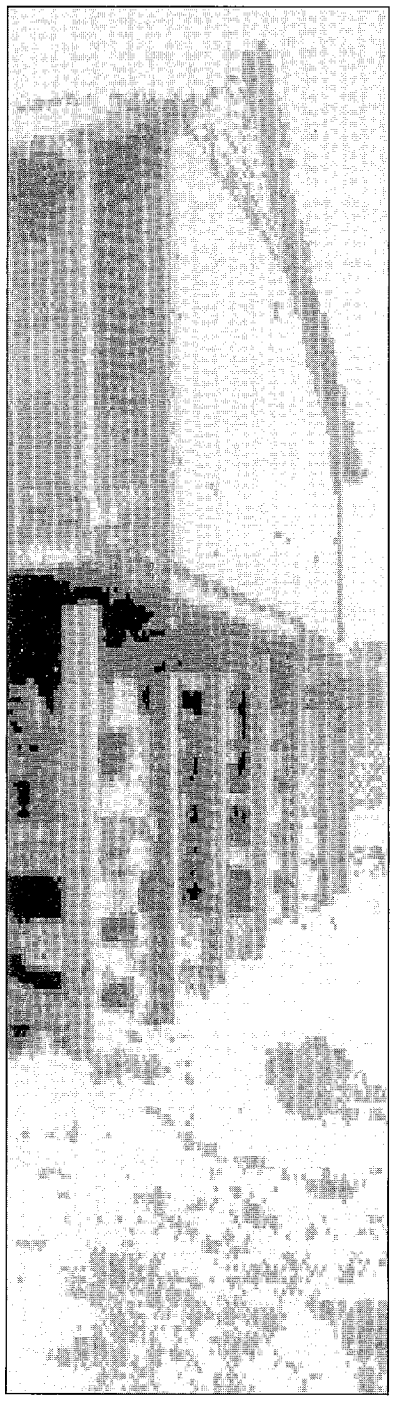
FEMA 257/October 1994

REPORT ON THE STATE OF THE ART

Mitigation of Flood and Erosion Damage to Residential Buildings in Coastal Areas



Federal Emergency Management Agency
Mitigation Directorate
Federal Insurance Administration

October 1994

THE NATIONAL FLOOD INSURANCE PROGRAM

Created by the Congress in 1968, the National Flood Insurance Program aims to reduce future damage to new and substantially improved construction through prudent floodplain development and to transfer the risk of that development from the taxpayer to the property owner through an insurance mechanism that protects the financial interest of the property owner while requiring a premium to be paid for that protection.

The Federal Emergency Management Agency identifies and maps flood hazards nationwide. Flood Insurance Rate Maps distinguish several flood hazard zones, including the 100-year floodplain, which is defined as an area inundated by a flood that has a one-percent chance of being equalled or exceeded in any year (i.e., the 100-year flood, also called the Base Flood Elevation). In riverine areas and tidal areas subject to waves of less than three feet in height, the 100-year floodplain is referred to as the Special Flood Hazard Area and is designated Zone A. In coastal areas where wave heights equal or exceed three feet, the 100-year floodplain is referred to as the Coastal High Hazard Area and is designated Zone V.

In communities that participate in the program, construction is allowed within the Special Flood Hazard Area if it complies with local floodplain ordinances that meet National Flood Insurance Program requirements. The fundamental requirement is that any new or substantially improved residential building must have its lowest floor elevated to or above the Base Flood Elevation. A building is considered substantially improved when the cost of any rehabilitation, addition, or other improvement, or repair or reconstruction after damage, equals or exceeds 50 percent of the pre-improvement/pre-damage value of the building. In A Zones, the lowest residential floor must be elevated either on earthen fill or solid or open foundations to or above the Base Flood Elevation. In V Zones, the lowest horizontal structural member must be elevated to or above the Base Flood Elevation on a foundation of piles or columns.

The foundation of the NFIP is a quid pro quo*: if a community will adopt and enforce ordinances to reduce future flood risks, the federal government will make flood insurance available to property owners in the community.*

Lending institutions require the purchase of flood insurance for buildings located in the Special Flood Hazard Area as a condition of obtaining a federally sponsored or insured mortgage or home improvement loan. Flood insurance policies are available from private insurance companies under an arrangement with the federal government or directly from the federal government.

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EXECUTIVE SUMMARY

Since 1991, severe storms have increasingly buffeted the coastline of the U.S., causing extensive flood damage and costing over $900 million in claims payments through the National Flood Insurance Program. In response to such storms, as well as local coastal zone management requirements, residents of the nation's shorelines are taking measures to floodproof, or retrofit, their homes.

PURPOSE OF INVESTIGATION

The purpose of this investigation was to document the broad range of nonstructural mitigation activities undertaken nationwide in communities exposed to coastal flooding and erosion. This survey provides necessary documentation on which to base a federal, state, or community coastal flood and erosion hazard mitigation program.

As of 2/28/94 Coastal Storm	Claims	NFIP Losses (millions)
Hurricane Bob *(New England)*	2,786	$ 49
Halloween 1991 Northeaster *(New England)*	9,306	$141
Hurricane Andrew *(Florida)*	5,327	$161
Hurricane Iniki *(Hawaii)*	409	$ 30
December 1992 Northeaster *(New York and New Jersey)*	24,417	$334
March Blizzard of 1993 *(East Coast and west coast of Florida)*	9,515	$207
TOTALS	**51,760**	**$922**

SUMMARY OF FINDINGS

FEMA's investigation revealed that many homeowners in coastal areas have floodproofed over the last several decades and, based on current construction activity, this trend continues. The primary floodproofing measures being used are elevation of homes in place and relocation of homes to safer locations.

Less frequently used floodproofing alternatives to elevation and relocation of threatened homes include demolition of the structure, or taking no action to floodproof, when it is hoped that future damages will be minimal or where floodproofing would not be financially desirable.

Design and construction methods for elevation and relocation of homes are well documented and have remained standard throughout the years because they have generally proven to be technically feasible and financially viable.

EXECUTIVE SUMMARY

FEMA found that in areas subject to significant wave action, elevation that keeps the lower area open and free of obstruction is the only in-place measure that can prevent structural damage. In areas subject to significant storm-induced scour (vertical erosion), residences whose foundations are not embedded well below the potential scour zone incur significant damage or total loss as a result of foundation failure. In areas subject to significant shoreline retreat over the long term (horizontal erosion), relocation and demolition are the only viable floodproofing measures unless actions are taken to forestall the erosion.

NFIP requirements for new coastal construction are being widely implemented and, where executed correctly, have performed successfully. Previous analyses of flood insurance claims data and post-storm building performance were substantiated: the majority of damage incurred is to non-elevated or improperly elevated homes built prior to implementation of the NFIP.

While FEMA requires minimum standards for coastal floodproofing in NFIP-participating communities, continued assistance and education programs are important because local governments, through their zoning, permit, and inspection efforts, determine the ultimate success or failure of floodproofing techniques and projects. Implementation of floodproofing programs in coastal areas can be most successful immediately after storm events, when homeowner motivation and awareness are highest.

Many states and communities have developed aggressive regulatory programs that are more restrictive than the NFIP; these programs have been successful in promoting prudent development in hazardous areas along the coast and in providing technical assistance and funding for floodproofing to homeowners.

Significantly, FEMA's investigation confirmed that floodproofing can avert flood insurance claims and disaster assistance payments, thereby reducing federal expenditures. The technology and resources exist for successful, cost-effective floodproofing of coastal homes. Although the two most effective floodproofing methods are elevating the home or relocating it out of harm's way, some homeowners have opted for alternatives to floodproofing such as demolishing their homes. Others are taking no action to reduce potential damages: letting nature take its course, and relying on flood insurance coverage and disaster assistance, if available.

INVESTIGATION STRATEGY

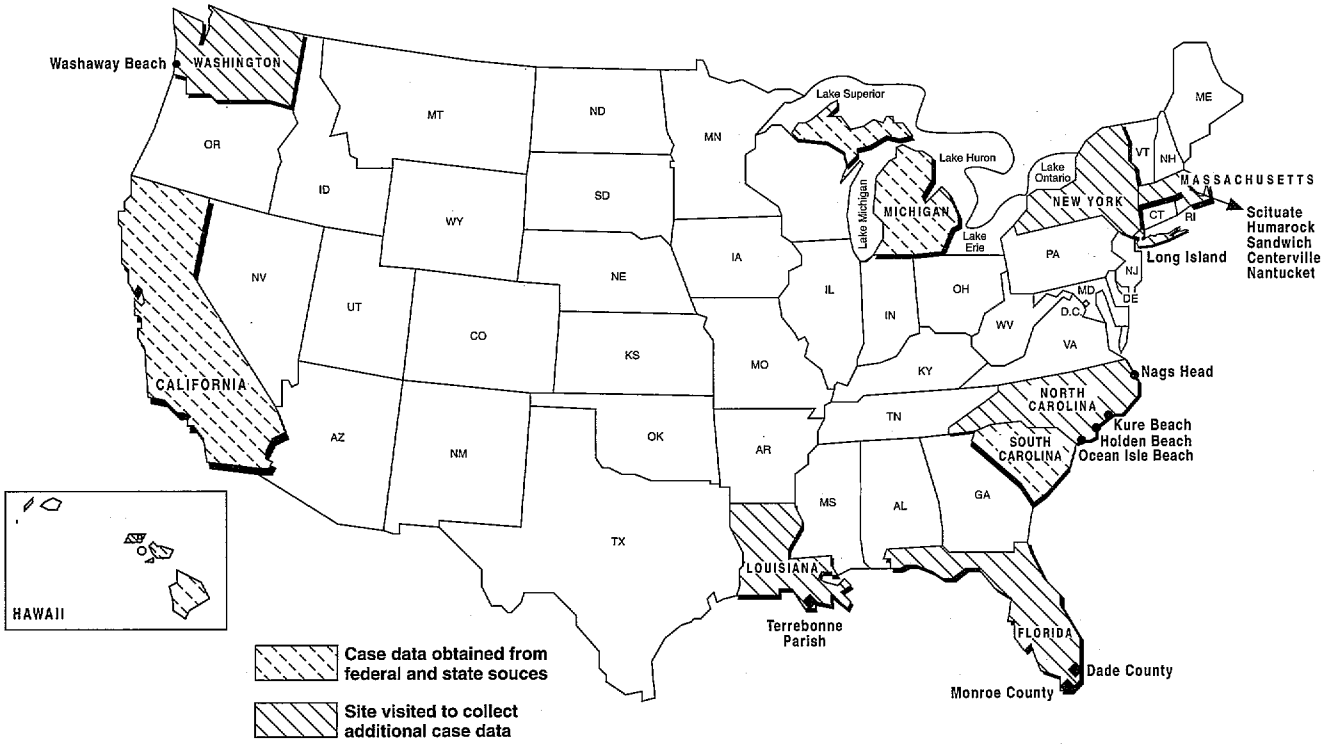
FEMA investigated coastal floodproofing techniques through a review of current literature, coordination with FEMA's regional offices, and visits to coastal communities in states on the Atlantic, Pacific, and Gulf Coasts. FEMA regional offices also provided case data on floodproofing in the Great Lakes region and Hawaii.

FLOODPROOFING INVESTIGATIONS

The Federal Emergency Management Agency (FEMA) observed floodproofing projects in coastal communities chosen to be representative of coastal flooding conditions in the U.S., as well as areas of known floodproofing activity. Community officials provided information on the impacts that the National Flood Insurance Program (NFIP), state, and local regulations have on floodproofing efforts.

This investigation revealed where various floodproofing techniques are being employed, and the level of design effort and expense involved.

