CHAPTER II

ADJUSTING FUTURE USES

Overview

Floodplain regulatory programs in the 1970s were designed primarily to guide the future use of undeveloped floodplains in order to reduce flood losses. Other goals included protection of natural resources, protection of the tax base, and implementation of federal, state, and local comprehensive land and water management plans. The overall objective was "wise" or socially beneficial use of floodplains in light of their values and special hazards.[1]

Regulations in the 1970s were most effective in establishing minimum flood protection elevations and guiding development away from rural floodplains where land values were low and where alternative building sites were available. In urban and urbanizing areas, they also effectively protected floodways, dunes, wetlands, and other critical areas. They guided "infilling" of partially developed areas and redevelopment. By guiding future development, regulations reduced future flood losses.[2]

Regulations to guide future uses differed from state to state and community to community. Nevertheless, they were remarkably similar in one respect--almost all required protection of new structures to the 100-year flood elevation where flood studies or maps that included this elevation were available. All state floodplain regulatory programs adopted the 100-year standard for mapping and regulation during the 1970s. The National Flood Insurance Program and the Floodplain Management Executive Order adopted the 100-year standard. Most federal maps applied the standard.

Two approaches were applied at state and local levels to require protection of structures to the 100-year flood elevation. The most common

required elevation of residential structures on fill, pilings, or other open works and (alternatively) elevation or floodproofing of commercial and industrial buildings. The second prohibited new structures or reconstruction in the 100-year floodplain.

The first approach, taken by the NFIP and most state and local programs, allowed for a balance of flood loss reduction and development needs in areas with broad floodplains. It was most widely applied in Atlantic and Gulf coastal areas and along major rivers and streams. Regulatory standards prohibited fill and structures in floodway, wave velocity, and dune and mangrove areas where these activities would increase the 100-year flood elevation or flood velocities on other lands. Storm drainage measures were also commonly required.

Despite its advantages, this approach rarely led to substantial reduction of floodplain development.[3] Problems, which are discussed below, also arose in defining 100-year flood elevations and in requiring adequate floodproofing of buildings. Moreover, the roads, sewers, and water supply systems that had to be extended to serve new flood fringe development increased total public flood losses. To be effective, implementation of this approach required detailed flood maps and technical expertise to evaluate floodproofing measures, flood heights, velocities, and other matters.

Hundreds of communities applied the second approach--one that prohibited all new development in the floodplain. This was most commonly used in areas with steep topography and narrow floodplains and in rural areas with low land values. The purpose was to prevent gradual increases in flood heights and velocities caused by the elimination of flood storage and encroachment in floodway areas and to reduce flood losses to costly public works such as roads, sewers, and water supply systems. It provides a measure of safety against uncertainties about the long-term effective-

ness of floodproofing measures. It protects resources and supports broader community land management objectives. Moreover, it can be applied with relatively imprecise flood data and low levels of expertise. However, it more often encountered political problems.

A combination of the two approaches was applied by thousands of local governments and many states. They prohibited all fill and structures in floodways and coastal areas, but permitted some fill and structures protected to the 100-year flood elevation in fringe areas. The restrictiveness of this approach depended on the definition of floodway, as discussed below.

Although the 100-year flood protection elevation requirement was used by much of the nation, the specifics of community regulations differed based upon community preferences, state standards and available flood data. NFIP requirements for state and local regulations varied according to the type and amount of information provided in its flood maps. Communities were required to upgrade regulations within six months of receiving upgraded flood data from the NFIP.

Problems in Implementation

Regulations were least effective in the 10,800 communities (as of January 1981) in the emergency program of the National Flood Insurance Program. Many of these communities have adopted only a resolution indicating their intent to adopt more detailed regulations in the future or a preliminary ordinance requiring building permits and general subdivision review. The legal sufficiency of the resolutions to control new development is questionable in some jurisdictions.[4] In addition, most emergency program communities lack adequate maps and staffs.

Regulations were more effective at the state level and in the 6,300 larger communities enrolled in the regular program of the NFIP. Three to four thousand more are expected to enter the regular program in 1981-1983.

TABLE 3

TECHNIQUES TO REDUCE LOSSES TO FUTURE DEVELOPMENT

Adoption of floodplain regulations to guide new development away from floodplains or floodways or require elevation or floodproofing of structures

- Zoning
- Subdivision controls
- Building codes
- Special codes

Planning of public facilities, roads, sewers, and water supply systems to avoid floodplains, to provide for elevation of facilities, etc.

