interagency coordination is exemplified by professional groups like the Association of State Floodplain Managers and the Association of State Dam Safety Officials, and bodies like the Interagency Committee on Dam Safety. Federal, state, and local officials, and representatives of the private sector form the memberships of these groups, and they have brought an important spirit of cooperation and coordination that has been of tremendous benefit to floodplain management over the past decade. They meet formally once a year and coordinate throughout the year through subcommittee work and special projects.

Coordination among Government Agencies

There is more coordination and better cooperation among all levels of government now than there was 25 years ago, but improvements could still be made. Each government agency involved with floodplain management has its own legislative mandate and in general, each has been diligent in carrying out that mandate within the imposed statutory limits. From the standpoint of an overall federal program for floodplain management, however, there are many inconsistencies of purpose and procedure, overlaps, gaps, and conflicts. Some of the inconsistencies can be reduced or eliminated by administrative action, but some conflicts result simply from differing attitudes and expectations about the ultimate responsibility and commitment of resources to respond to flood problems, and these are not likely to be readily resolved. Nevertheless, a spirit of cooperation and common purpose can smooth many conflicts and enhance existing efforts.

Providing for Local Conditions

Prescribing uniform national standards for the preservation, use, and development of floodplains and other hazard areas for application at the local level can be inefficient and result in social inequities. Many of the existing floodplain management tools are more easily applied in communities with fairly high standards of living, where the local government has adequate staff, resources, and expertise. This excludes many small rural communities and economically disadvantaged areas. Natural resource preservation is a bottom priority in low-income communities where a resident cannot even count on the availability of potable water or sanitary facilities during and after a flood. An awareness of local conditions could be incorporated into the national program through wider use of performance standards, provisions of the Community Rating System of the National Flood Insurance Program, and more flexibility in the application of requirements for a positive benefit/cost ratio for federal funding of flood control projects.

The Effectiveness of Floodplain Management Strategies and Tools

Additional accomplishments could be achieved through better or more extensive use of the strategies and tools of floodplain management. Of the four strategies, modifying flooding has traditionally been the most popular because most of the planning, funding, construction, and implementation for structural measures is carried out by the state or federal government, and because local and individual adjustments or sacrifices are minimal. In contrast, many measures to modify susceptibility to flood damages or to modify the impacts of flooding are implemented on a structure-by-structure or property-by-property basis and require constant vigilance, personal inconvenience, and financial sacrifice. These drawbacks resulted in a lack of public support for such measures in the past, and consequently local governments were often reluctant to impose or enforce them. By the mid-1980s, however, this impediment had been largely overcome and local officials began to focus on how to comply with federal and state requirements and administer community programs to manage floodplains. Measures to modify susceptibility to flood damage and disruption and to modify the impacts of flooding are now widely accepted, even though some communities still have difficulty administering them. The strategy of restoring and preserving the natural and cultural resources of floodplains has had little exposure to date and needs to be better integrated with the other strategies, both conceptually and in practice.

Modifying Susceptibility to Flood Damage and Disruption

The tools used for this strategy have enjoyed widespread, fairly successful implementation. Susceptibility to flooding in the United States is constantly being effectively lessened at individual and local levels through the use of regulations, development policies, programs for disaster preparedness and assistance, and warning systems. Evidence indicates, however, that overall vulnerability has either increased or stayed the same, probably because of the large amount of vulnerable development already in place, numerous exceptions to the state and local policies that would reduce that development, and the fact that population growth, movement, and urbanization sometimes take place so quickly or in such unexpected ways that adequate planning and regulation simply cannot be established soon enough to prevent unwise use of floodplain areas. This strategy may have the most potential for widespread future use, however, because its tools can be coordinated well with other strategies and because it provides an ongoing, more enduring way of adjusting to the flood hazard—that is, altering human behavior usually before the losses occur.

Improvements could be made in the implementation of this strategy by

- improving the enforcement of floodplain regulations by local governments;
- reducing the usually unfounded concern of local and state officials that strict floodplain regulations will be challenged as unconstitutional takings of private property;
- minimizing flood damage to existing infrastructure and properly designing and regulating future infrastructure that must be located in or near the floodplain; and
- ensuring that current disaster assistance policies do not undermine long-range floodplain management efforts.