Floodproofing is any structural or nonstructural change in the design, construction, or alteration of a building to reduce damage caused by flooding and flood-related factors such as erosion. The most common floodproofing techniques used in coastal areas are in-place elevation, relocation, and demolition.



THE NATIONAL FLOOD INSURANCE PROGRAM

In the face of mounting flood losses and escalating costs to the taxpayers for disaster relief, the Congress created the National Flood Insurance Program in 1968. The purpose of the NFIP is to reduce future damage to new and substantially improved construction through prudent floodplain development and to transfer the risk of that development from the taxpayer to the property owner through an insurance mechanism that protects the financial interest of the property owner while requiring a premium to be paid for that protection.

For decades, the government's response to flood disasters was limited to constructing flood control works, such as dams, levees, and seawalls, and providing relief to flood victims. This approach did not discourage unwise floodplain development, and in fact may have encouraged such development by creating a false sense of security to the public. To compound the problem, flood hazard coverage was not available from insurance companies, and building techniques to reduce flood damage were not widely recognized.

FEMA identifies and maps flood hazards nationwide. Flood Insurance Rate Maps (FIRMs) distinguish several flood hazard zones, including the 100-year floodplain, defined as an area inundated by a flood that has a one-percent chance of being equalled or exceeded in any year (i.e., the 100-year flood, also called the Base Flood Elevation). In riverine areas and tidal areas subject to waves of less than three feet in height, the 100-year floodplain is referred to as the Special Flood Hazard Area (SFHA) and is designated Zone A. In coastal areas where wave heights equal or exceed three feet, the 100-year floodplain (SFHA) is further referred to as the Coastal High Hazard Area and is designated Zone V.

In communities that participate in the NFIP, construction is allowed within the SFHA if it complies with state and local floodplain ordinances that meet NFIP requirements. The fundamental NFIP requirement is that any new or substantially improved residential building must have its lowest floor elevated to or above the Base (or 100-year) Flood Elevation (BFE) on the FIRM. A building is considered substantially improved when the cost of any rehabilitation, addition, or other improvement, or repair or reconstruction after damage, equals or exceeds 50 percent of the pre-improvement/ pre-damage value of the building. In A Zones, the lowest floor of residential construction must be elevated either on earthen fill or solid or open foundations to or above the BFE. In V Zones, the lowest horizontal structural member must be elevated to or above the BFE on a foundation of piers, piles, or columns.

The foundation of the NFIP is this: if a participating community will adopt and enforce ordinances to reduce future flood risks, the federal government will make flood insurance and certain forms of disaster assistance available to property owners who purchase flood insurance within that community.

Lending institutions enforce the purchase of flood insurance for buildings located in the SFHA as a condition of obtaining a federally sponsored or insured mortgage or home improvement loan. Identical flood insurance policies are available from private insurance companies under an arrangement with the federal government or directly from the federal government.

For flood insurance rating purposes, residential buildings are classified as being either pre-FIRM or post-FIRM. Pre-FIRM refers to new or substantially improved construction started on or before December 31, 1974, or before the effective date of the community's initial FIRM, whichever is later. Insurance for the first $35,000 of coverage for pre-FIRM buildings is subsidized, while rates for post-FIRM structures are fully actuarial, based on the zone shown on the FIRM and the differential between the building's lowest floor and the 100-year flood level. When a pre-FIRM building is substantially improved, flood insurance may no longer be subsidized and rates become post-FIRM (actuarial). This rate structure provides an incentive to property owners to elevate buildings in exchange for lower insurance rates.

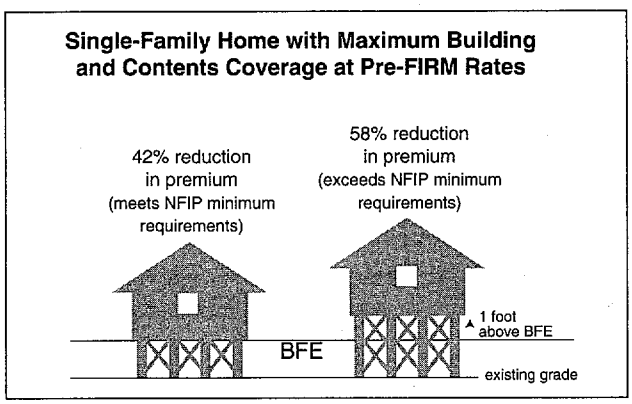
Upton-Jones Amendment

The "Upton-Jones Amendment" broadened NFIP coverage to include payment for demolition or relocation of a building subject to imminent collapse as a result of erosion or undermining caused by waves or currents exceeding anticipated cyclical levels.

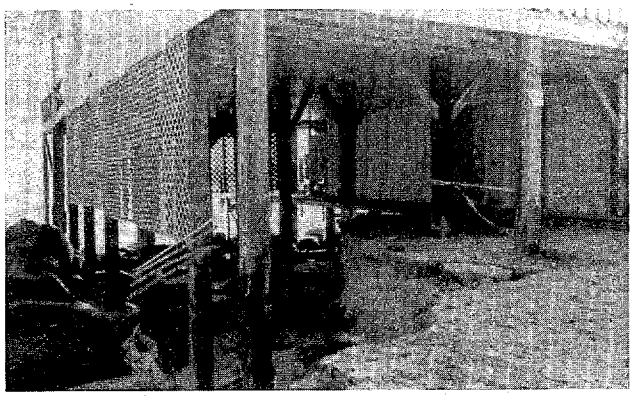
FEMA set and reviewed criteria by which states were eligible to certify structures subject to imminent collapse. For eligibility, a state had to administer an erosion management program that prohibited new, substantially improved, or relocated construction seaward of a setback line based on local erosion rates. In the absence of state certification, a structure had to be condemned by a state or local authority as being unsafe for human habitation.

In payments under the Upton-Jones Amendment, the insured could receive 100 percent of the value of the building plus the cost of demolition and cleanup, not to exceed 10 percent of the value of the building. Alternatively, the insured could

Flood insurance is available to all owners and occupants of insurable structures in communities that participate in the NFIP. An insurable building is a walled and roofed structure principally above ground and not entirely over water. Building contents are covered separately.



By elevating a home to meet NFIP requirements, a property owner can reduce the annual flood insurance premium by hundreds of dollars. Over the life of a mortgage, this can result in significant savings. However, elevating to or above the BFE does not eliminate the requirement to purchase flood insurance, because the foundation system itself is exposed to flood forces.



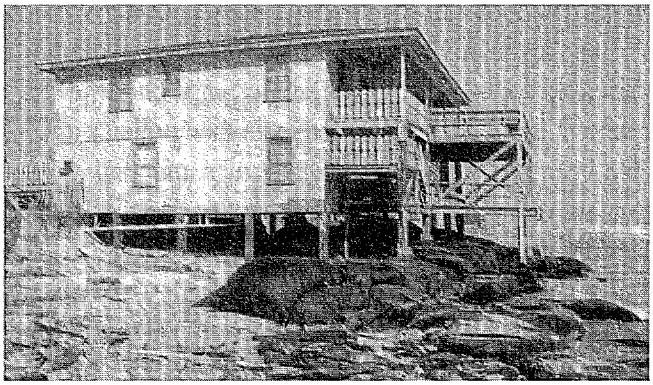
Owners of homes in danger of imminent collapse due to erosion could receive assistance under the NFIP to demolish or relocate their homes.

receive the cost of relocation not to exceed 40 percent of the value of the building.

Following a payment for relocation or demolition, flood insurance coverage and disaster assistance (except emergency assistance) was unavailable on the building lot seaward of a 30-year erosion setback for one- to four-dwelling units and a 60-year setback for all other buildings. These setbacks were measured landward from a reference feature based on the historical average annual erosion rate at the site.

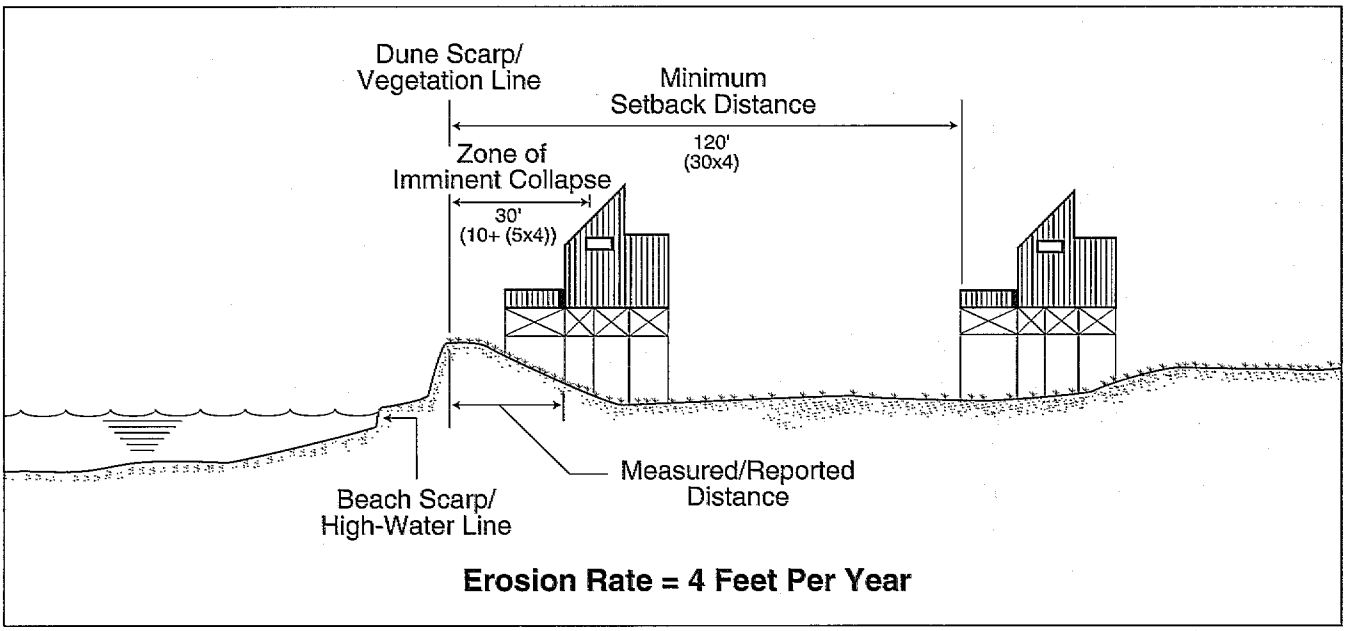
The zone of imminent collapse was an area experiencing erosion adjacent to the shoreline of an ocean, bay, lake, or river and defined by a setback distance equal to ten feet plus five times the average annual long-term erosion rate for the site. This distance was measured landward from a reference feature, such as the top edge of a bluff, escarpment, or eroding dune, or if such features are not present, the normal high-water line.

The diagram below illustrates how a zone of imminent collapse and erosion setbacks were determined under Upton-Jones.



Michigan, Pennsylvania, New Jersey, North Carolina, and South Carolina were eligible to certify structures in danger of imminent collapse, under the Upton-Jones provisions of the NFIP.

In accordance with the Community Development and Regulatory Improvement Act of 1994, Title V, National Flood Insurance Reform, Section 552, the Upton-Jones Amendment was repealed following a one-year transition period.



If the average annual erosion rate is four feet per year, the 30-year setback would be 120 feet landward of the reference feature, and the 60-year setback, 240 feet. After receipt of a relocation payment, a building had to be relocated landward of the applicable setback to be eligible for flood insurance. (The Upton-Jones Amendment was repealed in 1994.)

FLOODPROOFING TECHNIQUES

Flood insurance claims data since 1978 indicate that most losses in V Zones occur to pre-FIRM buildings constructed before the establishment of NFIP criteria. Elevation in place and relocation from the flood and erosion hazard area are the two most common floodproofing techniques utilized in coastal areas. These are the only methods that meet the NFIP's requirements for substantially damaged and substantially improved buildings.

