1 Introduction to Retrofitting

Retrofitting is any change made to an existing structure to reduce or eliminate the possibility of damage to that structure from flooding, erosion, high winds, earthquakes, or other hazards. The focus of this manual is on retrofitting buildings that are subject to flooding. The following sections describe the purpose, audience, and organization of the manual.

1.1 Goals and Intended Users

This manual has been prepared by the Federal Emergency Management Agency (FEMA) with assistance from other groups to assist local governments, engineers, architects, and property owners involved in planning and implementing residential flood retrofitting projects. Its objective is to provide engineering design and economic guidance to engineers, architects, and local code officials about what constitutes technically feasible and cost-effective retrofitting measures for flood-prone residential structures.

NOTE

Other flood-related technical resources are available through Federal agencies such as FEMA, the U.S. Army Corps of Engineers (USACE), and the Natural Resources Conservation Service (NRCS), as well as State, regional, and local agencies.

The focus of this manual is the retrofitting of one- to four-family residences subject to flooding situations without wave action. The manual presents various retrofitting measures that provide both active and passive efforts and employ both dry and wet floodproofing measures. These include elevation of the structure in place, relocation of the structure, construction of barriers (floodwalls and levees), dry floodproofing (sealants, closures, sump pumps, and backflow valves), and wet floodproofing (flood damage-resistant materials and protection of utilities and contents).

WARNING

This manual will provide valuable assistance to the design professional. It is not intended to be used as a code or specification, nor as a replacement for the engineer's or architect's standard of performance.

The goal of this manual is to capture state-of-the-art information and present it in an organized manner. To the maximum extent possible, existing data and current standards have been utilized as the cornerstone of this document. Detailed sections covering the evaluation, planning, and design of retrofitting measures are included along with case studies of completed retrofitting efforts. Methods for performing economic analyses of the various alternatives are presented.

WARNING

Coastal situations subject to wave action are not addressed in this manual. For information on that area, the reader is referred to FEMA's *Coastal Construction Manual* (FEMA P-55, 2011, fourth edition), and the *USACE Shore Protection Manual* (USACE, 1984).

The architect, engineer, or code official must recognize that retrofitting a residential structure influences how that structure reacts to hazards other than those associated with floodwaters, such as wind hazards. A holistic approach should be taken with regards to hazards when possible. Flood-related hazards such as water-borne ice and debris impact forces, erosion forces, and mudslide impacts, as well as non-flood-related hazards such as earthquake and wind forces, should also be considered in the retrofitting process. Retrofitting a structure to withstand only floodwater-generated forces may impair the structure's ability to withstand the multiple hazards mentioned above. Thus, it is important to approach the retrofitting method selection and design process with a multi-hazard perspective.

1.2 Organization of the Manual

This manual has six main chapters and eight appendices.

Chapter 1: Introduction to Retrofitting
This chapter gives a basic overview of the different flood retrofit options. Each option is defined and the pros and cons to each retrofit type are discussed. An overview of the general retrofitting process is also given.

Chapter 2: Regulatory Requirements
This chapter discusses the typical community floodplain management and building code environment. The role of local officials in a retrofitting project, the various tenets of the National Flood Insurance Program (NFIP), and the compatibility of items covered in the International Building Code (IBC) series are discussed.

Chapter 3: Parameters of Retrofitting
This chapter presents the factors that influence retrofitting decisions and the intimate role they play in choosing a retrofit method. The chapter provides two generic retrofitting matrices that were designed to help the designer narrow the range of floodproofing options.

Chapter 4: Determination of Hazards
This chapter gives guidance on how to focus on the specific retrofitting solution that is most applicable for the residential structure being evaluated.

Chapter 5: General Design Practices
This chapter provides step-by-step design processes for each retrofitting measure. (Note: Each retrofitting measure has its own tab and is organized as a subchapter.)

Chapter 6: Case Studies
This chapter is a collection of information on the actual retrofitting of specific residential structures.

Appendix A: Sources of FEMA Funding
This appendix discusses Increased Cost of Compliance Coverage (ICC) and includes a summary of the Hazard Mitigation Assistance (HMA) grant programs and references to additional information.