Modifying Flooding

National efforts to modify flooding have probably been more successful than those directed toward any other strategy. The approach of controlling floods is older than the other strategies, and over the course of five or six decades countless floodprone situations have been alleviated with structural measures.

There is increasing recognition that the strategy of modifying flooding can be counterproductive in at least two ways. First, it has been suggested that the creation of structural protective works encourages development in the

REDUCING LOSSES THROUGH WARNING SYSTEMS

Annual flood damages in the Connecticut River Basin were reduced by $750,000 with a flood warning system that cost about $250,000 annually.

FLOOD CONTROL INVESTMENT AND RETURN

The federal government spent over $13 billion for dams and other flood control structures between 1936 and 1975. About $360 million had been expended on shoreline protection studies and projects by 1985. In return for these investments, billions of dollars in property damage have been avoided and hundreds of thousands of people have been protected from anxiety, injury, and death.

"protected" area, resulting in increased vulnerability, perhaps not to the design flood, but to larger ones or to unforeseen catastrophic events like structural failure. Second, structural measures can have adverse impacts on wildlife habitat, scenic resources, and water quality, thus undercutting other floodplain management strategies.

Partly as a result of these concerns, there has been a considerable shift away from reliance on structural solutions since the early 1960s. The planning and installation of measures to modify floods, however, have not been abandoned. Flood control projects are still needed to complement the application of other floodplain management strategies, particularly to protect existing development.

There is an opportunity now to reformulate this strategy to acknowledge its relationship to other techniques. Some of the tools to implement this strategy, such as land treatment measures, on-site detention, and shoreline protection, can be important components of comprehensive floodplain management and resource protection programs.

Modifying the Impact of Flooding on Individuals and the Community

The impacts of flooding on individuals and communities have definitely been modified over the last 25 years, largely through increased awareness of flood hazards as a result of the provision of information and education, and because of the availability of flood insurance. After many years of counterproductive effects, two of the tools for this strategy have recently undergone basic revisions that may make them more effective at reducing future losses: tax adjustments for flood losses have been reduced, and postflood recovery measures designed to minimize future losses have been determined to be an appropriate use of disaster assistance funds.

The implementation of this strategy could be improved by

- expanding individual awareness of and knowledge about floodplains;
- improving training programs for code administrators, planners, inspectors, public works directors, and other local government personnel directly involved in floodplain management;
- enlarging the premium base by increasing the number of insured structures, and thereby moving the National Flood Insurance Program closer to a fully actuarial basis; and
- ensuring that postdisaster mitigation funds are used completely and creatively.

Restoring and Preserving the Natural and Cultural Resources of Floodplains

As the latest addition to the array of floodplain management strategies and the one least well-integrated with the others, it is not surprising that this strategy has met with limited success. Floodplain land is being preserved in a limited way through acquisition, public understanding and support for preservation and restoration of natural resources is growing, and mapping of the nation's wetlands is more than half finished. These accomplishments, however, have been the result largely of programs, policies, and efforts outside the floodplain management arena. Regulations to protect and manage natural resources in general are not well coordinated with those to reduce flood losses, resulting in conflicts when implementation and enforcement are at stake. The strategy itself needs to be better integrated both with other floodplain management tools and strategies and with compatible efforts in other fields, such as river corridor management, endangered species protection, and nonpoint pollution control programs.

THE EXTENT OF THE NFIP

As of 1990, 82% of the nation's 20,000 floodprone communities had joined the National Flood Insurance Program. In 1990, 2.39 million flood insurance policies were in force, providing over $200 billion in coverage. From 1978 to 1989, over 384,000 flood damage claims had been paid, totalling about $3.1 billion.

PROTECTING RIVERS FROM ALTERATION

As of 1990, 9,351 miles on 123 of the nation's rivers had been designated as wild or scenic, and therefore protected under federal law. But these protected stretches are greatly outnumbered by the stream segments that would be altered by proposed dams, channel modifications, and other projects.

The restoration and preservation of floodplains as natural resources is largely the result of efforts that are not well coordinated with the principal programs of floodplain management.

Floodplain, Wildcat Falls, Joyce Kilmer Memorial Forest, North Carolina.