FLOODPROOFING ALTERNATIVES

Floodproofing decisions must include an assessment of flood and erosion hazards affecting the structure. The following table summarizes the floodproofing methods currently being used in the four most common flooding and erosion hazard scenarios encountered in the coastal United States. While any of these techniques may be used to retrofit a pre-FIRM building, the NFIP does not allow solid foundation walls to be used for substantially damaged or improved buildings located in V Zones.

Flood Insurance Zone Designation	Flooding and Erosion Hazards	Alternatives					
			Elevation				
		No Action	Piles	Columns (Piers/Posts)	Solid Foundation Walls	Relocation	Demolition
V Zone	Coastal High Hazard Areas subject to erosion	**Yes**	**Yes**	**No**	**No**	**Yes**	**Yes**
	Coastal High Hazard Areas not subject to erosion	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**
A Zone	Coastal plain areas subject to tidal flooding	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
No Designation or C or X Zone	Coastal waterfront on bluffs subject to erosion	**Yes**	**No**	**No**	**No**	**Yes**	**Yes**

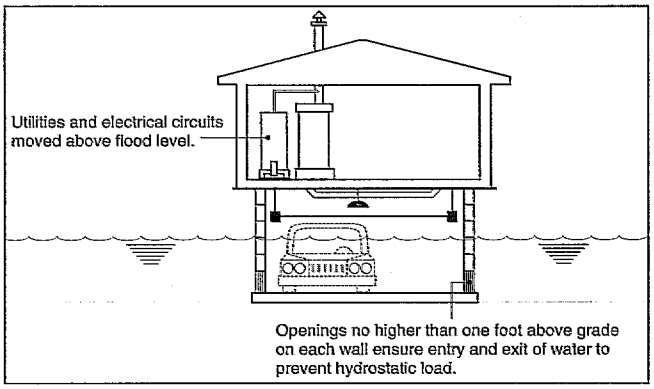
Elevation

Elevating a structure so that flood waters are less likely to cause damage is an effective permanent floodproofing technique when erosion is not a concern. Elevating to the BFE, as required by the NFIP substantial improvement and damage regulations, can significantly reduce or prevent damages when floods do occur.

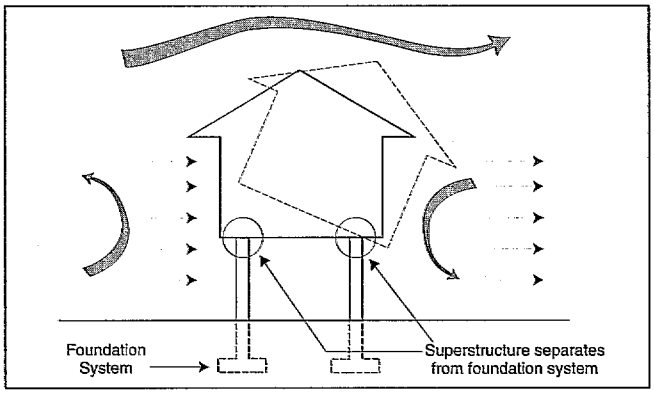
If the building is located in an area subject to wave action, such as a Coastal High Hazard Area (V Zone), an open foundation is the only effective way to elevate. Elevating a building on an open foundation involves raising it onto piers, posts (columns), or piles, which are embedded sufficiently below the expected depth of erosion. If the building is subject to significant water depths, wave heights, or debris flow, or potential storm-induced erosion, the property owner should also consider elevating on an open foundation. This will allow water and debris to flow beneath the building and reduce potential damage that could result if solid foundation walls were to fail.

No matter what type of foundation on which a home is elevated, high winds in coastal areas will impose significant forces on the home and the structural elements of its foundation. Wind loads on elevated structures are increased, and damage potential is higher when the wind forces occur in combination with flood forces. Therefore, wind loads must be taken into consideration in the design of elevated buildings.

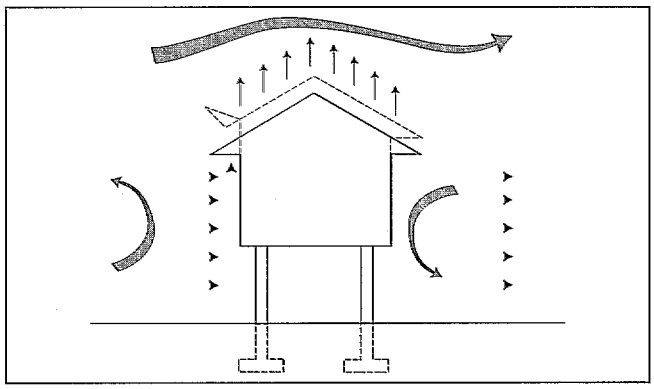
Cost is also an important factor to consider in elevating structures. Wood frame buildings are lighter than masonry buildings and are therefore easier and less costly to raise. Masonry buildings are not only more expensive to raise, but also may be susceptible to cracking. If homeowners opt for elevation of the building, contents or materials susceptible to flood damage should not be stored underneath the elevated building, unless a plan to remove them prior to flooding is adopted.



In a typical residential elevation, an eight-foot or higher area below the house can be used for parking, access, and limited storage during non-flood conditions.

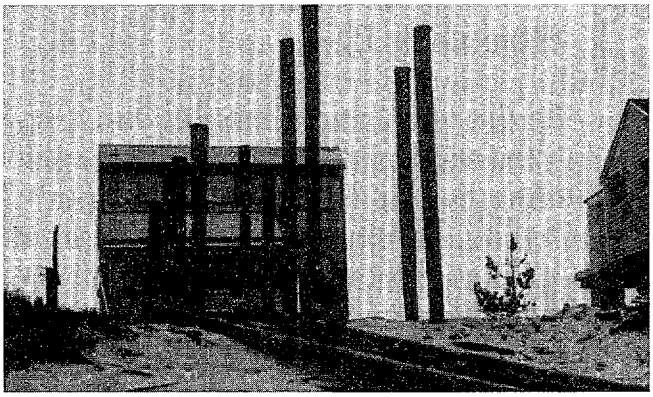


Horizontal wind forces and associated suction (negative forces) on the rear wall can cause an overturning effect.



As the wind blows over the roof, its increasing speed can draw the roof upward and off the house. Wind forces also stress connections between structural members, such as between piles and floor beams, weakening the structure.

For aesthetic or security reasons, many homeowners wish to enclose the area under the house. This can be accomplished in V Zones by installing NFIP-compliant latticework or solid walls that are designed to break away during floods. In A Zones, solid walls are permitted, but any enclosure must have openings to allow for the automatic entry and exit of flood waters to equalize hydrostatic loads on the structure.

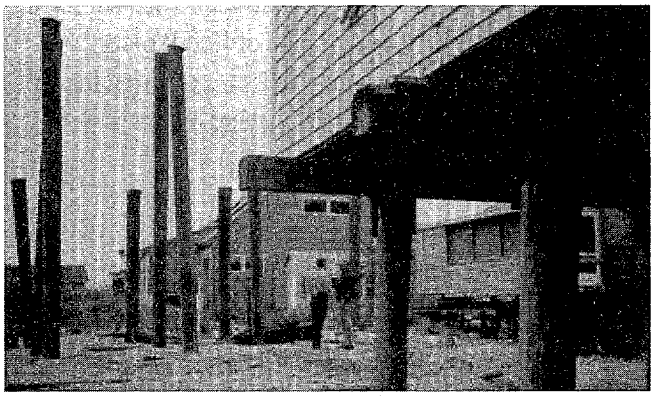


Because driving piles requires heavy machinery, a building being elevated in place may have to be temporarily moved aside and set on cribbing until the driving of piles is complete.

Elevation on Piles

Due to velocity flow, wave impacts, and soil types, elevation on deeply embedded piles is the primary technique used in Coastal High Hazard Areas subject to episodic storm-induced erosion. Shorelines that are relatively stable or retreating very slowly over time may still be subject to large horizontal and vertical variations during storms.

Elevation on adequately embedded piles can provide a stable foundation until the beach is recovered post-storm. However, elevation on even the most deeply embedded piles is not adequate in areas where historical erosion is severe. In such cases, the building is inevitably rendered uninhabitable as it ends up seaward of the shoreline.



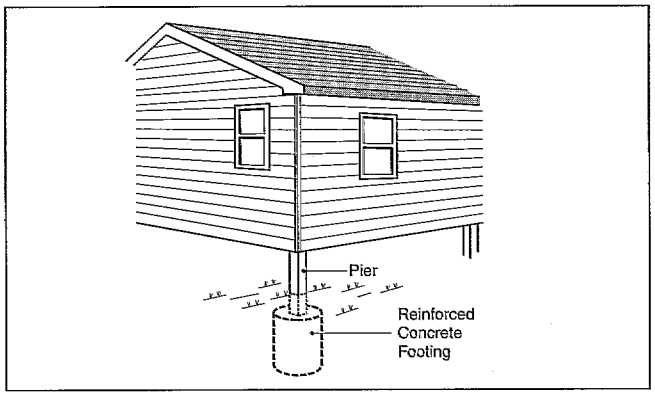
Piles are generally made of wood or prestressed concrete. They often are braced against lateral and shear forces using wood knee and cross bracing, steel rods, and guy wires.

Where high-velocity flooding can result in scouring (erosion of supporting soil), piles usually provide the most effective foundation. Piles are mechanically driven or jetted deep into the ground. Because they are normally deeply embedded, piles are less susceptible to the scouring effects of high-velocity flood waters than columns or piers. Piles must be either wedged into the bedrock or driven deeply enough that there is sufficient friction between the pile and surrounding soil to transfer the loads acting on the building into the surrounding ground. Effective load transfer must be ensured even during conditions of predicted erosion.

The home is set on the new pile foundation system.

Elevation on Piers

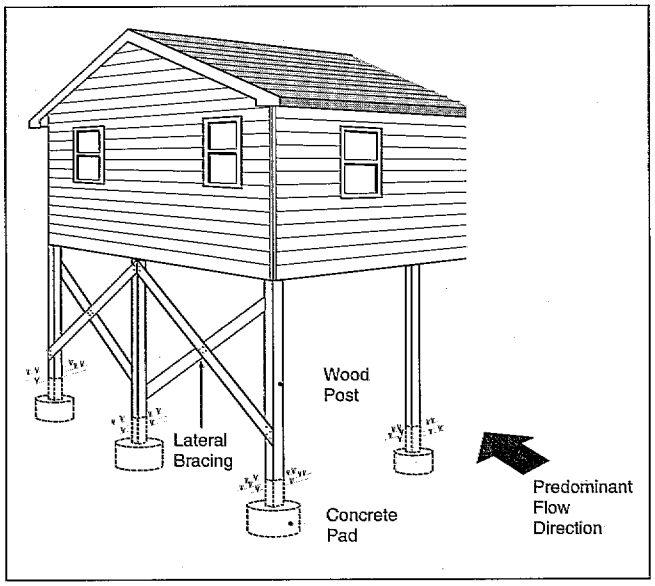
Piers are vertical structural members that are supported entirely by concrete footings. While they may be the most commonly used type of open foundation in areas subject to riverine flooding and coastal plains not subject to wave action or high-velocity flow, they are the least suited for withstanding flood forces in Coastal High Hazard Areas. In conventional use, piers are designed primarily for vertical loading. When located in Coastal High Hazard Areas, however, they will also experience hydrodynamic forces. For this reason, piers used in floodproofing must be substantial enough to support the structure and sufficiently reinforced to resist a range of flood forces. Therefore, elevation on piers is not recommended in coastal flooding areas, where hydrodynamic forces are significant.