Appendix B: Understanding the FEMA Benefit-Cost Process
The appendix emphasizes the importance of benefit-cost analysis (BCA) for FEMA grant funding, clarifies the input data required to run a BCA module, and includes references to additional information.

Appendix C: Sample Design Calculations
This appendix includes detailed sample design calculations for elevation, dry floodproofing, wet floodproofing, and floodwall and levee retrofit problems.

Appendix D: Alluvial Fan Flooding
This appendix includes a description of alluvial fan flooding and its associated hazards, along with regulatory and design considerations in alluvial fan flooding areas.

Appendix E: References
This appendix includes a list of references cited throughout this publication.

Appendix F: Other Resources
This appendix includes a list of other resources that may be of interest.

Appendix G: Summary of NFIP Requirements and Best Practices
This appendix includes a table that is a summary of selected key NFIP provisions, and recommended best practices for exceeding the requirements. It cross-references citations from the I-Codes and other publications, including the American Society of Civil Engineers (ASCE) engineering standards.

Appendix H: Acronyms
This appendix includes acronyms used in this publication.

Icons

Throughout this manual, the following icons are used, indicating:

Special Note: Significant or interesting information

Terminology: Definition or explanation of pertinent terms

Cross Reference: Reference to another relevant part of the text or another source of information

Equation: Use of a mathematical equation

Warning: Special cautions need to be exercised

1.3 Methods of Retrofitting

Retrofitting measures for flood hazards include the following:

Elevation: The elevation of the existing structure on fill or foundation elements such as solid perimeter walls, piers, posts, columns, or pilings.

Relocation: Relocating the existing structure outside the identified floodplain.

Dry Floodproofing: Strengthening of existing foundations, floors, and walls to withstand flood forces while making the structure watertight.

CROSS REFERENCE

See page 1-18 for general cautions to consider in the implementation of a retrofitting measure.

COST

Cost is an important factor to consider in elevating structures. As an example, lighter wood-frame structures are easier and often cheaper to raise than masonry structures. Masonry structures are not only more expensive to raise, but are also susceptible to cracks.

Wet Floodproofing: Making utilities, structural components, and contents flood- and water-resistant during periods of flooding within the structure.

Floodwalls/Levees: The placement of floodwalls or levees around the structure.

Retrofitting measures can be passive or active in terms of necessary human intervention. Active or emergency retrofitting measures are effective only if there is sufficient warning time to mobilize labor and equipment necessary to implement the measures. Therefore, every effort should be made to design retrofitting measures that are passive and do not require human intervention to implement protection.

1.3.1 Elevation

Elevating a structure to prevent floodwaters from reaching damageable portions is an effective retrofitting technique. The structure is raised so that the lowest floor is at or above the Design Flood Elevation (DFE) to avoid damage from a base flood. Heavy-duty jacks are used to lift the existing structure. Cribbing supports the structure while a new or extended foundation is constructed below. In lieu of constructing new support walls, open foundations such as piers, posts, columns, and piles are often used. Elevating a structure on fill may also be an option in some situations. Closed foundations are not permitted in Zone V or Coastal A Zones.

While elevation may provide increased protection of a structure from floodwaters, other hazards must be considered before implementing this strategy. Elevated structures may encounter additional wind forces on wall and roof systems, and the existing footings may experience additional loading. Extended and open foundations (piers, posts, columns, and piles) are also subject to undermining, movement, and impact failures caused by seismic activity, erosion, scour, ice or debris flows, mudslides, and alluvial fan forces, among others.

NOTE

FEMA strongly encourages that flood retrofits provide protection to the DFE (or BFE plus 1 foot, whichever is higher). However, there may be situations where it is appropriate for the flood protection level to be lower. Homeowners and design professionals should meet with a local building official to discuss the selected retrofit measure and the elevation to which it will protect the home. The text and examples in this manual assume flood protection measures will be implemented to the DFE.

TERMINOLOGY: BASE FLOOD

Base flood is defined as the flood having a 1-percent chance of being equaled or exceeded in any given year. The Base Flood Elevation (BFE) is the elevation to which floodwaters rise during a base flood.

TERMINOLOGY: DFE

DFE is the regulatory flood elevation adopted by a local community. Typically, the DFE is the BFE plus any freeboard adopted by the community. The Flood Protection Elevation (FPE) or Flood Protection Level (FPL) is equal to the DFE (or BFE + 1 foot, whichever is higher). This manual uses the DFE.