Conclusion

Over the past 25 years, floodplain management has matured from a focus on reducing flood losses by using structural measures to a broader approach that incorporates structural and nonstructural measures for flood loss reduction and also takes into consideration the protection of the natural and cultural resources of floodplains. The examples of flood damages averted, lives saved, and resources preserved are plentiful. It is evident that substantial progress has been made, and that diligent work is underway to remedy past shortcomings and reach even greater levels of achievement.

If current trends continue, the near future will see a further broadening of the scope of floodplain management to encompass such activities as stormwater management, greenway and river corridor management, and watershed management. Further integration of individual strategies and tools is likely, so that a more unified floodplain management program can emerge, with fewer conflicts among goals and activities. Technological advances also promise the improved application of existing strategies and tools.

A number of important opportunities are emerging for improving the future effectiveness of floodplain management in the United States. This report on the nation's floodplain management activities—the first comprehensive assessment in over 25 years—has identified a plethora of actions to be pursued if significant improvements are to be made in floodplain management in the coming decade. Of these, two stand paramount: a simplification of the concept of floodplain management, and a set of specific national goals with a timetable for their achievement. These two needs should be addressed as the Federal Interagency Floodplain Managment Task Force undertakes to further refine the *Unified National Program for Floodplain Management*.

INTEGRATING FLOOD LOSS REDUCTION AND NATURAL RESOURCE PROTECTION

Most local flood loss reduction programs focus primarily on the 100-year floodplain, while natural resource protection programs focus on a particular resource (wetlands, for example) which may or may not be located in the floodplain. The two types of programs also are triggered by different events. Disaster relief is provided after a flood; a section 404 permit is required when dredging or filling is planned; a wild and scenic river study begins after Congressional action. These basic differences make integration of the programs difficult.

Retrospect and Prospect

—an invited comment by Gilbert F. White

This Assessment is unprecedented in its depth of analysis of the nature and effectiveness of the nation's management of floodplains. It is the most detailed and nearly comprehensive of all studies of those matters since the concept of floodplain management took official root in the mid-1960s. It places that concept in a broader context than ever before, and it provides a base for launching a series of steps to assure that local and state as well as federal programs can at last approach the aspirations that have evolved over the past 65 years.

That evolutionary process has been reflected in a stream of laws, executive orders, regulations, new groups, and reports. Debate over the wisdom of reliance on simple levees and channel modifications began in the wake of the 1927 flood on the Lower Mississippi. It widened to include issues of dams and economic justification after the Ohio River floods of 1936 and 1938 and a concurrent upstream versus downstream controversy over land treatment. By 1966 a still broader view of the potential role of nonstructural measures found favor. Then followed a series of revisions and expansions of federal and state activities. Those included the National Flood Insurance Act of 1968, a National Science Foundation appraisal of flood research in 1977, a *Unified National Program for Floodplain Management* in 1976, with revisions in 1979 and 1986, three Executive Orders, a formal linkage with emergency management programs, and the organization of vigorous nongovernment groups such as the Association of State Floodplain Managers and the Association of State Wetland Managers. All of this and much more is examined in the Assessment. To sum up, the report tells the country what has been happening in floodplain management; how well or how poorly the responsible federal and state agencies have been doing; and what are promising means of improving the prospect. The result is the first thorough appraisal of ambiguous national aims and how those compare with the present situation on the lands at risk—the diverse areas of watercourses, adjacent wetlands, and the shores of streams, lakes, and oceans.

The report candidly recognizes the severe handicaps of incomplete and inconsistent collection of data on which policy judgments must be based. The data base is the one need specified in the 1966 House Document on which almost no action has been taken.

For other needs, the record of change has been diverse but generally positive. In no instance, however, has achievement matched the hopes of earlier years. The definition of precisely what is meant by floodplain management in particular areas of the country or under the jurisdiction of specific agencies is still far from clear or uniform in either principle or practice. The policy goals for the sustainable use of floodplains have progressed in agency thinking but are proving difficult to meet in operation in the field. It has not been made clear how floodplain use is inseparably linked to the maintenance of natural resources for the common good for the foreseeable future. The effectiveness of individual federal and state programs, each with a different statutory authority, suffers thereby.

Cooperation among the administrators of federal programs, while generally cordial and helpful, has not yet yielded a genuinely unified effort. Lacking exemplary effectiveness at that level, state and local agencies cannot be expected to act in concord in meeting national goals.