While commonly used in riverine areas, piers are not suitable to withstand the hydrodynamic forces associated with coastal flooding.

Elevation on Posts

Elevation on posts has limited applicability in Coastal High Hazard Areas because these areas may be affected by scour or erosion. This technique is used in coastal areas where the underlying ground is bedrock or coral to which the column can be structurally tied and building loads transferred, or in areas where conditions make it appropriate to simulate the effect of bedrock or coral by pouring enough concrete in the post hole to transfer the load to the surrounding soil. Posts are made of wood, steel, or precast reinforced concrete. Posts differ from piles in that posts are thicker and are set in pre-dug holes, perhaps at a more shallow depth. Concrete, earth, gravel, or crushed stone is backfilled around the hole once the post is set.



Commonly used bracing techniques include wood knee and cross bracing, steel rods, and guy wires.

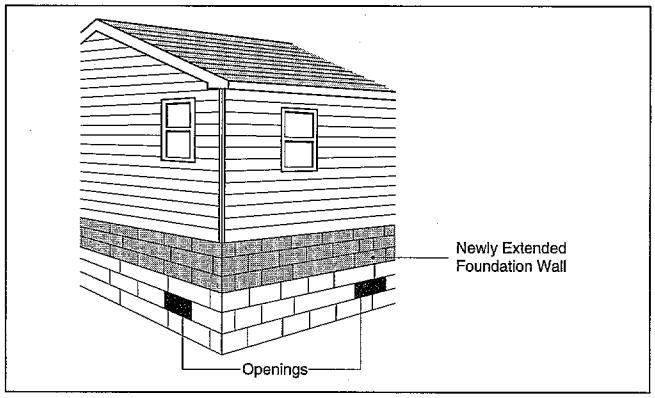
Elevation on Solid Foundation Walls

Elevation on extended solid foundation walls is normally used in areas of low to moderate water depth and velocity. The most important concern is that the original foundation and footing be able to withstand the extra loading, not only from the additional vertical dead load of the new wall, but also from the additional flood and wind forces associated with coastal storms. If the footings are not deep and wide enough, they may not be able to resist the additional loads, which could result in overturning or settlement. Another consideration is that erosion could result in undermining of the footing. In addition, the original foundation walls may not be thick enough to be properly extended upward.

Depending on the potential flood and wind forces, the usual practice is to reinforce both the footings and walls using steel reinforcing bars if new footings have to be poured. Regardless of what type of foundation wall construction is used, hydrostatic forces can result in collapse of the building. In order to reduce this danger, solid foundations in substantially damaged or improved homes in A Zones must be constructed with openings that allow flood waters to pass through the walls and equalize the hydrostatic forces (in V Zones, walls must be designed to break away). However, if velocities are excessive, hydrodynamic forces may still cause failure; an open foundation may be appropriate.

One solution to excessive hydrodynamic flood forces in A Zones is to elevate the structure on extended foundation walls and backfill in and around them, creating the appearance of a home set on a mound.

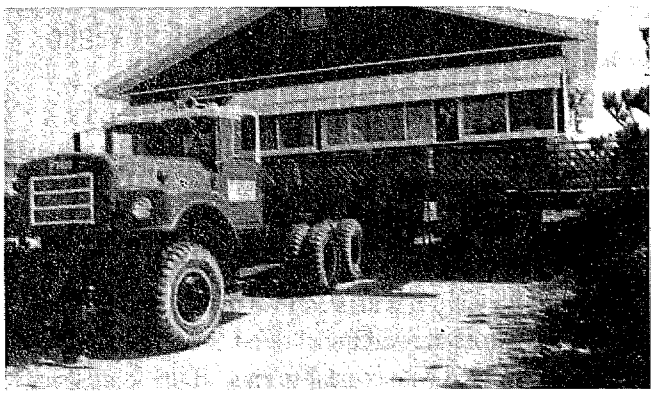
NFIP regulations prohibit elevation on extended solid foundation walls in V Zones for post-FIRM structures or substantially improved or damaged pre-FIRM structures. This is because research conducted by the Army Corps of Engineers identified a three-foot breaking wave to be critical in terms of causing significant structural damage to solid walls. V Zones are subject to wave heights equal to or exceeding three feet.



After the house is raised above the BFE, the foundation walls are extended vertically to at least the BFE. The house is then set onto the newly extended walls.

Relocation

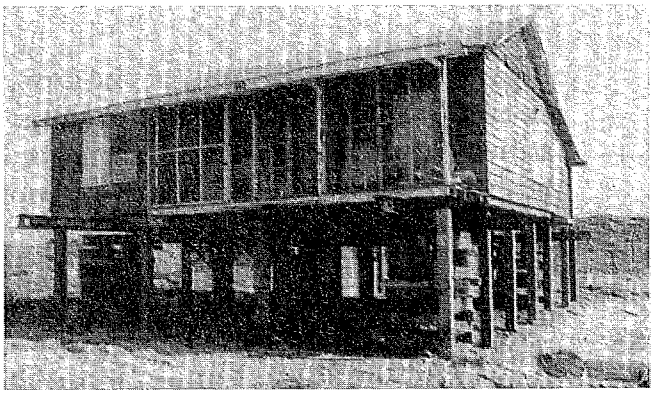
A floodproofing alternative to elevation that is also common in coastal areas is relocation of the building beyond the reach of erosion and either the limits of the floodplain or the level of the BFE at the new location. The building may be moved to either another location less threatened by flooding and erosion on the existing property or to a new site.



Relocation involves separating the building from its existing foundation and transporting it to a new location, where it is placed on a new foundation.

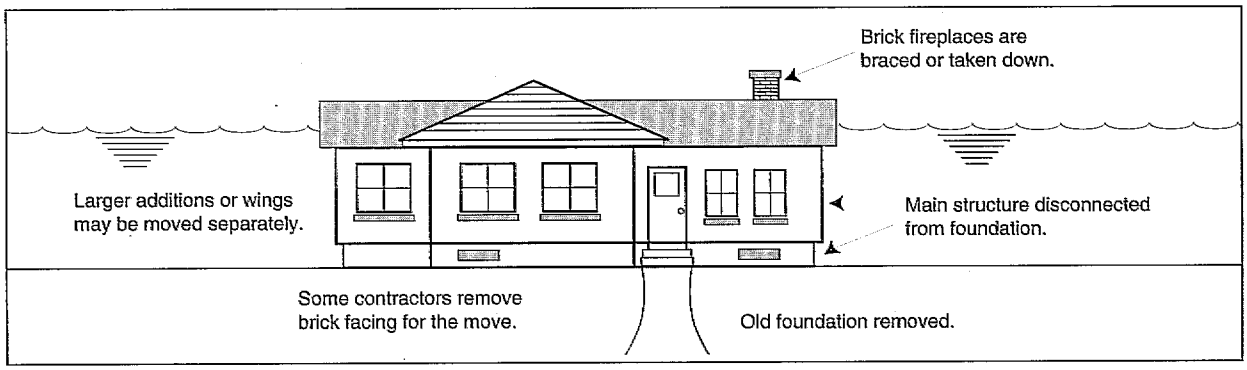
Relocation is appropriate if flood and erosion hazards are such that continued occupation of the building at its present location is unsafe. It is also an option for the property owner who wants to reduce the damages and safety risks associated with flooding and erosion.

Factors that can affect the property owner's decision to relocate include availability of a new location; economics; federal, state, and local regulations; the building's structural soundness; and whether there are bridges or other obstructions, such as power lines, along the proposed transportation route. During the move, the property owners must live elsewhere, perhaps for several weeks, and may need to store furniture and belongings temporarily.



A home to be relocated is supported on cribbing prior to lowering onto a wood post foundation.

Cost, in relation to building value, is the major concern associated with relocation. In addition to

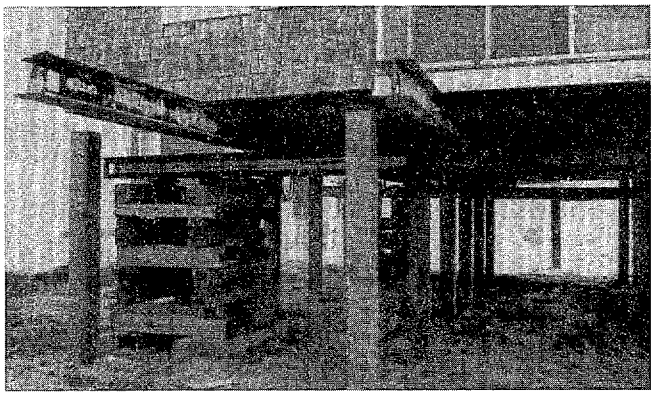


Relocating a building provides the greatest potential of reducing the threat of flood damage.

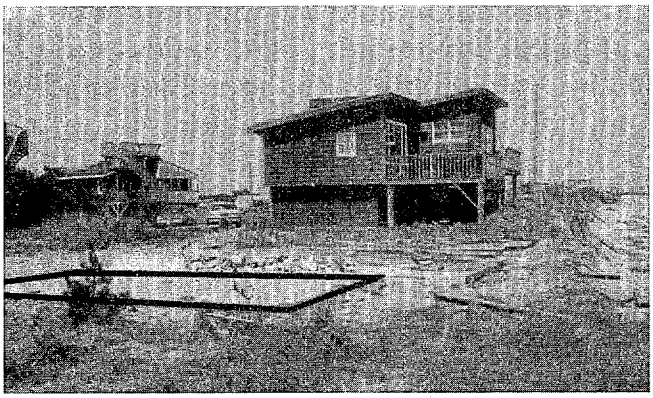
paying the moving contractor, the property owner may need to purchase a new lot, build a new foundation, relocate utilities, landscape, clean up the former home site, and pay for professional services and fees.

The relocation procedure is similar to elevating a structure in place, with some additional steps related to the actual move. Temporary utility connections are usually not required as it is generally not possible to continue living in the home during the moving process. Due to their shapes, sizes, or weights, some structures must be moved in sections. When this is the case, most or all of the contents may need to be removed and stored.

The most readily elevated or relocated structure is a single-family, one-story, wood-frame dwelling, square or rectangular in shape, constructed over an open foundation. Buildings constructed over crawl spaces at least 18 inches or higher are also easy to move. The process is more difficult and expensive for a building with a basement, a slab-on-grade building, a building constructed of masonry, a multistory building, or a building with additions. Any kind of a sound building can be elevated or relocated. Masonry buildings, which may be subject to cracking, are often elevated but are less frequently relocated.



Steel beams are used to lift and support the residence during the relocation process.



Many jurisdictions require that the old lot be returned to pristine conditions or its natural state. Note the concrete slab and construction materials that must be removed. Some of these lots have remained private property, while others have been utilized for public access to waterfront areas.

Where compliance with the NFIP's substantial damage and improvement requirements is not an issue, homeowners are exercising options other than elevation or relocation. Although not required by NFIP regulations to floodproof, some homeowners are taking such measures anyway.

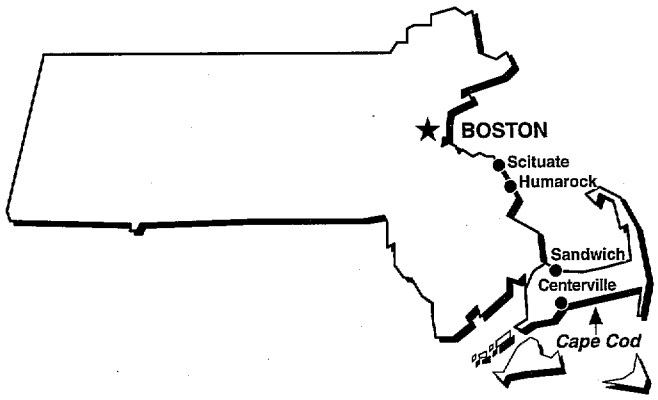
Demolition

In some cases, demolition of the structure may be a reasonable course. The Upton-Jones Amendment provides up to ten percent of the value of eligible insured homes to defray demolition costs, in addition to paying for the value of the structure itself (subject to policy limits). In most areas, removal of debris following demolition is required to avoid the hazards floating debris can cause; a notable exception is Washaway Beach, Washington, where the erosion rate is so great that large stands of timber, roads, and other debris wash into the ocean regularly.