1.3.1.1 Elevation on Solid Perimeter Foundation Walls

Elevation on solid perimeter foundation walls is normally used in areas of low to moderate water depth and velocity. After the structure is raised from its current foundation, the support walls can often be extended vertically using materials such as concrete masonry units (CMU) or cast-in-place concrete. Figure 1-1 shows an elevation on solid perimeter foundation walls and Figure 1-2 shows a home elevated on extended foundation walls. The structure is then set down on the extended walls. While this may seem to be the easiest solution to the problem of flooding, there are several important considerations.

NOTE

Refer to FEMA 347, *Above the Flood: Elevating Your Floodprone House* (FEMA, 2000), for details on the elevation of residential structures.

Depending on the structure and potential environmental loads (such as flood, wind, seismic, and snow), new, larger footings may have to be constructed. It may be necessary to reinforce both the footings and the walls using steel reinforcing bars to provide needed structural stability.

Deep floodwaters can generate loads great enough to collapse the structure regardless of the materials used. Constructing solid foundation walls with openings or vents will help alleviate the danger by allowing hydrostatic forces to be equalized on both sides. For new and substantially damaged or improved buildings, flood openings are required under the NFIP.

Figure 1-1. Elevation on solid perimeter foundation walls

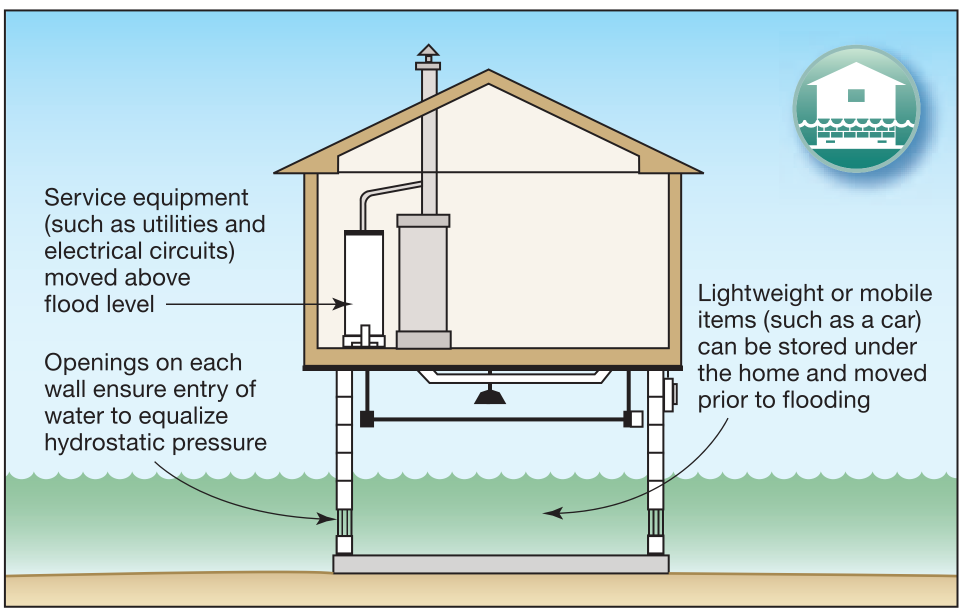


Figure 1-2.
Elevation of existing residence on extended foundation walls

1.3.1.2 Elevation on Open Foundation Systems

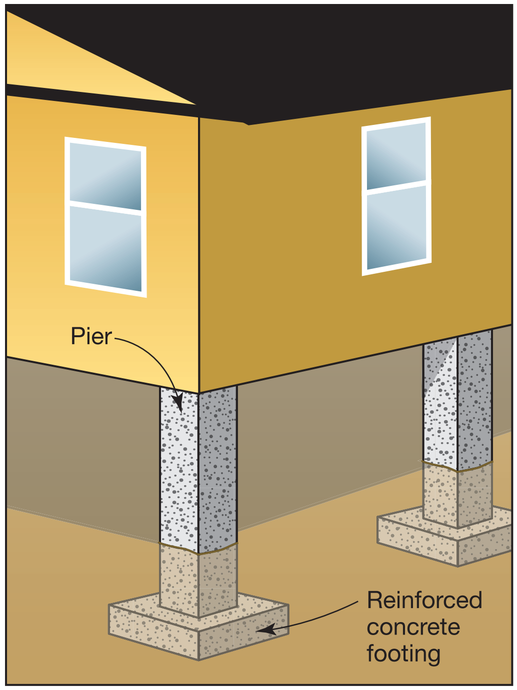
Open foundation systems are vertical structural members that support the structure at key points without the support of a continuous foundation wall. Open foundation systems include piers, posts, columns, and piles.