Great gains have been made in public information and education. Far more legislators, administrators, business executives, farmers, householders, and school children are aware of flood hazards than a decade ago. The level and quality of information, however, still is far below what would be required to induce effective action in the event of a threatening flood, and even more so in the days when measures are needed to mitigate future emergencies.

Flood forecasting precision has generally improved. The demonstrated ability of communities to respond positively to a warning is less certain and is uneven.

The report suggests lines along which improvement can be brought about and recommends consideration of a number of changes in policy and procedure. The report's Review Committee does likewise with its *Action Agenda for Managing the Nation's Floodplains.* These must be examined now against the background of experience with previous statements of optimal floodplain policy, such as House Document 465 or the *Unified National Program for Floodplain Management.* Only fragments of those proposals were adopted. Can anything be learned from the conditions that either promoted or blocked them? What are the factors in climate of public opinion and in government organization that worked for or against them at that time and that may have changed subsequently?

It is evident that the reconciliation of thinking among professional groups, for example, has been advanced by research, conferences, training, and publications. Hydrologists, engineers, geographers, economists, land planners, ecologists, city managers, insurance executives, and disaster relief directors, among others, now are speaking the same language. But there are at least three directions in which lessons learned are still not practiced.

One important lesson is that quick and nation-wide change in procedures without careful trial in selected areas and without subsequent critical appraisal can be counter-productive. When the Tennessee Valley Authority established its community assistance program for flood damage prevention planning in 1953 and the Corps of Engineers introduced its floodplain management services program in 1960, they moved cautiously and employed a variety of trial approaches. In contrast, when national flood insurance was introduced in 1968 there was a brave commitment to offer coverage to all parts of the country at once. Little attention was given to post-audits of the rates, terms of insurance, map adequacy, and relation of detailed regulations to local physical and social conditions. As a result, the Federal Insurance Administration found itself locked into sometimes unwieldy or ineffective procedures that might well have been avoided in the light of experimentation. The attempt in the late 1970s to set up a nation-wide floodplain map file was likewise an unfortunately hasty enterprise. In its 23 years of operations, the National Flood Insurance Program has achieved much and continues to gain new experience. The current implementation of the Community Rating System now offers special opportunities to appraise the suitability of national standards and procedures at the local level. As new improvements are made in federal programs, it will be important to craft them on an experimental basis with careful provision for evaluation as they are launched.

A second lesson derives from the contrast over the years between expressions of desirable unified policy and measures to, in practice, unify the activities of agencies which in theory subscribe to the policy. There has been neither a single statement of Congressional intent with respect to floodplain management similar to the Earthquake Hazards Reduction Act of 1977, nor a delegation to a single executive agency of responsibility for coordination of the various federal programs. The Bureau of the Budget was interested in such coordination in the mid-1960s but did not take a strong hand. The Water Resources Council served as a meeting place of interested agencies without having statutory authority. After the council disbanded in 1982 it was followed by the Interagency Task Force, a voluntary group that also lacked authority to enforce desirable action as outlined in three Executive Orders. It cannot be expected that conscientious administrators will abandon their own statutory authority and responsibility before joining cooperative ventures, no matter how desirable the goals. It is just as clear that unless a strong statement is made by the Congress on the ways in which the basic policies of the individual federal agencies are to be related to the underlying aims in managing floodplain resources, those policies will have little significance in the field, where they influence or are constrained by state and local practices.

The third major lesson is that floodplain policy changes must be taken in the context of broad environmental goals applied to local conditions. This was the case in the unfolding of the Coastal Zone Management Act where four federal agencies have joined in a partnership for action on habitat protection, nonpoint source pollution management, and sediment control. It occurs in the implementation of soil conservation programs on lands where environ-

mental integrity must harmonize with economic considerations. It is acutely the case in the delineation of wetlands, where the rigidity of proposed national criteria confronts wide variety in interpretation of suitable floodplain use. Coastal erosion raises similar issues. The reconciliation of multiple and sometimes inconsistent national goals is an endemic problem in resource management. It can only be achieved effectively by dealing with particular landscapes in particular regions. When national goals shift or are clarified, as they surely will, the complexity increases. Unless floodplain management practices take into account local food and fiber production, biota, water supply, urban land use, recreation, and more—in addition to flood loss reduction—the goals for maintaining the sustainability of floodplains will surely not be met.