Floodproofing of new structures

- Elevation on fill or open works
- Temporary or permanent waterproofing
- Wet floodproofing
- Structural design elements
- Water resistant materials

Emergency evacuation

- Flood forecasting
- Flood warning
- Evacuation procedures

Acquisition of undeveloped hazard areas

- Fee (purchase, donation, exchange)
- Easements
- Transfer of development rights

Education

- Floodplain mapping
- Flood warning signs
- Workshops
- Distribution of pamphlets, newspaper articles, etc.

Preventing increases in stormwater runoff

- On-site storage requirements
- Regulations protecting flood storage areas

Resource protection and management regulations with hazard mitigation standards

- Wetland
- Dune
- Coastal setbacks
- Agricultural and forestry zoning
- Performance zoning

TABLE 3 (continued)

Tax incentives

- Preferential assessment of real estate in hazard areas pursuant to open space tax statutes
- Income tax incentives for bargain sales, donation of lands to public agencies, non-profit corporations
- Estate and gift tax incentives for donation of lands to public agencies, non-profit corporations

Flood control measures

- Dams
- Dikes, levees, seawalls
- Channel modifications

A community must enter the regular program within six months after FEMA completes a flood insurance study, which includes a map showing 100-year flood elevations, or the community's participation in the program will be suspended. A community qualifies for additional flood insurance upon entry into the regular program. It also must upgrade its regulations.

States and communities in both phases of the program encountered the following problems in reducing flood losses to future uses:

- NFIP and community criteria for defining the 100-year flood protection elevation sometimes underestimated hazards by failing to recognize wave and erosion hazards, changing watershed conditions, and other related factors.
- Flood maps defining 100-year floodplain boundaries and the 100-year flood elevation were available for only a portion of the nation.
- NFIP criteria for defining floodways (i.e., one foot of backwater effect) increased flood damages.
- NFIP criteria for defining coastal high hazard areas were inadequate in some instances. Few coastal high hazard zones have been mapped.
- Regulations failed to provide adequate protection for dunes and wetlands.
- Few floodplain mapping and regulatory standards were adequate to meet the combined needs of flooding and stormwater management in urbanizing areas.
- Methods for protecting structures to the 100-year elevation were subject to limitations.
- Federal subsidies for some flood control works and flood insurance undermined nonstructural floodplain management.

These problems and ways states and communities addressed them are discussed more fully below.

Inadequacies of the 100-Year Flood Protection Elevation

Most states and communities adopted the minimum NFIP standards for protection of structures in flood fringe areas. The NFIP requires that new structures in coastal and inland fringe areas either be elevated on pilings or fill or be floodproofed to the 100-year flood protection ele-

vation. Residential uses are to be elevated on pilings or fill.[5] Commercial and industrial uses can be either elevated or floodproofed.

During the late 1960s, the NFIP selected the 100-year flood as the basis for regulation because it was considered a "middle-of-the-road" approach to balance potential damage against the costs of protection. NFIP studies during the 1970s showed that elevation to the 100-year flood level was, in general, cost-effective for landowners.[6] Despite some controversy, states and localities also accepted the 100-year elevation as a general standard, but permitted some structures such as those for agricultural storage at lower elevations and required higher elevations for particularly sensitive or dangerous "critical uses" such as hospitals or nuclear power facilities.

Two problems were encountered in applying the 100-year standard: lack of agreement on criteria for establishing the 100-year elevation and lack of agreement on the most appropriate flood protection measures based upon this standard.

The first problem concerned assumptions in calculating the 100-year elevation. The NFIP decided to use existing watershed conditions to calculate the 100-year elevation because future watershed conditions are difficult to predict and FEMA had concluded that flood insurance rates must be calculated according to existing, not future hazards. One hundred-year surge elevations were calculated for coastal areas without consideration of wave heights because at first the method of determining wave heights was technically questionable and because strong political pressures opposed using such heights since they may add 50% or more to the 100-year flood elevation. These criteria and guidelines were challenged by some states and localities.