Elevation on Piers

The most common example of an open foundation is piers, which are vertical structural members that are supported entirely by reinforced concrete footings. Despite their popularity in construction, piers are often the elevation technique least suited for withstanding significant horizontal flood forces. In conventional use, piers are designed primarily for vertical loading. However, when exposed to flooding, piers may also experience horizontal loads due to moving floodwater or debris impact forces. Other environmental loads, such as seismic loads, can also create significant horizontal forces. For this reason, piers used in retrofitting must not only be substantial enough to support the vertical load of the structure, but also must be sufficient enough to resist a range of horizontal forces that may occur.

Piers are generally used in shallow depth flooding conditions with low-velocity ice, debris, and water flow potential, and are normally constructed of either CMU or cast-in-place concrete. In either case, steel reinforcing should be used for both the pier and its support footing. The reinforced elements should be tied together to prevent separation. There must also be suitable connections between the superstructure and piers to resist seismic, wind, and buoyancy (uplift) forces. Overturning can occur from the combination of vertical and horizontal forces on a shallow depth pier foundation. Figure 1-3 shows a schematic of a residential structure on piers.

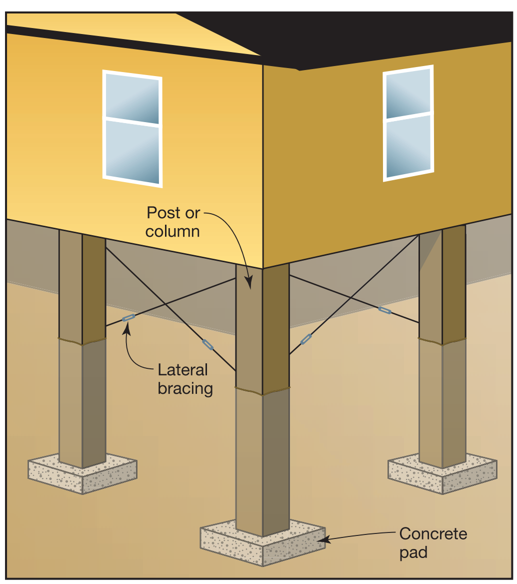
Figure 1-3.
Elevation on piers



Elevation on Posts or Columns

Elevation on posts or columns is frequently used when flood conditions involve moderate depths and velocities. Made of wood, steel, or precast reinforced concrete, posts are generally square-shaped to permit easy attachment to the house structure. However, round posts may also be used. Set in pre-dug holes, posts are usually anchored or embedded in concrete pads to handle substantial loading requirements. Concrete, earth, gravel, or crushed stone is usually backfilled into the hole and around the base of the post.

Figure 1-4.
Elevation on posts or columns



NOTE

Columns differ from posts in the size of their application. Posts are small columns.

While piers are designed to act as individual support units, posts normally must be braced. There are a variety of bracing techniques such as wood knee and cross bracing, steel rods, and guy wires. Cost, local flood conditions, loads, the availability of building materials, and local construction practices frequently influence which technique is used. Figure 1-4 shows an example of a post and column foundation.

Elevation on Piles

Piles differ from posts in that they are generally driven, jetted, or set (augured) deeper into the ground. As such, they are less susceptible to the effects of high-velocity floodwaters, scouring, and debris impact. Piles must either rest on a support layer, such as bedrock, or be driven deep enough to create enough friction to transfer the anticipated loads to the surrounding soil. Piles are often made of wood, although steel and reinforced precast or prestressed concrete are also common in some areas. Similar to posts, they may also require bracing.