Other Methods

Contractors experienced in floodproofing have developed interesting technologies to accomplish elevation projects. For example, a method of angular pile driving may eliminate the need to temporarily relocate a structure to be elevated during pile placement. In another case, a contractor has used inflatable bags to lift structures being elevated in areas where site conditions restrict the placement of lifting beams under the home.

Taking no action at all to floodproof can be a considered decision on the part of some homeowners. In some cases, the homeowner may be willing to risk the loss of the home when the potential rental income from the property is high. If the house is eventually damaged or destroyed, it would still be covered by flood insurance.



Residential floodproofing projects were observed in Coastal High Hazard Areas and areas subject to erosion in communities on Cape Cod and Massachusetts' Atlantic Coast. Floodproofing methods observed in these communities include elevation and relocation.

Regulatory Environment:

- Coastal construction affected by state Wetlands Protection Act and environmental code.
- State codes restrict placement of septic systems in NFIP Zones AO and V, and state-mapped dune fields. Leaching trenches must not be less than four feet above groundwater elevations.
- State provides guidance to communities in implementing codes.

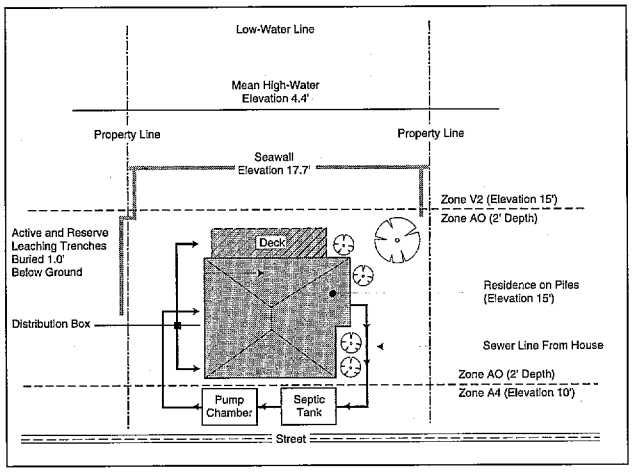
FLOODPROOFING PROJECTS OBSERVED

Elevation on Piles

Humarock, Massachusetts

Cost of Floodproofing:		
	Moving on Site:	$10,000
	Pile Foundation:	20,000
	Design/Permits:	8,000
	Septic System:	12,000
	Total:	$50,000

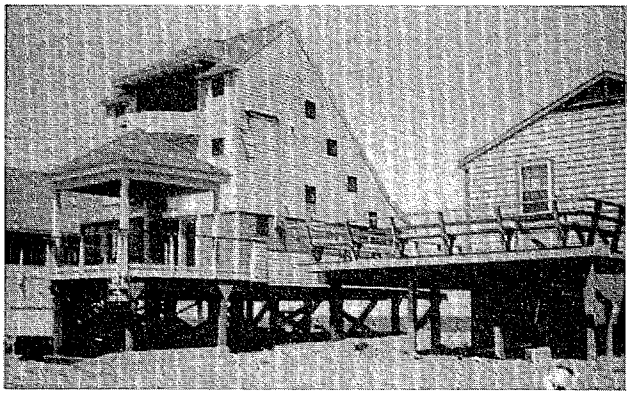
- Residential structure on Atlantic Ocean elevated on wood piles. Seawall of 17.7 feet above sea level protects the home from direct wave action. Owner chose to elevate for added safety.
- Property located in three separate flood insurance zones: Zone V with BFE of 15 feet; Zone A with BFE of 10 feet; and Zone AO with depth of 2 feet.



Because this property (shown in plan) is in three flood insurance zones, including an A Zone, the septic system did not have to be located within the elevated structure, as is usually mandated by state environmental codes impacting coastal construction.

Humarock, Massachusetts (Continued)

- State environmental codes prohibit placement of septic systems in Zones V and AO.
- Septic system was placed in the small portion of an A Zone located at the property's landward end.



Residences are typically elevated on pressure-treated, cross-braced wood piles. One local contractor constructs over 25 residential elevation projects a year.

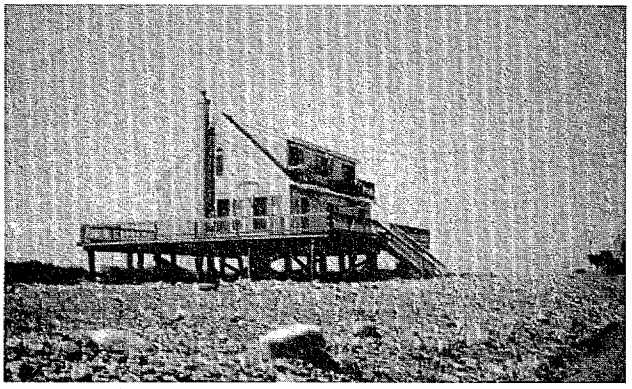
Elevation on Piles

Scituate, Massachusetts

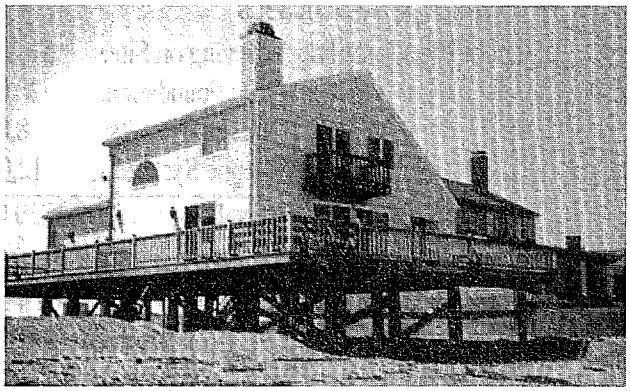
Cost of Floodproofing:

Moving on Site:	$10,000
Pile Foundation:	20,000
Design/Permits:	8,000
Septic System:	12,000
Total:	$50,000

- Coastal High Hazard Area subject to episodic erosion (Zone V). Portions of some properties located in Zones A and AO.
- Many homes floated or dislodged from foundations during 1991's Hurricane Bob.
- Rebuilding subject to NFIP, state, and local ordinances. If substantially damaged, homes were required to be elevated to BFE.
- Engineering and construction of typical new homes is similar to elevating an existing home. Typical home is a 900-square-foot, wood-frame structure.



Decking is generally supported by concrete columns. Additional piles or a deeper foundation are used when disturbed soil is encountered.



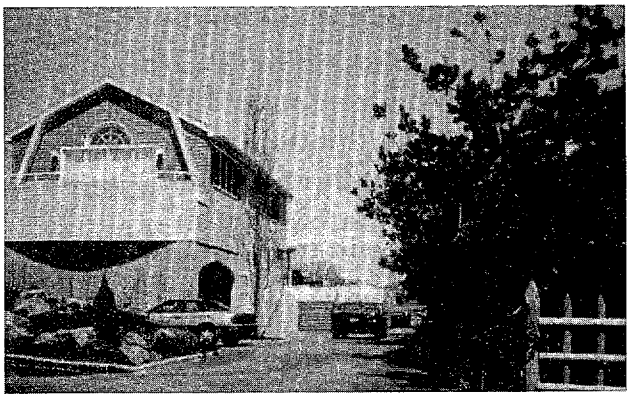
Flexible connections between building support beams and wooden piles allow adjustments to be made to account for imperfect pile driving.

Elevation on Solid Foundation Walls

Centerville, Massachusetts (Cape Cod)

Cost of Floodproofing: $20,000 - $25,000 (range)

- Homes in this community suffer repetitive flood damage when high tides inundate the tidal flats for long periods.
- Damage caused primarily by ponding of water rather than wave action. Properties are in Zone A.



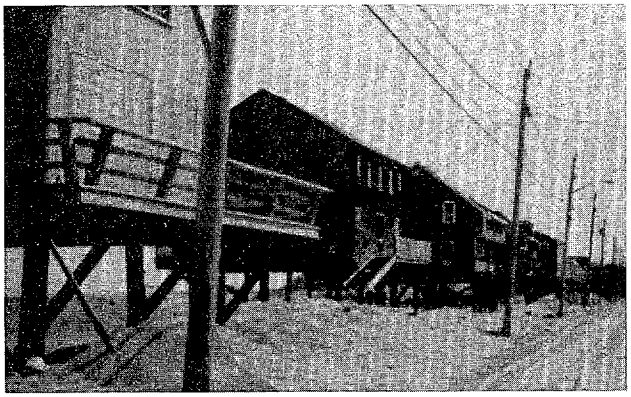
The elevation of this home resulted in the elimination of $25,000 annually in repetitive flood insurance claims. Plantings and berms disguise the retrofit and enhance the landscape.

Relocation

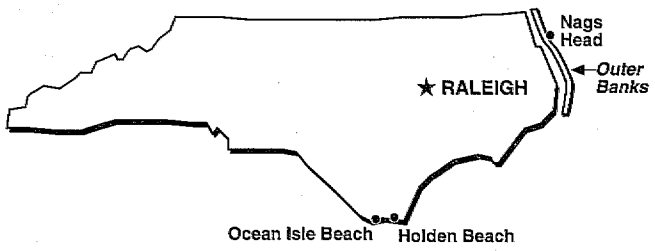
Sandwich, Massachusetts (Cape Cod)

Cost of Floodproofing: $8,000 - $12,000 (range)

- Many homes relocated on their lots or elevated since a devastating October 1991 Northeaster. The protective dune has eroded, eliminating the homes' first defense against wave action. Properties are in Zone V.
- Community is investing in repairing public works with federal disaster assistance and, with other federal assistance, a beach and dune replenishment project.



Many homes in Sandwich, Massachusetts, were relocated landward on their existing lots after severe dune erosion from an October 1991 Northeaster.



Income-producing rental properties are common to the popular resorts along North Carolina's coast. Homeowners there must weigh the cost of floodproofing against the risk of losing rental income. The many owners who do opt to relocate their homes are subject to state and local building requirements that exceed the NFIP.

Regulatory Environment:

- State Coastal Area Management Act provides setbacks, limiting development to landward of the crest of the primary or frontal dune or the long-term erosion setback line. Where erosion is less than two feet per year, the required setback is 60 feet from the applicable reference feature.
- State Building Code applies to homes that are relocated or undergo substantial improvement. Code requires that all one- and two-family homes in Coastal High Hazard Areas be constructed on wood or concrete pile foundations.
- Local regulations deal primarily with setbacks, land use, and other requirements to obtain building permits.

FLOODPROOFING PROJECTS OBSERVED

Relocation

Holden Beach, North Carolina

Cost of Floodproofing: $14,000 (average)

- Most residences in this Outer Banks community are rental properties located in A and V Zones.
- As of March 30, 1993, 45 homes met the requirements for assistance under the Upton-Jones program. Houses ranged in value from $29,480 to $204,920.

The Town of Holden Beach is considering enacting requirements more stringent than the NFIP substantial damage regulations, making the amount of improvements cumulative over several years. The intent is to prevent owners from doing major renovations on a piecemeal basis and to bring many more homes into compliance with current codes such as elevation requirements.