Basing flood protection measures on particular 100-year flood elevation criteria was also challenged. One study pointed out that per-

haps 60% of the flood damages in the 1970s resulted from floods exceeding 100-year levels as defined by NFIP criteria.[7] If the capacity of a levee designed to the 100-year criteria is exceeded, backlying structures are flooded to the full height of the 100-year flood.[8]

After severe floods in the 1970s demonstrated these deficiencies in applying a 100-year flood elevation criteria, some states and communities adopted more stringent protection elevations.

Regulations for urbanizing watersheds. Because FEMA flood maps assume existing watershed conditions in calculating flood flows in urbanizing watersheds, they can quickly become outdated. Urbanization may increase peak flow two to six times.[9] To avoid this problem, a number of urban and metropolitan communities prepared their own maps based on assumptions of future urbanized watershed conditions.

- Arvada, Colorado, and other communities in the Denver area adopted floodplain regulations for the 100-year floodplain as defined through studies of the Denver Urban Drainage and Flood Control District which accounted for projected watershed development.
- Dallas, Texas, calculated runoff according to projected land use in the watershed.
- Tulsa, Oklahoma, has assumed future watershed conditions in its mapping and regulations since 1975.
- Racine County and other counties in the Southeastern Wisconsin Regional Planning Commission adopted regulations based on Commission studies that assumed future watershed conditions.

Regulations for broader inland floodplain areas. Most state regulatory programs and several thousand local programs have added "freeboard" (additional elevation) requirements to the NFIP 100-year flood elevation or have regulated based on the height of floods larger than the 100-year flood. This has been done in order to deal with increasing flood levels from urbanizing watersheds, special problems such as ice jams, or destruction of flood storage areas. For example, Wisconsin requires two feet of freeboard in all of its communities. Highland Park, Illinois,

requires two and one-half feet of freeboard, while Sioux Falls, South Dakota, and Howard County, Maryland, require two feet.

Regulations for coastal velocity zones and erosion areas. Some communities and states have gone beyond NFIP standards to reflect more accurately coastal wave and erosion problems.

- Massachusetts took into account wave heights when the state amended its building code regulations after the severe winter storm of 1979.
- Following the devastating hurricane in 1954, the governor of Rhode Island appointed a hurricane damage reduction task force, which formulated recommendations for two-zone regulations of coastal hazard areas. These were implemented by East Providence, Rhode Island, which prohibited structures in a high hazard zone severely damaged by the 1954 hurricane and required that structures in backlying low hazard zones be protected to a height of 15 feet, in contrast to a 100-year storm surge elevation of about 10 feet. South Kingston, Rhode Island, adopted a similar ordinance in 1975.
- Southampton, New York, requires a minimum elevation of 15 feet for new structures. The 100-year storm surge elevation is 10 to 12 feet.

Other communities with regulations reflecting anticipated wave heights and/or erosion hazards are Gulf Shores, Alabama, with a protection elevation of 15 feet; Santa Rosa Island, Florida, with a protection elevation of 13 feet; and a portion of Virginia Beach, Virginia, with protection elevations of 18.5 feet.

In remapping coastal areas, the NFIP now includes wave heights, but it will be several years before the maps are completed. FEMA is also considering individual insurance rating of structures in velocity zones to take into account wave heights.

Lack of 100-Year Flood Boundary Maps

As discussed in Chapter I, the USGS prepared "approximate" flood maps for 20,000 communities in the early 1970s. These maps were based on historical flood maps, records of flooding, and other sources of information. They varied greatly in accuracy, depending on available

information. These approximate maps have been of some value for regulatory purposes, but their use has been limited because they lack floodway and coastal high hazard area boundaries and 100-year flood elevations. FEMA did not require communities with approximate maps (about 11,000 of 17,000 in the NFIP) to undertake more detailed flood analyses to determine how proposed development would affect flood heights and velocities. Consequently, some development occurred in the 1970s (and is now occurring) in floodway and wave velocity areas and at elevations below that of the 100-year flood. Some of this development was encouraged by subsidized flood insurance, which is still available for new development.[10]

Some states and communities have taken steps to regulate new uses more effectively where only approximate flood maps are available.

- Some communities have prohibited development on an interim or long-term basis until detailed data becomes available for the entire approximate floodplain to avoid possible encroachments into high hazard areas and construction at inadequate elevations.

