Flood and erosion-damaged road, St. Augustine, Florida.

Photo by Jon Kusler.

land. Federal investment in roads, sewers, water supply systems, and flood insurance has encouraged and helped finance this growth.[43]

Despite the severity of flood hazards in wave action areas, floodplain regulations have been only partly effective. FEMA flood maps did not reflect wave elevations and erosion. State regulations for such areas were virtually nonexistent until the mid-1970s, even though state regulation of inland flood hazard areas was widespread. Most of the 188 local governments with jurisdiction over barrier islands adopted minimum NFIP regulations, but the regulations did not cover wave heights or erosion. State programs lacking technical assistance capability limited the effectiveness of local programs. Flood insurance subsidies were also high in wave zones, which may have encouraged private development.

FEMA is now developing new maps and individual ratings for structures in velocity areas. However, it will be at least several years before revised maps are available for most of the coast.

Hurricane Frederic pointed up the seriousness of flood problems for coastal velocity zones and the inadequacy of existing maps and standards.[44] A modest-sized storm, Frederic seriously affected about 50 sparsely populated miles of the nation's 58,200 miles of coastline. A combination of storm surge, waves, wind, and erosion damaged or destroyed approximately 1,500 structures, with losses exceeding $2 billion. Wind and waves destroyed 80% of the 500 structures in the first tier along a 20-mile barrier spit from Fort Morgan to Gulf Shores, Alabama. Many had been elevated to the 100-year flood protection level, but that elevation did not account for wave heights on top of the standing water. Consequently, many houses were swept off their pilings. Much of the dune system was also destroyed. Shoreline erosion averaged 45 feet inland along the Gulf side of the western two-thirds of Dauphin Island and 76 feet along the Mississippi sound side.[45] Erosion was particularly

severe where driveways, drainage channels, boat channels, and marina entrances acted as conduits for flood water. House supports (even where houses were built on pilings) increased turbulence and accelerated erosion.

Hurricanes of this sort are not freak events. On the average, two hurricanes strike the mainland United States each year, with the likelihood of one hitting Florida every 1.5 years.[46] One hundred twenty-nine hurricanes have struck the Atlantic and Gulf coasts since 1900. Fifty-three had winds of at least 110 miles per hour. The two deadliest killed 6,000 in Galveston in 1900 and 1,500 at Lake Okeechobee, Florida, in 1928. The fact that a major hurricane has not struck the Florida or Atlantic coast in the last 20 years has led to unwarranted optimism.

Although velocity zone damages are often the most serious, problems with coastal development are not confined to this zone. Backlying lands one-half to several miles inland along the mid- and south-Atlantic and Gulf coasts are often flooded three to eight feet by a 100-year storm. These areas are also subject to much greater wind velocities (75 to 150 miles per hour) and combined wind and water damage than are comparable riverine properties for a similar 100-year flood. Winds and the rapid rise and fall of hurricane-driven flood waters increase wave heights and water velocities, although backlying areas do not technically qualify as wave velocity zones. Regulations have been adopted for most coastal areas, but most do not protect against high velocity winds or waves.