No Action

Ocean Isle Beach, North Carolina

- Owner of rental property in Zone V who was issued a certificate of imminent collapse has withdrawn the Upton-Jones claim.
- Rather than elevating or relocating to an inland site, the owner will have new shoring placed to temporarily protect the home and maintain the rental income.
- While risking the chance of a destructive storm against rental property income, the structure would still be eligible for flood insurance coverage if the house is damaged or destroyed by a flood.

Ocean Isle Beach zoning regulations require construction to start at the 25-foot setback line of the landward edge of the lot, and that the house not cover more than 36 percent of the lot. A new ordinance addressing relocation projects would require the structure to meet all current codes as well as be superior in appearance to the general nature, quality, and character of the neighborhood into which it is relocated.

Relocation and Demolition Projects

Nags Head, North Carolina (Outer Banks)

- Local requirements in addition to federal and state regulations address relocation or demolition of houses in Coastal High Hazard Areas (V Zones).
- Prior to relocation of a building, public service authorities must be notified of the move. A bond may be required for the use of town streets. Former foundations, utilities, and concrete and asphalt must be removed. Demolition requirements are similar to those for a relocation project.
- Dune at former site must be stabilized or rebuilt.
- Local building inspector and state Coastal Area Management Act official inspect and approve cleared site.

This multistory home in Nags Head, North Carolina, was relocated from an oceanfront VE Zone to an AE Zone.

SOUTH CAROLINA

Coastal zone management in the form of erosion setbacks has proven effective in South Carolina as an alternative to placement of erosion control devices. Elevation and relocation are the most common floodproofing methods. Where state regulations exceed NFIP requirements, homes have performed even better in the face of major storms, including Hurricane Hugo.

Regulatory Environment:

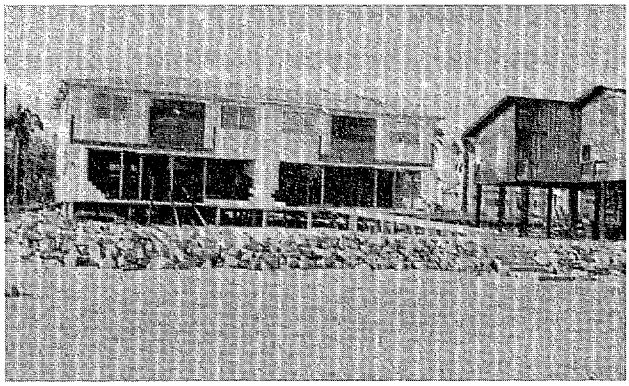
- State Coastal Zone Management Act of 1977 created a coastal council.
- State Beachfront Management Act of 1988 authorizes coastal council to regulate development in critical erosion areas: coastal waters, tidelands, and the beach and dune system.
- Erosion setbacks are measured from baseline established by coastal council. New construction is prohibited seaward of the baseline; repairs to damaged structures are severely restricted seaward of the setback or baseline.

FLOODPROOFING PROJECTS OBSERVED

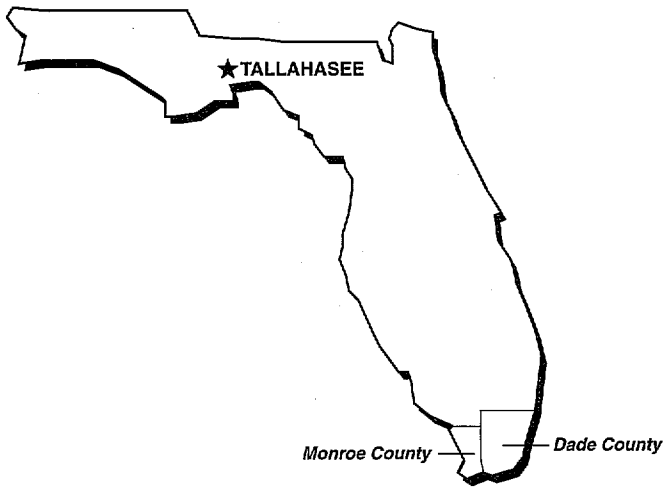
Elevation on Piles

Charleston County, South Carolina

- Two-story single-family home surpasses NFIP minimum construction requirements. The home is elevated three feet above BFE.
- Breakaway walls enclosing lower area designed to fail.
- Builder took extra measures to protect under-structure utilities, parking pad, and roof.



Exceeding minimum building requirements, this home performed well compared to its neighbors during Hurricane Hugo (1989).



In non-erosion-prone areas of Florida, column foundations can be tied to the bedrock or coral that lies under the sand. Some homeowners have floodproofed by taking advantage of a FEMA policy that encourages NFIP-conforming construction practices for additions while not requiring expensive rehabilitation of non-damaged pre-FIRM structures.

Regulatory Environment:

- State Department of Environmental Protection regulates all construction seaward of the Coastal Construction Control Line (CCCL), a jurisdictional line defined on the east coast by the line of bluff erosion, and the west coast by the limit of the three-foot wave.
- State reviews all construction seaward of the CCCL to protect the beach and dune systems and enforce design criteria more restrictive than the NFIP.

FLOODPROOFING PROJECTS OBSERVED

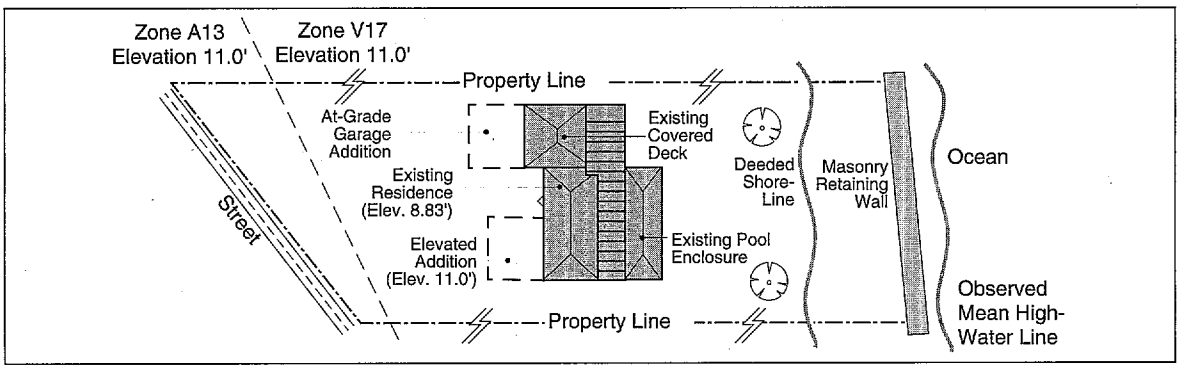
Elevation on Columns

Marathon, Florida

Cost of Floodproofing: $28,500 (Phase II)

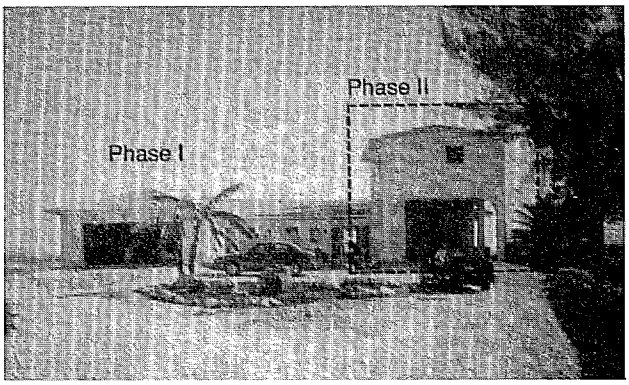
- Property located in both A and V Zones. Existing house of concrete block on a concrete foundation.
- Initial improvement, an at-grade garage, was not considered substantial improvement. Pre-FIRM insurance rating status remained in force.

Although the addition planned on this property constituted a substantial improvement and was therefore elevated above the BFE, the pre-FIRM rate continues to be applied to the whole home.



Marathon, Florida (Continued)

- Phase II improvement was an addition of 469 square feet.
- Because this substantial improvement was elevated above BFE, the pre-FIRM insurance rating still applies.



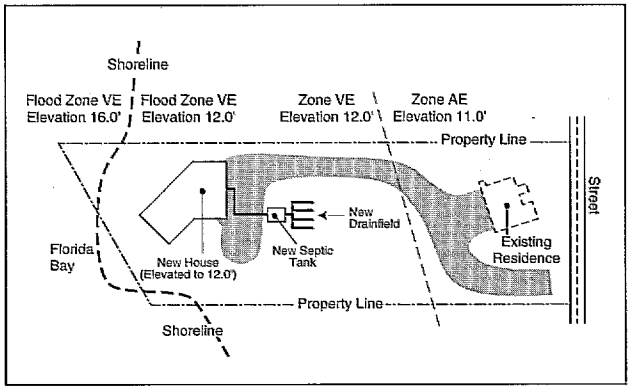
The addition was constructed to withstand expected storm events. If substantially damaged, the original home would have to be reconstructed in compliance with NFIP requirements.

Elevation on Columns

Marathon, Florida

Cost of Floodproofing: $50,000 (estimated)

- NFIP and state codes will allow a 1,680-square-foot elevated structure to be built seaward of the owner's current home.
- New septic system, water lines, and stormwater and natural retention areas are required to meet state codes.



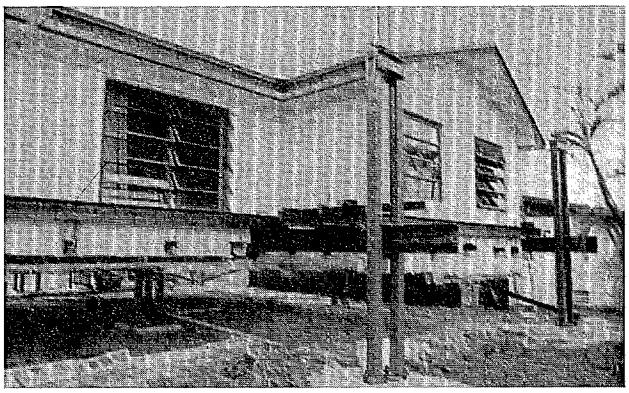
To expand living space and improve views of Florida Bay, construction plans call for a new structure, elevated above the BFE, to be located seaward of the existing home.

Elevation on Solid Foundation Walls

Dade County, Florida

Cost of Floodproofing: $14,400 to $41,900 (range)

- Substantially damaged homes being restored following wind and flood damage from Hurricane Andrew must be elevated per NFIP regulations.
- Typical residence is a one-story, 2,000-square-foot, concrete block structure.
- Often it is more economical to raise the roof, build a new second story, and convert the use of the lower area to building access, parking, and storage than to lift the entire house.

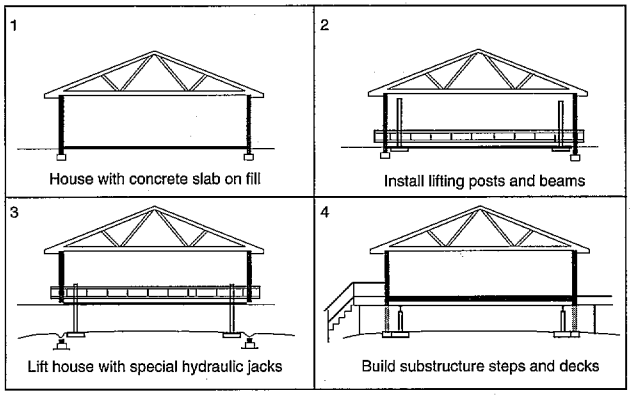


FEMA evaluated seven alternatives for elevating a typical home following Hurricane Andrew. Costs ranged from $14,400 to $36,900 for raising a home one to three feet, and from $21,400 to $41,900 for raising a home eight feet.