Because driving piles generally requires bulky, heavy construction machinery, the effort to replace the foundation often requires that an existing home be moved off the foundation, set on cribbing until the operation is complete, and then replaced. The additional cost and space needs often preclude the use of piles in areas where alternative elevation methods for retrofitting are technically feasible.

Several innovative methods have been developed for setting piles. These include jetting exterior piles in at an angle using high-pressure water flow, and trenching, or auguring, holes for interior pile placement. Augured piles utilize a concrete footing for anchoring instead of friction forces. This measure requires that the existing home be raised several feet above its final elevation to allow room for workers to install the piles. Jetting and auguring piles reduces the uplift capacity compared to driven piles. Figures 1-5 and 1-6 show homes elevated on piles.

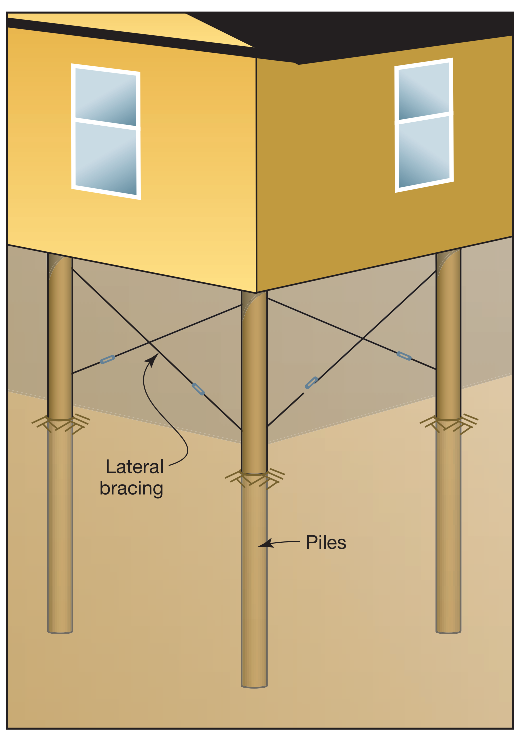


Figure 1-5. Elevation on piles

Figure 1-6.
Structure elevated on piles

Table 1-1 provides advantages and disadvantages associated with elevating a home.

Table 1-1. Advantages and Disadvantages of Elevation

Advantages	Disadvantages
Brings a substantially damaged or improved building into compliance with the NFIP if the lowest horizontal structural member of the lowest floor is elevated to the BFE	May be cost-prohibitive
Reduces flood risk to the structure and its contents	May adversely affect the structure's appearance
Eliminates the need to relocate vulnerable items above the flood level during flooding	Does not eliminate the need to evacuate during floods
Often reduces flood insurance premiums	May adversely affect access to the structure
Uses established techniques	Cannot be used in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion unless special measures are taken
Can be initiated quickly because qualified contractors are often readily available	May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems
Reduces the physical, financial, and emotional strains that accompany flood events	Requires consideration of forces from wind and seismic hazards and possible changes to building design
Does not require the additional land that may be needed for floodwalls or levees	

NFIP = National Flood Insurance Program BFE = Base Flood Elevation

1.3.2 Relocation

Relocation involves moving a structure to a location that is less prone to flooding or flood-related hazards such as erosion. The structure may be relocated to another portion of the current site or to a different site. The surest way to eliminate the risk of flood damage is to relocate the structure out of the floodplain. Relocation normally involves placing the structure on a wheeled vehicle, as shown in Figure 1-7. The structure is then transported to a new location and set on a new foundation.

Figure 1-7. Structure placed on a wheeled vehicle for relocation to a new site

Relocation is an appropriate measure in high hazard areas where continued occupancy is unsafe or owners want to be free from flood worries. It is also a viable option in communities that are considering using the resulting open space for more appropriate floodplain activities. Relocation may offer an alternative to elevation for substantially damaged structures that are required under local regulations to meet NFIP requirements.

Relocation of a structure requires steps that typically increase the cost of implementing this retrofitting method compared to elevation. These additional costs include moving the structure to its new location, purchase and preparation of a new site to receive the structure (with utilities), construction of a new foundation, and restoration of the old site. Most types and sizes of structures can be relocated either as a unit or in segments. One-story wood-frame houses are usually the easiest to move, particularly if they are located over a crawlspace or basement that provides easy access to floor joists. Smaller, lighter wood-frame structures may also be lifted with ordinary house-moving equipment and often can be moved without partitioning. Homes constructed of brick, concrete, or masonry are also movable, but usually with more difficulty and increased costs. A schematic of a home prepared to be relocated is shown in Figure 1-8.