- Minnesota, Wisconsin, Maryland and other states have required permit review at the state level for development in approximate flood hazard areas in order to calculate 100-year flood elevations on a case-by-case basis and to study how the proposed development will affect flood flows. The states provide the results of this review to local governments and landowners.

- Maryland and Michigan require developers to undertake detailed flood studies consistent with state criteria to calculate 100-year flood elevations and whether new development will affect flood flows.

- California, New Jersey, Wisconsin, Arizona, several other states and many local governments undertook independent mapping with the help of consultants, regional planning agencies, or special districts. Some local governments produced flood maps exceeding minimum NFIP standards in accuracy and scale. FEMA later remapped these areas without use of the locally produced maps.

Problems with the Regulatory Floodway and the Lack of Floodway Maps

During the 1970s, many regulations applied the concept of the hydraulic conveyance regulatory floodway (i.e., the stream channel and a portion of the adjacent floodplain needed to convey flood flows from upstream to downstream points without increasing flood heights more than a predetermined amount). FEMA regulations require that riverine communities with a flood insurance rate map but without a floodway map prevent new construction, substantial improvements, or other development in the 100-year floodplain "unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community."[11] Where floodway maps are available, communities must "adopt a regulatory floodway based on the principle that the area chosen for the regulatory floodway must be designed to carry the water surface elevation of that flood with no more than a one foot rise in surface water elevation at any point."[12] The community must also prohibit encroachments and construction within the regulatory floodway "that would result in any further increase in flood levels within the community during the occurrence of the base flood discharge."[13] Similar standards have been adopted by many communities and states.

Problems have arisen in understanding and accepting these standards. The standards assume that some continued floodplain development will be permitted even if increased flood heights and velocities and increased flood damages result. The NFIP floodway based on one foot of allowable increase in flood heights also widens the floodplain. The increase of one foot in surface water elevation and resulting increase in water velocity may make the difference between flooding that can be controlled through emergency levees and flooding that cannot. The feasibility of

floodproofing structures is also affected because floodproofing higher than two feet for residences or three feet for commercial buildings is usually impractical due to water pressure on the floors and walls.

Because of these problems, at least a dozen states and many communities have adopted a more restrictive floodway standard. Water surface elevations may be raised no more than one-half foot (depending on the state and community). The "no-rise" floodway, which prohibits all future development which would increase flood heights measurably, is becoming more common. For example, Dallas, Texas and Rockville, Maryland, have adopted "no-rise" floodway regulations which apply to the entire 100-year floodplain. More restrictive approaches like these have been endorsed by the National Science Foundation.[14]

The FEMA floodway concept is difficult to apply in mountainous areas where steep topography and stream gradients cause high velocity flows throughout the floodplain. Water several inches deep can cause severe damage when it flows at five or more feet per second. Mathematical models for computing floodways are difficult or impossible to apply in high velocity flow areas. Consequently, some communities prohibit development throughout the entire high velocity floodplain rather than attempt to define a specific floodway.

Floodway mapping has been costly and time consuming. Maps are available for only 3,500 of the 20,000 communities with flood problems. Without such a data base, the flood conveyance function of floodways has little protection except in states or communities that prohibit all development in the floodplain or provide case-by-case analyses of the potential effects of development on conveyance or individually determine floodway boundaries.

Some communities use other means to define floodways if NFIP floodway maps are not available. Brown County, Wisconsin; Prince George's

County, Maryland; and Lewisburg Borough, Pennsylvania, have defined the floodway to be the 50-year floodplain. Other communities have established stream setback lines of 50 to 200 feet. Still others have applied an approximate "no-rise" or "natural" floodway concept which assumes no permissible increase in flood heights and can often be mapped more easily than a one-foot NFIP floodway.

With a traditional floodway permitting a one-foot rise, each floodplain must be hydrologically modeled to determine how much area is needed to convey specific flows with a one-foot rise. Detailed topographic information, flood flows, and estimates of existing development are needed to compute the one-foot rise. In contrast, mapping of a no-rise floodway is less complicated since it assumes that most of the floodplain is needed to convey flood flows. Thus, only outlying areas (e.g., tributary valleys) are omitted from floodway boundaries. Relatively accurate estimates of a no-rise floodway based on topography can often be made without detailed modeling.