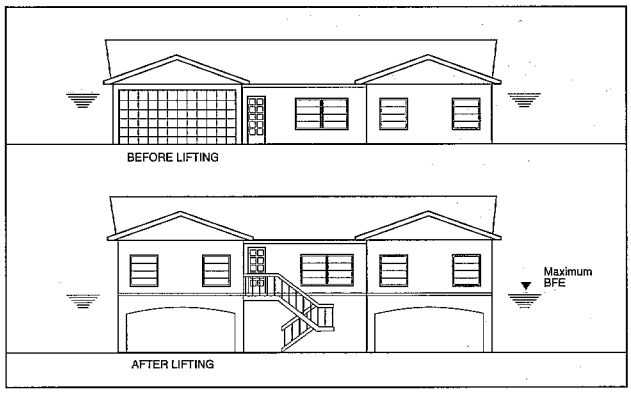
Elevation on Solid Foundation Walls

Saga Bay, Dade County, Florida

- Concrete, slab-on-grade home with masonry walls that was damaged by Hurricane Andrew.
- Unique lifting method employed to hydraulically lift the structure, including the floor slab.
- A steel substructure was then built to permanently support the house at the new elevation.

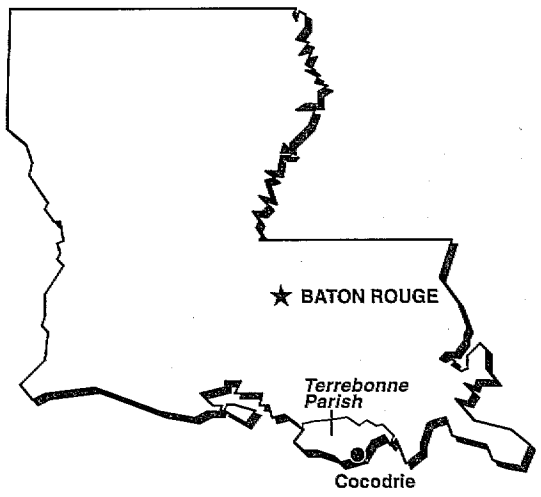


This patented lifting method of elevation involves placing steel lifting beams on top of the floor and pulling it up by suspender rods. The main beams extend through openings in the wall to lifting posts around the house.



This method for elevating masonry homes is synchronized to keep the house level during lifting to avoid cracking and other damage.

LOUISIANA



Elevation is the most common floodproofing technique in the low-lying bayou areas of Southern Louisiana. Although these Coastal High Hazard Areas are not subject to extreme erosion, elevation projects must take into account the local phenomenon of subsidence of the earth.

Regulatory Environment:

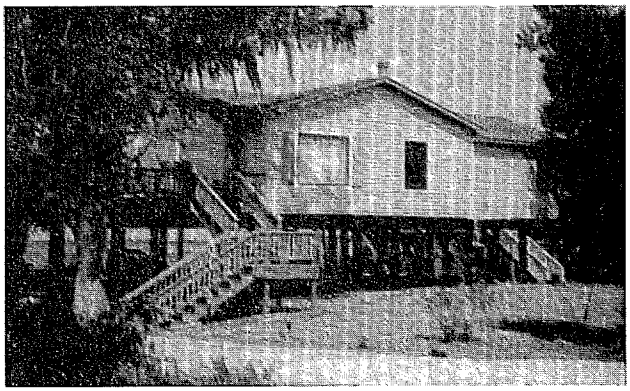
- Houma/Terrebonne Parish Board of Health regulates residential construction with regard to sewage.
- Homes on less than half an acre must have self-contained sewage treatment systems rather than septic tanks, the cost of which can be 20 to 40 percent of the cost of elevating a home.

FLOODPROOFING PROJECTS OBSERVED

Elevation on Piles

Terrebonne Parish, Louisiana
Cost of Floodproofing: $13,500

- Home is a 1,100-square-foot, wood-frame structure in Zone A.
- After home was elevated above work area, pile holes were dug and piles driven into place.
- Cross beams and bracing were connected, and the structure was lowered onto the new pile foundation.
- Over 4,000 pounds of concrete was poured as a collar into each pile hole, providing a factor of safety against overturning.
- A separate, nonstructural parking pad was poured below the structure.



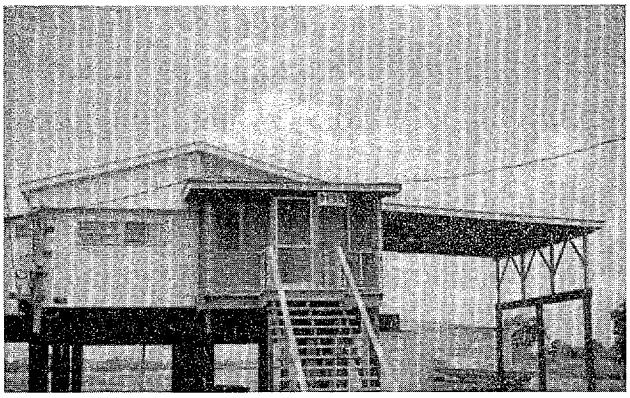
This 1,100-SF residential elevation project was accomplished in five days.

Elevation on Piles

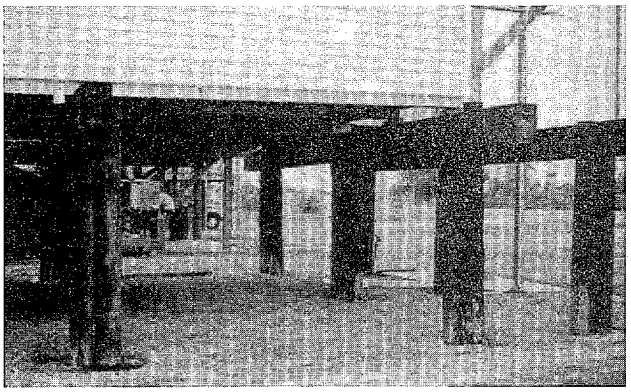
Cocodrie, Louisiana

Cost of Floodproofing: $12,500

- Bayou Laesione property located in designated Coastal High Hazard Area (Zone V).
- Double-pile foundation system eliminates need for cross bracing, and creates a continuous connection from the superstructure to the ground.

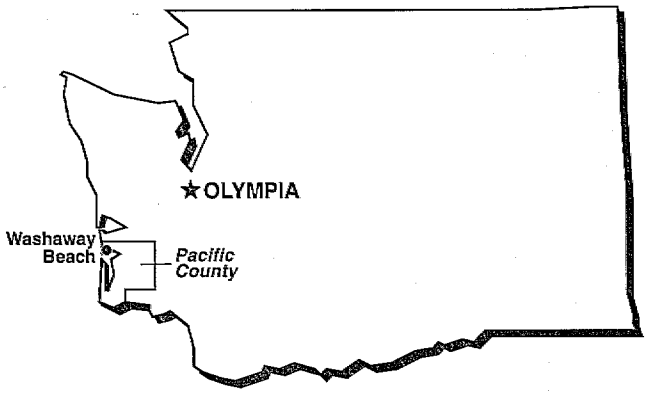


Residence on Bayou Laesione elevated on wood piles placed in pairs.



Each pair of piles is connected with bolts.

The cross beams supporting the structure rest on one pile and are bolted into the second pile with a steel T-strap.



Many homes along the West Coast are located on bluffs and are subject to severe erosion. Because the homes are above the BFE, most owners have not taken advantage of benefits under the NFIP's Upton-Jones Amendment. An exception to this situation is in the Cape Shoalwater area of Washington, which is thought to be experiencing the most rapid erosion rate in the U.S., from 100 to 300 feet per year.

Regulatory Environment:

- Pacific County, an area where low-income housing is falling into the ocean, passed an ordinance defining the erosion zone based on U.S. Army Corps of Engineers projections.
- Pacific County is educating homeowners about the benefits available under the NFIP and Upton-Jones. Homes being relocated must be upgraded to meet the Uniform Building Code and new septic requirements, adding significantly to the cost of relocating.

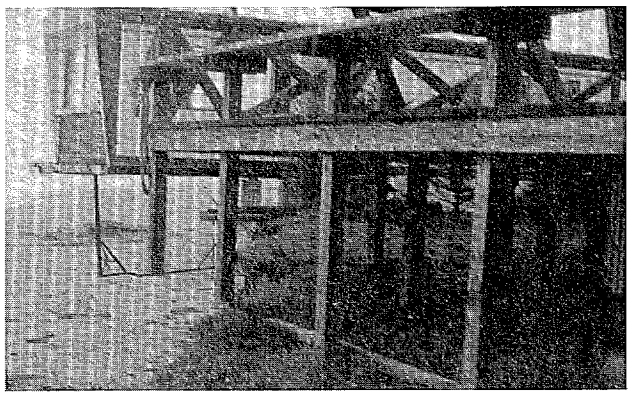
FLOODPROOFING PROJECTS OBSERVED

Relocation

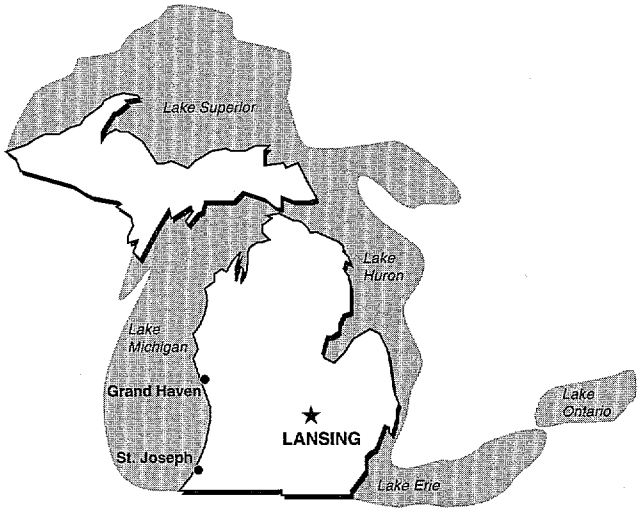
Washaway Beach, Washington

Cost of Floodproofing: $12,000-$15,000 (estimated range)

- Low-income neighborhood in Zone D (undetermined flood hazard; subject to severe erosion) has lost many homes to erosion in the last 20 years.
- Homes are located in an area recently designated by the community as an erosion zone. Community has made homeowners aware of their potential eligibility to relocate under Upton-Jones.
- Six homes have been relocated, with an average house-moving cost of $3,000; however, local requirements to upgrade relocated homes to meet building code and septic requirements have escalated the cost to up to $15,000.



The Corps of Engineers estimates that Washaway Beach, Washington, is experiencing the fastest rate of coastal erosion in the U.S.



Along the bluffs overlooking the Great Lakes, erosion has created such a threat to life and property that Michigan enacted an emergency program to move homes away from the coast. Some homeowners were able to combine benefits from this state program and its federal successor, the NFIP's Upton-Jones Amendment, to relocate their homes.

Regulatory Environment:

- Shorelands Protection and Management Act regulates construction in so-called high-risk erosion areas, environmental areas, and flood risk areas along the Great Lakes.
- State has documented average long-term erosion rates for entire Great Lakes shoreline and established 30-year bluffline erosion setbacks.
- From 1985 to early 1987, the state administered the Great Lakes Emergency Home Moving Program (EHMP) and the Great Lakes Flood Protection Program. The EHMP provided low-interest loans for relocation or protection of structures in danger of destruction by coastal erosion or flooding. The Flood Protection Program provided loans to elevate structures above the BFE.

FLOODPROOFING PROJECTS OBSERVED

Relocation

St. Joseph, Michigan

Cost of Floodproofing: $28,241

- Property in a state-designated high-risk erosion area with 130-foot setbacks along Lake Michigan.
- House foundation was 52 feet from the edge of a rapidly eroding, 150-foot-tall bluff on a 500-foot-deep lot.