Structural relocation professionals should help owners to consider many factors in the decision to relocate. The structural soundness should be thoroughly checked and arrangements should be made for temporary housing and storage of belongings. Many States and communities have requirements governing the movement of structures in public rights-of-way.

Figure 1-8.
Structure to be relocated

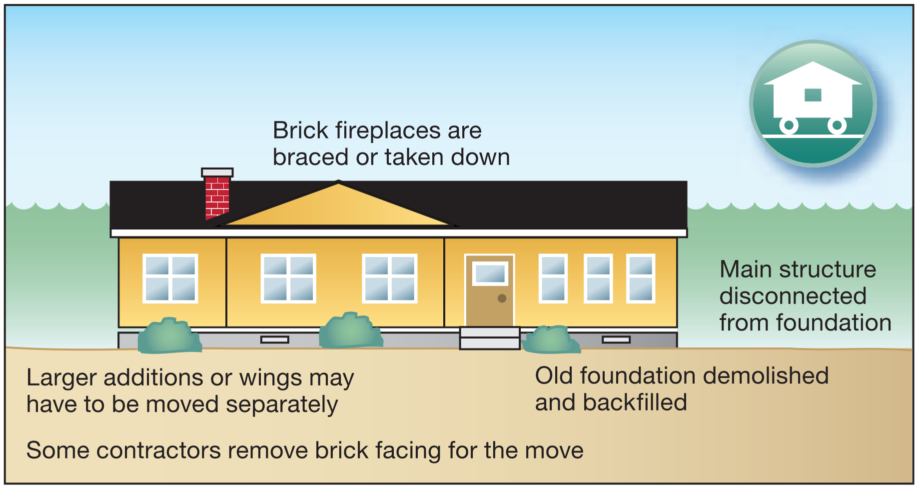


Table 1-2 provides advantages and disadvantages associated with relocating a home.

Table 1-2. Advantages and Disadvantages of Relocation

Advantages	Disadvantages
Allows substantially damaged or improved structure to be brought into compliance with the NFIP	May be cost-prohibitive
Significantly reduces flood risk to the structure and its contents	A new site must be located
Uses established techniques	Requires addressing disposition of the flood-prone site
Can be initiated quickly because qualified contractors are often readily available	May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems
Can eliminate the need to purchase flood insurance or reduce the premium because the home is no longer in the floodplain	
Reduces the physical, financial, and emotional strains that accompany flood events	

NFIP = National Flood Insurance Program

1.3.3 Dry Floodproofing

In dry floodproofing, the portion of a structure that is below the DFE (walls and other exterior components) is sealed to make it watertight and substantially impermeable to floodwaters. Such watertight impervious membrane sealant systems can include wall coatings, waterproofing compounds, impermeable sheeting and, supplemental impermeable wall systems, such as cast-in-place concrete. Doors, windows, sewer and water lines, and vents are closed with permanent or removable shields or valves. Figure 1-9 is a schematic of a dry floodproofed home.

The expected duration of flooding is critical when deciding which sealant systems to use because seepage can increase over time, rendering the floodproofing ineffective. Waterproofing compounds, sheeting, or