Problems with Definition Criteria and Maps for Coastal High Hazard Areas

Most states and coastal communities have adopted NFIP standards that require elevation to the 100-year base flood elevation for coastal areas, if data on the elevation is available. Communities in the regular phase of the NFIP and with identified coastal high hazard (velocity wave) areas must ensure that construction is "located landward of the reach of the mean high tide."[15] However, under NFIP standards, structures may be built in wave velocity zones and erosion areas if protection is provided to the 100-year flood elevation and a registered architect or professional engineer certifies that the structure is "securely anchored to adequately anchored pilings or columns in order to withstand velocity waters and hurricane wave wash."[16] Structures may be elevated by construction on pilings, columns, or piers.

Special restrictions for coastal high hazard areas have been only partially implemented because many NFIP maps do not designate velocity zones. Moreover, as discussed earlier, wave heights have not been considered in establishing mapped 100-year base flood elevations. Water-related erosion, which poses a more serious threat than flooding near bluffs and on some beaches, is also omitted from maps and the NFIP's regulatory standards.

Because of these deficiencies, some states have adopted standards that exceed the NFIP's for protection of development in coastal high hazard areas. For example, in 1970, Florida adopted interim legislation requiring that construction begun after July 27, 1970, be at least 50 feet inland from the mean high water mark to protect structures from erosion and waves. This statute was amended in 1971 to provide a variable "engineered" setback line for high energy beaches.[17] The Hawaii legislature adopted a beach setback line in 1968.[18] Rhode Island prohibits development on most dunes, beaches, and wetlands under a variety of laws.[19] Regulations cover erosion areas and require a minimum structural elevation of six feet above the base flood elevation. Since 1978, Delaware has required protection against waves for development in beach zones. Many of these states have complained that less restrictive NFIP standards undercut their programs.

A variety of more restrictive local programs were also adopted.

- San Diego and Santa Barbara, California require sufficient setbacks from eroding bluffs to provide protection for the expected life of the structure. Where erosion rates are three feet per year, for example, a 300-foot setback is required for a structure expected to last 100 years. Regulations are usually part of more comprehensive coastal zone management provisions required by the California Coastal Zone Acts of 1972 and 1975.

- Washington communities require erosion setbacks as part of the state's Shoreland Zoning Act of 1971, which applies to all coastal beaches and floodplains.[20] All communities are required to prepare "master programs" consistent with standards of the Department of Environmental Regulation. The Department pre-

pared a detailed atlas of coastal areas showing 100-year flood elevations, erosion areas, and wave hazard areas to assist communities in their planning and regulation.

- Some Florida jurisdictions such as Sarasota County adopted coastal setback lines for distances of 25 to 150 feet from the high water mark to protect against erosion and wave action. Community setback lines usually coincide with setbacks defined by the state.

- At least 10 Michigan communities along Lake Michigan adopted erosion setback lines consistent with standards of the Michigan Department of Natural Resources.[21] The 1971 Shoreline Act authorized the Department to define high risk erosion areas, flood areas, and "environmental" areas. The Department conducted a detailed inventory of erosion areas based on air photo sequences dating from 1938 to the present. Field inspections were also used to define a setback line reflecting a 30-year erosion recession rate. After definition, the state required that state or local construction permits be granted only for areas behind the setback line.

Inadequate Protection for Dunes and Wetlands

The NFIP requires that coastal communities with defined coastal high hazard areas adopt regulations prohibiting "man made alteration of sand dunes and mangrove stands...which would increase potential flood damage."[22] Protection is required because FEMA recognizes that dunes and mangrove stands reduce wave heights and water-related erosion. However, the NFIP does not provide for the mapping of dunes and mangroves and has not effectively monitored the adoption of regulations for their protection. Consequently, the extent and results of adoption are uncertain.

Several states and many localities have adopted dune protection measures meeting or exceeding NFIP standards. Maine prohibits alteration of dunes under a coastal wetland act.[23] Rhode Island and North Carolina regulate dune alteration under coastal zone management acts.[24] Georgia and North Carolina have adopted dune protection legislation. Florida has adopted the setback line discussed above. Many communities in these and other states regulate or prohibit alteration of either primary or both primary and secondary dune systems.

- Wrightsville Beach, North Carolina, has setback lines and dune protection ordinances.

- Rhode Island coastal communities such as South Kingston, Warwick, and Westerly have dune protection regulations.