The Upton-Jones Amendment

Claim payments could be made for relocation or demolition when a building met the following criteria:

1. *It was covered by a flood insurance policy for a minimum of two consecutive years prior to condemnation or certification or from date of ownership if less than two years.*
2. *It was condemned by a state or local authority, or certified to be subject to imminent collapse by an eligible state authority; and*

St. Joseph, Michigan (Continued)

- State EHMP loan financed relocation of the home 300 feet back from its former position. Effort involved moving the house and garage intact, excavating a new basement, placing the home, block and concrete work, and backfilling.

Relocation

Grand Haven, Michigan

Cost of Floodproofing: $25,500

- Property in a state-designated high-risk erosion area with 70-foot setbacks on the bluff edge of Lake Michigan.
- Owner utilized a combination of subsidized loans under EHMP and funds available under Upton-Jones to relocate vacation home landward on a 500-foot-deep lot.
- Effort involved demolishing a guest cottage on the property, moving the main house and garage, construction of a new full basement, pouring of concrete for a garage slab, and removal of trees.

The Upton-Jones Amendment (Continued)

3. It was within an identified zone of imminent collapse.

A zone of imminent collapse was defined as an area experiencing erosion adjacent to the shoreline of an ocean, bay, lake, or river and defined by a setback distance equal to 10 feet plus five times the average annual long-term erosion rate for the site.

This distance was measured landward from a reference feature, typically the top edge of a bluff, top edge of an escarpment on an eroding dune, or, if such features were not present, the normal high-water line, indicated by the vegetation line, beach scarp, debris line, or limit of wet sand. Exceptions to these criteria were allowed at the discretion of the FIA Administrator in cases of unusual erosion conditions. Upton-Jones was repealed in 1994.

Erosion of bluffs overlooking the Great Lakes has caused an immediate hazard to many lakefront homes. Some were certified as being in danger of imminent collapse and were eligible for federal assistance under Upton-Jones to be relocated.

Through additional site visits and contact with federal, state, and local officials, FEMA learned of several other state and community programs that regulate and encourage floodproofing of coastal homes.

New York

- State Environmental Conservation Law provides the following:
  - Standards for minimizing and preventing damage to structures and natural resources from coastal flooding and erosion.
  - Regulations for land use and development activities in these areas.
  - Restrictions on public investment in services, facilities, or activities that are likely to encourage new permanent development in erosion hazard areas. State Department of Environmental Conservation is required to establish a 40-year set-back in structural hazard areas.
- State has mapped a tidal floodplain overlay district based on the U.S. Army Corps of Engineers' standard project hurricane storm.
- Town of Southampton adopted a coastal erosion management program and dune setback ordinance prohibiting new construction or replacement of buildings and structures in or on a dune area. A 100-foot landward setback for new and replacement buildings with ocean beach water frontage and a 75-foot landward setback for all other tidal water frontages apply.

New Jersey

- State Department of Environmental Protection and Energy has developed coastal area management regulations relating to erosion hazard areas and construction setbacks.
- State's attempt to expand the coverage of the Coastal Area Facility Review Act through emergency regulations was held judicially invalid in 1991.

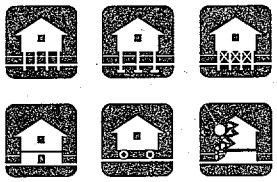
Ohio

- State Department of Natural Resources establishes and regulates 30-year erosion hazard setback area along Lake Erie.

Rhode Island

- Coastal Resources Management Council has discretion in regulation and permitting on each case of coastal construction.

POLICY CONCLUSIONS



The technology and resources exist for successful, cost-effective floodproofing of coastal homes. The two most effective methods are elevating the home above the flood hazard or relocating it out of harm's way. Some homeowners have opted for an alternative to floodproofing such as demolishing their homes; others are taking no action to reduce damages: letting nature take its course, and relying on flood insurance coverage and disaster assistance, if available.

INVESTIGATION CONCLUSIONS

The NFIP's requirement to elevate the lowest floor of new or substantially improved homes to or above the BFE has proved effective in mitigating damage to structures from flooding. Where coastal flooding has occurred, structures elevated to or above the BFE are typically minimally damaged–if damaged at all–when compared to neighboring non-elevated structures or structures elevated to lower levels built prior to their communities' implementing NFIP requirements.

Although FEMA can play a role in providing the regulatory framework (as well as technical documents and technical guidance in specific instances) for successful coastal floodproofing programs, the community determines if floodproofing projects succeed. It is the community that must adopt and enforce NFIP requirements or elect to enforce requirements more stringent than the NFIP's. Local building officials, by reviewing plans, issuing building permits, and monitoring construction, can assure that floodproofing is completed in accordance with NFIP and local requirements. Where the state has become involved in floodplain management, the rate of success has been even higher. In areas where local governments have created a receptive environment to floodproofing, floodproofing projects often are carried out in greater numbers at lower costs.

Homeowners sometimes face obstacles to floodproofing. When elevating or relocating a structure, it can be expensive

By reaching the public and building industry through education and awareness programs, the community can have a profound impact in encouraging owners of flood- or erosion-prone structures to floodproof.

to upgrade components of the building not associated with providing flood protection such as electricity or plumbing to comply with local codes. These costs can be more than half the total cost of the floodproofing project.

Homeowner motivation also plays a role in the success of floodproofing. Motivation is typically high for floodproofing immediately after a flood-induced disaster. However, those property owners who have not experienced damage from flooding may not feel the need to floodproof.

GLOSSARY

A Zone: The flood insurance zone designation on Flood Insurance Rate Maps for portions of the 100-year floodplain subject to velocity wave action of less than three feet, also referred to as Special Flood Hazard Area.

AO Zone: The flood insurance zone designation for portions of the 100-year floodplain where flood depths are identified on Flood Insurance Rate Maps in feet above grade. AO Zone depths range from between one and three feet.

Anchor: To secure a structure to its footings or foundation wall such that a continuous load transfer path is created and so that it will not be displaced by flood or wind forces.

Base Flood Elevation (BFE): The elevation for which there is a one-percent chance in any given year that flood levels will equal or exceed it. The BFE is determined by technical analyses for an area and designated on that area's Flood Insurance Rate Map. It is also known as the 100-year flood.

Coastal High Hazard Area: That portion of the 100-year coastal floodplain subject to storm-driven velocity waves of three feet or more in height. Coastal High Hazard Areas are designated as Zone V on Flood Insurance Rate Maps.

Crawl Space: Low space below the first floor of a house where there has not been excavation deep enough for a basement, but where there is often access for pipes, ducts, and utilities.

Elevation: Raising a structure to place it above anticipated flood waters on an extended support structure (foundation).

Episodic Erosion: Erosion induced by a single storm event. Episodic erosion considers the vertical component of two factors: 1) general beach profile lowering; and 2) localized conical scour around foundation supports. Episodic erosion is relevant to foundation embedment depth and potential undermining.

Extended Foundation Walls: Additional walls constructed above existing foundation walls in order to elevate a structure above flood levels.

Federal Emergency Management Agency (FEMA): Agency created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness, response, and recovery. FEMA administers the National Flood Insurance Program.

Federal Insurance Administration: The component of FEMA directly responsible for administering the flood insurance aspects of the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM): Map produced by FEMA for a community that distinguishes flood hazard zones, including the 100-year floodplain.

Floodproofing: Structural or nonstructural changes or adjustments included in the design, construction, or alteration of a building to reduce flooding and erosion damage to the building and its contents.

Footing: The enlarged base of a foundation wall, pier, or column, designed to spread the load of the structure so that it does not exceed the soil bearing capacity.

Hydrodynamic Loads: Forces imposed on an object, such as a building, by water moving around it. Among these loads are positive frontal pressure against the structure; drag effect along the sides; and negative pressure on the downstream side.

Hydrostatic Loads: Forces imposed on a surface, such as a wall or floor slab, by a standing mass of water. The water pressure increases with the square of the water depth.

Impact Loads: Forces imposed on a structure by solid objects or masses carried by or floating on the moving water surface.

Jetting of Piles: The use of high-pressure water to place a pile in sandy soil by forcing the sand away from the pile driving direction.

Mitigation Directorate: The component of FEMA directly responsible for administering the floodplain management aspects of the NFIP.

National Flood Insurance Program (NFIP): The federal program, created by an act of Congress in 1968, that makes flood insurance available in communities that enact satisfactory floodplain management regulations. This program is administered by FEMA.

Pier: An upright support member of a building, with a height limited to a maximum of three times its least lateral dimension. It is designed and constructed to function as an independent structural element in supporting and transmitting building and environmental loads to the ground.

Pile: An upright support member of a building, usually long and slender in shape, driven into the ground by mechanical means and primarily supported by friction between the pile and the surrounding earth. Piles often cannot act as individual support units and require bracing to other pilings.

Post: Long upright support units for a building, set in holes backfilled with compacted material. Each post usually requires bracing to other units. They are usually made of wood.

Post-FIRM: For insurance rating purposes, post-FIRM construction means construction or substantial improvement to a structure that started after December 31, 1974, or on or after the effective date of the initial FIRM for a community, whichever is later. For floodplain management purposes, post-FIRM construction means structures for which the start of new or substantial improvement construction commences on or after the effective date of a floodplain management regulation adopted by a community.

Pre-FIRM: For insurance rating purposes, pre-FIRM construction means construction or substantial improvement to a structure that started on or before January 1, 1985, or before effective date of the initial FIRM for a community, whichever is later. For floodplain management purposes, pre-FIRM construction means structures for which the start of new or substantial improvement construction commences before the effective date of a floodplain management regulation adopted by a community.

Relocation: Moving a structure from a flood- or erosion-prone area to a new location where there is a significantly reduced threat of flooding or erosion.

Retrofit: In floodproofing, any change made to a structure designed to reduce or eliminate damages to that structure from flooding or erosion.

Scouring: The removal of unconsolidated sediment by velocity waters. The term is frequently used to describe storm-induced, localized conical erosion around pilings and other foundation supports where flow obstruction increases turbulence.

Shoreline Retreat: Progressive movement of the shoreline in a landward direction caused by the composite effect of all storms considered over decades and centuries (expressed as an annual average erosion rate). Shoreline retreat considers the horizontal component of erosion and is relevant to long-term land use decisions and the siting of buildings.

Slab-on-Grade Building: A structural design where the first floor lies directly on a poured concrete slab that bears directly on the ground.

Special Flood Hazard Area (SFHA): Portion of the floodplain subject to the 100-year flood, also known as the A Zone. In coastal regions, this area is subject to velocity wave action of less than three feet.

Substantial Damage: Damage that has a repair cost equal to or exceeding 50 percent of the market value of the structure either before the improvement is started or, if the structure has been damaged and is being restored, before the damage occurred.

Substantial Improvement: Any repair, reconstruction, or improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure either before the improvement is started, or, if the structure has been damaged and is being restored, before the damage occurred.

Thirty-Year Erosion Setback: A state or local requirement that prohibits new construction and certain improvements and repairs to existing coastal buildings located in an area anticipated to be lost to shoreline retreat over a 30-year period, calculated by multiplying the annual average erosion rate by 30.

Undermining: A process whereby the vertical component of erosion exceeds the base of a building foundation or the level below which the bearing strength of the foundation is compromised.

V Zone: The flood insurance zone designation on FIRMs for the portions of the 100-year floodplain subject to storm-driven velocity waves of three feet or more in height. Also referred to as the Coastal High Hazard Area.

Zone of Imminent Collapse: An area experiencing erosion adjacent to the shoreline of an ocean, bay, lake, or river and defined by a setback distance equal to 10 feet plus five times the average annual long-term erosion rate for the site. This distance is measured landward from a reference feature, typically the top edge of a bluff or the top edge of an escarpment or an eroding dune; or if such features are not present, the normal high-water line, which is indicated by the vegetation line, beach scarp, debris line, or limit of wet sand.

USEFUL READING

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