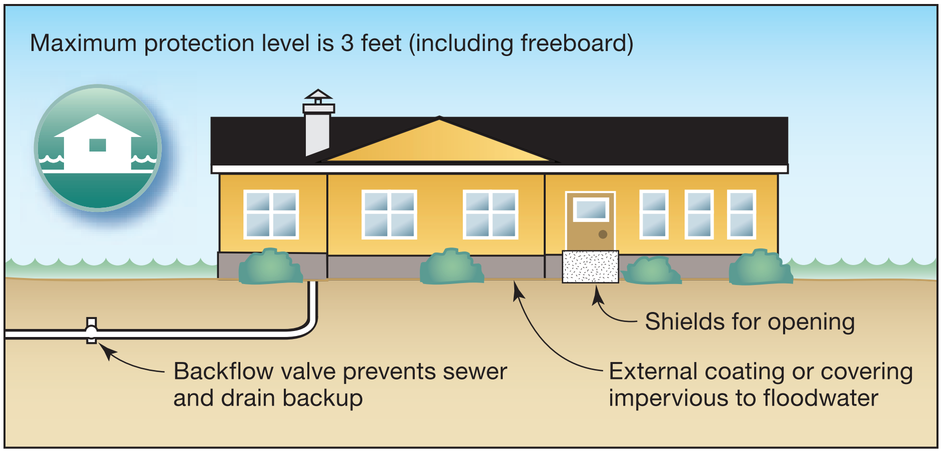


Figure 1-9. Dry floodproofed structure

sheathing may fail or deteriorate if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, or ice or debris flow. The USACE National Flood Proofing Committee has investigated the effect of various depths of water on masonry walls. The results of their work show that, as a general rule, no more than 3 feet of water should be allowed on a non-reinforced concrete block wall that has not previously been designed and constructed to withstand flood loads. Therefore, application of sealants and shields should involve a determination of the structural soundness of a building and its corresponding ability to resist flood and flood-related loads. An engineer should be involved in any design of dry floodproofing mitigation systems so that they can evaluate the building and run calculations to determine the appropriate height of dry floodproofing. Research in this subject area is available in *Flood Proofing Tests – Tests of Materials and Systems for Flood Proofing Structures* (USACE, 1988).

WARNING

Dry floodproofing is not allowed under the NFIP for new and substantially damaged or improved residential structures located in a SFHA. Additional information on dry floodproofing can be obtained from FEMA Technical Bulletin 3-93, *Non-Residential Floodproofing Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP* (FEMA, 1993). Non-residential techniques are also applicable in residential situations.

Table 2 of FEMA's NFIP Technical Bulletin 2-08, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (FEMA, 2008a), provides class ratings with regards to flood damage-resistance for standard construction materials. It needs to be noted, however, that the materials are deemed "acceptable" and "unacceptable" for use below the BFE in a Special Flood Hazard Area (SFHA) within the confines of the NFIP. The NFIP does not allow for dry floodproofing for new and substantially damaged or improved residential structures located in a SFHA. Table 1-3 provides advantages and disadvantages associated with dry floodproofing a home.

WARNING

Even brick or concrete block walls should not be floodproofed above a height of 3 feet (without an extensive engineering analysis) due to the danger of structural failure from excessive hydrostatic and other flood-related forces.

Table 1-3. Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
Reduces the flood risk to the structure and contents if the design flood level is not exceeded	Does not satisfy the NFIP requirement for bringing substantially damaged or improved residential structures into compliance
May be less costly than other retrofitting measures	Requires ongoing maintenance
Does not require the extra land that may be needed for floodwalls or reduced levees	Does not reduce flood insurance premiums for residential structures
Reduces the physical, financial, and emotional strains that accompany flood events	Usually requires human intervention and adequate warning time for installation of protective measures
Retains the structure in its present environment and may avoid significant changes in appearance	May not provide protection if measures fail or the flood event exceeds the design parameters of the measure
	May result in more damage than flooding if design loads are exceeded, walls collapse, floors buckle, or the building floats
	Does not eliminate the need to evacuate during floods
	May adversely affect the appearance of the building if shields are not aesthetically pleasing
	May not reduce damage to the exterior of the building and other property
	May lead to damage of the building and its contents if the sealant system leaks

NFIP = National Flood Insurance Program

Dry floodproofing is also not recommended for structures with a basement. These types of structures can be susceptible to significant lateral and uplift (buoyancy) forces. Dry floodproofing may not be appropriate for a wood-frame superstructure; however, in some instances, buildings constructed of concrete block or faced with brick veneer may be considered for dry floodproofing retrofits. Weaker construction materials, such as wood-frame superstructure with siding, will often fail at much lower water depths from hydrostatic forces.

NOTE

The designer should consider incorporating freeboard into the 3-foot height constraint as a factor of safety against structural failure (limiting flood height to a maximum of 2 feet). Other factors of safety might include additional pumping capacity and stiffened walls.