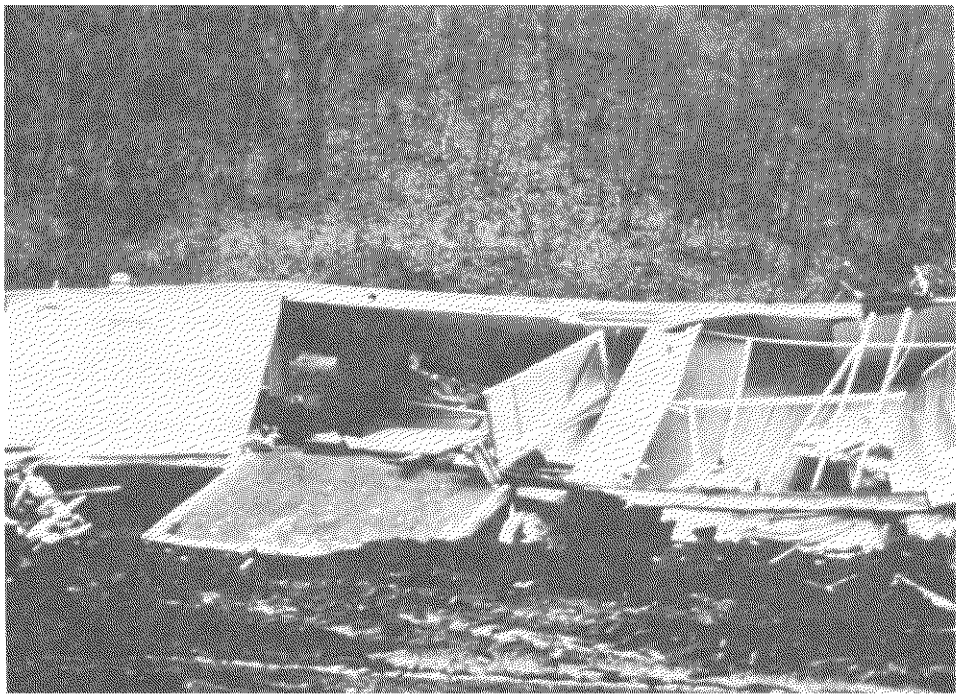
Inland Areas

Floodplain management in the 1970s was more successful in inland areas where the combined threat of wind, water and erosion was less serious. Development could be shifted to upland sites in many instances; the demand for waterfront sites was not as strong. Relatively permanent

adjustments such as elevation on fill were more successful than in coastal areas that are eroded by high velocity water. Many states adopted strong floodplain regulations. Moreover, many communities have adopted their own aggressive and innovative floodplain management programs. The concept of a "floodway" linked to the prevention of damage to upstream and downstream landowners had broad-based political and legal acceptability. Structural solutions and relocation also proved practical in many situations.

Despite the greater success of inland floodplain management efforts, problems with implementation also arose in some areas. Approximate flood maps that failed to provide the 100-year flood elevation and floodway boundaries were the only maps available for most rural and urbanizing areas where much of the new development occurred. Some local governments lacked sufficient expertise to administer regulations, particularly in rural areas. Only a portion of the country had state floodplain programs with strong technical assistance capability. Development in upstream areas often substantially increased flood heights in downstream areas, particularly in urbanizing watersheds.[47] The possibility of federally funded flood control measures discouraged communities from adopting stringent floodplain regulations.

Lack of specificity in measures for inland flooding was also a problem. NFIP standards and those of most states have been quite successful for low-velocity and moderate-duration flood areas located along major rivers and streams. The single-district and two-district ordinances developed for Volumes 1 and 2 of Regulation of Flood Hazard Areas, were designed for these areas. However, for inland areas with unique flood characteristics application of these standards and models has caused problems.



Mobile home destroyed by flooding at Buffalo Creek, West Virginia.

Photo source: The Federal Emergency Management Agency

Flash flooding and high velocity flows. High gradient streams with rapid flood flows and, in some instances, flash flood characteristics are found in all areas of the nation, but they are concentrated in the mountain states. The National Weather Service (NWS) has identified at least 2,500 communities with flash flood problems.[48] Particularly serious flash floods occurred in Rapid City in 1972 and Big Thompson Canyon in 1978. The two floods killed 372.

The regulations established by the NFIP and those proposed in Volumes 1 and 2 were partially unsatisfactory for such areas. Floodway modeling that assumes subcritical flows was not satisfactory for high velocity or supercritical flows. These areas needed much stricter regulations to deal with high velocities and flash flood conditions. Unfortunately, no manuals or ordinances have been developed for high velocity or flash flood conditions.

Long duration flooding along lakes and ponds. Long duration flooding occurs along major lakes with fluctuating water levels such as the Great Lakes and also around thousands of smaller lakes and ponds fed by groundwater. Regulations developed for riverine areas that permit elevated development in areas subject to short duration flooding have proved inadequate for these areas, since most structures on pilings will be damaged or rendered useless if surrounded by water for months or years. For example, once flood insurance became available, Lake Elsinore, a community along Lake Elsinore in California, amended its floodplain regulations to permit buildings elevated on pilings to the 100-year flood protection elevation, as permitted by the NFIP. Previously it had prohibited development on ground below the elevation of fluctuating lake levels. After basinwide rainfall caused long-duration flooding in 1979, elevated structures were isolated and rendered unusable. In many instances, the water and waves gradually destroyed them. Because of

this problem, the community again tightened its regulations and prohibited development except where the land surrounding the structures was above the 100-year flood elevation.