- Beach Haven, Avalon, and many other New Jersey communities adopted beach setback and dune protection regulations following the severe winter storm of March 1962, which destroyed much of the primary dune system along the coast. Beach setbacks have generally been combined with dune restoration and protection, such as planting grasses.

Inadequacies in Combined Flood Hazard and Stormwater Management

Prior to 1970, floodplain regulations in urban areas were rarely adopted for small streams and watercourses. Future urbanization was not considered in calculating flood flows. Subdivision regulations usually required that subdividers install drainage systems sufficient to accommodate the discharge of the 5- to 15-year storm, but not larger events.

In the 1970s, many urban and metropolitan areas adopted floodplain regulations for small rivers and creeks based on flood studies that included projected urbanization of watershed areas. These floodplain regulations and stormwater management ordinances usually require developers to install stormwater management measures maintaining peak runoff levels or increasing runoff by no more than a specified amount. Aboveground drainage systems for the 100-year flood as well as below-ground storm sewers for small floods (e.g., 5- to 10-year storms) are required. Onsite detention areas or "compensatory storage" are also usually required. Some ordinances permit developers to contribute to a general drainage fund rather than require a drainage system and detention areas. The community uses this fund to construct and maintain common drainage systems and detention areas. The funds may also be used for stream channelization projects, levees, and other flood control measures.

Some communities or developers have also carried out detailed mapping and hydrologic studies on a watershed basis for drainageways and

small streams not included in the NFIP flood studies. Map scales range from 1"=500' to 1"=200' with 1' to 4' contour intervals. "Urbanized" watershed conditions are assumed in flow calculations. If floodways are not mapped, setbacks of 50 to 200 feet from small streams and drainageways are sometimes required.

The community or developer typically computes stormwater runoff prior to subdivision approval. Some communities have prepared computer models to help evaluate impact. Examples of effective stormwater management are:

- Baltimore County adopted both floodplain and stormwater management regulations requiring onsite detention. Some of the funds for flood-related drainage repairs were combined to create a $27 million floodplain acquisition program.

- Alexandria, Virginia, adopted sophisticated stormwater management regulations for Four-Mile Run. A computer model prepared by the Corps of Engineers calculates the effect of proposed development on storm runoff.

- Montgomery County, Maryland, adopted a stormwater management ordinance that requires onsite detention to prevent runoff from exceeding the quantity expected from a 10-year storm. Rockville, Maryland, also requires that stormwater held in onsite detention be released at no greater than a 2-year rate of flow.

- King County, Washington, has studied and is adopting a stormwater management program that requires a utility fee (based on quantity of discharge) for discharges into the county drainage system. Arvada, Colorado, also adopted a drainage fee ordinance. In addition, developers must provide compensatory storage and must deed 6% of the land to the city. Santa Barbara County, California, adopted a similar "benefit assessment" ordinance.

- Howard County, Maryland, requires detailed flood studies if a subdivision is partially within a floodplain or if the watershed drainage covers more than 50 acres. The county also adopted a phased-growth management policy to prevent overburdening of streams and comprehensive subdivision design standards to encourage clustered development and preserve as much open space in the floodplain as possible.

- Lake County, Illinois, adopted a natural resources protection plan prohibiting all floodplain development. In addition, runoff from other watershed areas must not be increased above certain "performance" levels. Maximum

limits are placed on the areal extent of impervious surfaces and development densities. Many towns in Bucks County, Pennsylvania, have adopted similar performance controls.