Experience over the past 25 years suggests that to help achieve the improvements in prospect will require a willingness to test and appraise new programs, a Congressional definition of unified federal policy, an executive decision to assure the coordination of the federal agencies, and a commitment by representatives of the principal state, local, and nongovernment groups to collaborate in adapting national aims to local conditions where the benefits will be seen—on the borders of the nation's rivers, lakes, and coasts. Without these measures, the resources of those areas will remain unduly vulnerable to natural extremes in stream flows and tides, and the people of this nation will receive less than optimal benefits from floodplains' amenities, soil, water, and biota.

Gilbert F. White has been observing the nation's floodplains for over 50 years. He is a Distinguished Service Professor Emeritus of Geography and the founder and former director of the Natural Hazards Research and Applications Information Center at the University of Colorado. He was chair of the Task Force on Federal Flood Control Policy, 1965-66, and of the National Review Committee established in 1989 to assist in carrying out the assessment summarized in this volume.

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Back cover:
Illustration of some flood consequences and floodplain management measures. Clockwise from top: 1. Flood water detention. 2. Regulations and development policies. 3. Information. 4. Coastal protection. 5. Flood emergency measures. 6. Natural protection systems. 7. Preserving natural resources. 8. Mapping flood hazard areas. 9. Structural elevation.

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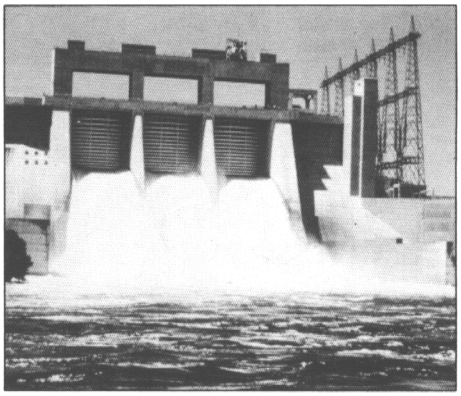

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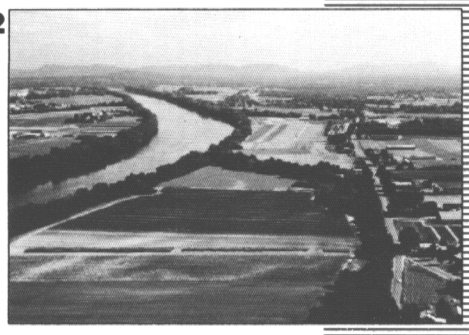

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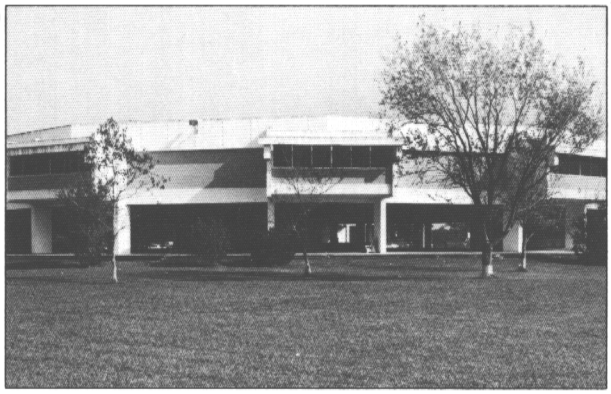

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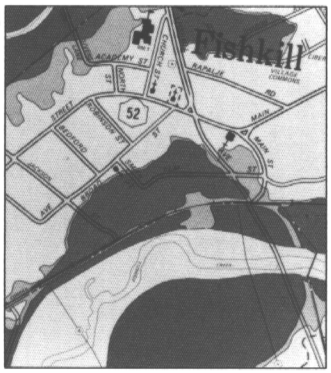

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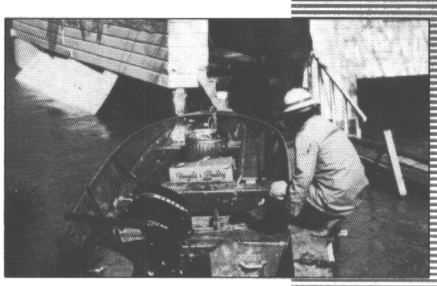

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FEDERAL EMERGENCY MANAGEMENT AGENCY

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