Flooding behind dikes and levees. Regulations have been difficult to enforce in areas that have levees and dams to protect from a 100-year flood. Landowners often believe they are protected, so they oppose regulation, unaware that inadequate drainage causes flood problems in such areas. When a flood exceeds design capacity, damage to backlying areas can be catastrophic. For example, $500 million in damages occurred along the Pearl River in Jackson, Mississippi, when flooding overtopped levees, inundating backlying areas to the full heights of the flood.

Flooding along small streams and drainageways. Floodplain mapping and regulations in the 1970s focused on the floodplains of larger rivers and streams. However, substantial urban and metropolitan flood damages were caused by flooding along smaller creeks and streams. Urbanization also increases peak flows. Adequate watershed mapping and programs that combine floodplain regulation and stormwater management are rare.

Alluvial fans and mud flows. Flood mapping and regulation for riverine areas have been only partially applicable to areas built on alluvial fans or those subject to mud flows. In these regions, a traditional floodway concept does not apply and elevation requirements make little sense if the force of the flow will destroy pilings or the lower floors of structures. Alluvial fan flood problems occur in the canyon areas of the West and Southwest. Rather than following a well-defined course, flood waters exit the canyons through many small, rapidly shifting channels. Flash flooding is common, and flood damages are often compounded by severe erosion.

Mud flows are caused by unstable, supersaturated soils. The great force of the moving mass makes mud flows particularly damaging. The cost of cleanup is very high since mud must be mechanically removed.

FEMA and the Corps are trying to address alluvial fan and mud flow problems more specifically, but maps and regulatory standards tailored to these special needs are still needed.

Program Problems

Although problems with implementing state and local floodplain management in the 1970s have varied, most programs have the following difficulties.

Federal efforts focus on urban areas. Most NFIP floodplain mapping and technical assistance has focused on urban areas that have the most existing flood-prone uses and the greatest potential for flood insurance. The NFIP has paid much less attention to rural and urbanizing areas where the opportunity for guiding future uses is greatest.

Existing uses. The 1970s demonstrated that floodplain regulations are least effective in reducing losses to existing uses, unless the uses are destroyed or very seriously damaged by floods.[49] For developed areas, even after a severe flood, pressures for rebuilding are often so great that communities permit redevelopment without flood protection measures. Regulations have not effectively controlled repair of damaged buildings.

Untested floodproofing measures. The long-term adequacy of many structural floodproofing measures for commercial, industrial, and residential buildings is questionable.[50] Preliminary surveys after actual flooding show that total waterproofing from even low levels of inundation (2 to 3 feet) is difficult. Structural floodproofing is particularly vulnerable to large floods, waves, and high-velocity flows: few structures can withstand the force of a three-foot breaking wave. In

addition, temporary floodproofing measures such as emergency doors are likely to be placed incorrectly or become inoperative. Long-term losses are also likely when flood adjustments are used such as elevation on wooden pilings which may deteriorate over time.

Flood maps underestimate hazards. Flood maps often underestimate the elevation and severity of actual hazards.[51] This problem is particularly serious in coastal areas where wave heights and combined erosion and flood hazards are not considered. At some points along the coast with steep offshore water depths and high waves, the 100-year elevation shown on FEMA maps may be reached annually or with a 5- to 10-year recurrence interval. Flood velocities, erosion, and duration of flooding are also inadequately considered in some inland areas. Because urbanization of watersheds greatly increases flood flows, flood maps become quickly obsolete.

Activities with severe flood damage potential are unregulated. Regulations that require elevated or floodproofed structures often do not apply to public works such as bridges, roads, sewer systems, and water supply systems that must be constructed to serve these areas. Increased and repetitive flood losses to these works result. Location of hospitals and low income housing in hazard areas threatens public safety.

Placement of hazardous items such as gasoline and propane tanks is also often inadequately regulated. These may cause fire and pollution during floods and injury to rescue workers. If inadequately anchored, they may also break free and lodge in bridge openings, obstructing the flow of flood water.

Mobile homes and mobile home parks are common in the floodplain and are subject to severe flood damages. Mobile homes often break free from their foundations and lodge in bridge openings or crash into other