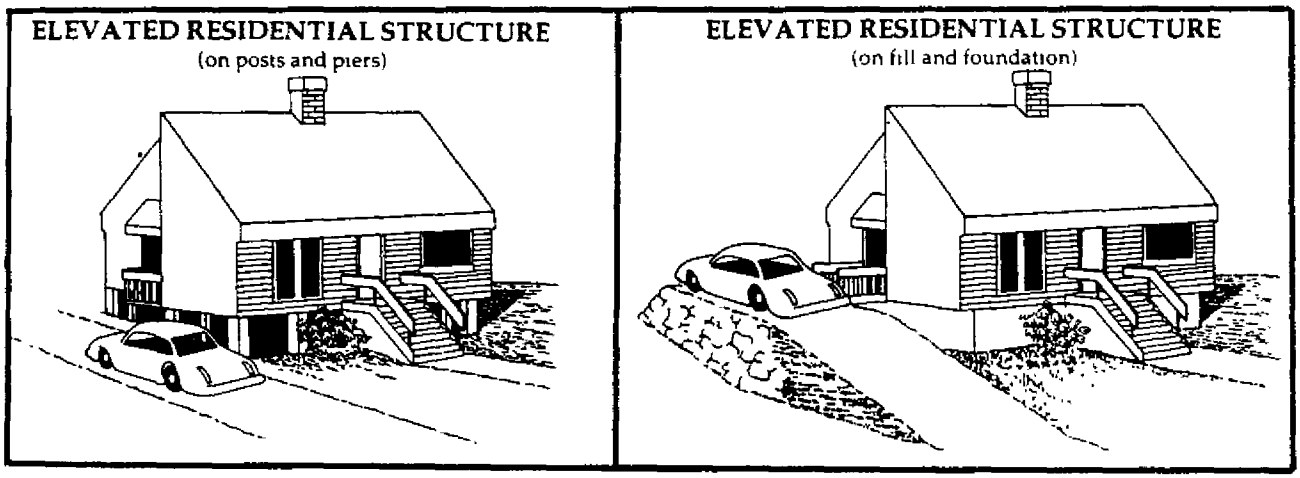
Comprehensive stormwater management has encountered problems. Some onsite detention has increased rather than decreased flood peaks where natural flood peaks occur slowly. Debris and sediment have clogged underground detention areas. Runoff techniques that did not include flood storage were difficult to integrate into traditional floodway/flood fringe regulations.

Limitations of Flood Protection Measures

Implementation of floodplain regulations was hindered in the 1970s by uncertainties about the long-term effectiveness of elevating structures on pilings in wave velocity zones and floodproofing industrial and commercial buildings.

Elevation on fill. State and local governments favored elevation on fill for inland areas in 1970 when Volumes 1 and 2 of Regulation of Flood Hazard Areas were written. Even though it is not favored by FEMA because it eliminates flood storage, many states and localities continue to favor this approach for inland areas. Elevation on fill up to a few feet is relatively inexpensive and permanent. In addition, it has a built-in safety factor: if the base flood elevation is exceeded, often only minor flooding occurs in a structure elevated on fill, causing limited damage. By contrast, a floodproofed structure will be flooded to the full flood height or it may collapse if the base flood elevation is exceeded.

Despite its advantages in low velocity inland areas, fill destroys wetlands and flood storage capacity. It is subject to erosion in high velocity flow areas and it creates a mounded effect, which, even with skillful landscaping, may be aesthetically unattractive, especially if existing structures were built at substantially lower elevations.



ELEVATED STRUCTURES

Source: Missouri Department of Public Safety, Disaster Planning and Operations Office

Elevation on pilings and other open works. The NFIP, state, and local programs prefer elevation on wooden, concrete, or steel pilings or other "open works" such as walls, columns, or piers in most coastal and inland floodway areas. Elevated structures offer less resistance to waves and flood flows. Pilings and other open works are not as easily eroded as fill. Open works have negligible effects on conveyance and flood storage, and are less disruptive of wetlands.

However, open works are also subject to limitations. In coastal areas, the elevated structure and its supports must be designed to withstand not only the stress of waves and swiftly flowing water (often not considered), but also hurricane winds of 70 to 200 miles per hour. Inadequately braced structures may tilt and fall. Buildings may also be blown or swept off the open works if not adequately secured by bolts or tie-downs. Pilings without deep footings in wave and high velocity flow areas may be undermined by erosion. Wood pilings may also rot or be weakened by termites. Structures elevated on open works become inaccessible during flooding, complicating the evacuation of occupants and rendering the structure unusable.

As discussed in Chapter I, Hurricane Frederic dramatically revealed problems with elevation on inadequately designed pilings. Winds and waves almost totally destroyed the first tier of structures along 36 miles of beach, 70% in the second tier, and 50% in the third tier. Most structures had been elevated on pilings, ostensibly to the 100-year flood elevation, but without consideration of waves or erosion.

Floodproofing. Design standards for floodproofing advanced during the 1970s, although the effectiveness of these designs during actual flood conditions is still questionable. The NFIP and most state and local regulations permit the construction of commercial and industrial but not