1.3.4 Wet Floodproofing

Another approach to retrofitting involves modifying a structure to allow floodwaters to enter it in such a way that damage to the structure and its contents is minimized. This type of protection is classified as wet floodproofing. A schematic of a home that is wet floodproofed is shown in Figure 1-10.

WARNING

Wet floodproofing is not allowed under the NFIP for new and substantially damaged or improved structures located in a SFHA. Refer to FEMA's Technical Bulletin 7-93, *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in Accordance with the NFIP* (FEMA, 1993).

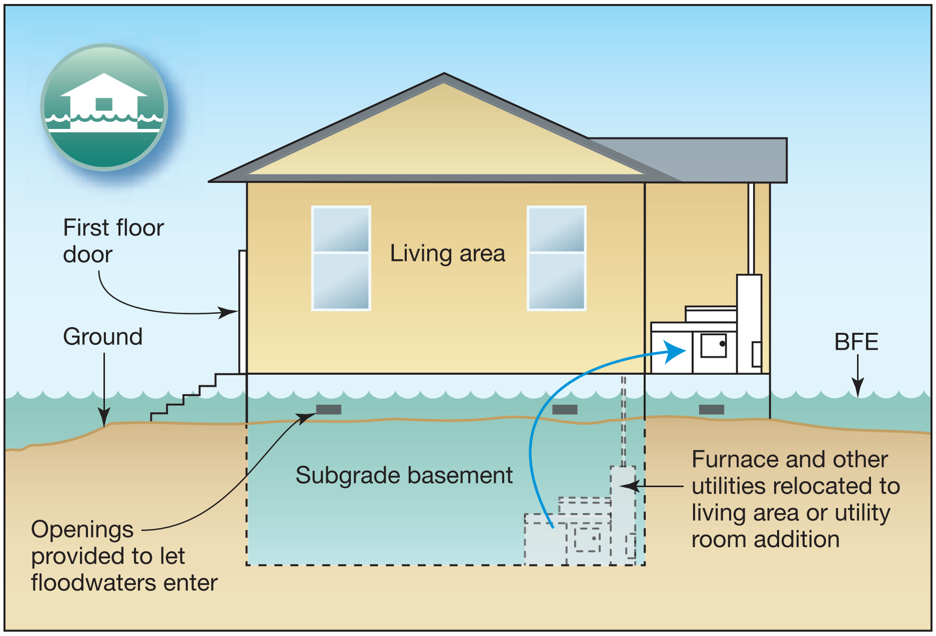


Figure 1-10. Wet floodproofed structure

Wet floodproofing is often used when all other mitigation techniques are technically infeasible or are too costly. Wet floodproofing is generally appropriate if a structure has available space where damageable items can be stored temporarily. Utilities and furnaces may need to be relocated or protected along with other non-movable items with flood damage-resistant building materials. Wet floodproofing may also be appropriate for structures with basements and crawlspaces that cannot be protected technically or cost-effectively by other retrofitting measures.

NOTE

For additional information, refer to FEMA 348, *Protecting Building Utilities From Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems* (FEMA, 1999).

Compared with the more extensive flood protection measures described in this manual, wet floodproofing is generally the least expensive. The major costs of this measure involve the rearrangement of utility systems, installation of flood damage-resistant materials, acquisition of labor and equipment to move items, and organization of cleanup when floodwaters recede. Major disruptions to structure occupancy often result during conditions of flooding.

Table 2 in FEMA's NFIP Technical Bulletin 2-08, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (FEMA, 2008a), provides class ratings with regards to flood damage-resistance for standard construction materials. It needs to be noted, however, that the materials are deemed "acceptable" and "unacceptable" for use below the BFE in a SFHA within the confines of the NFIP. The NFIP does not allow for wet floodproofing for new and substantially damaged or improved residential structures located in a SFHA.

Table 1-4 provides advantages and disadvantages associated with wet floodproofing a home.

Table 1-4. Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
Reduces the risk of flood damage to a building and its contents, even with minor mitigation	Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance
Greatly reduces loads on walls and floors due to equalized hydrostatic pressure	Usually requires a flood warning to prepare the building and contents for flooding
May be eligible for flood insurance coverage of cost of relocating or storing contents, except basement contents, after a flood warning is issued	Requires human intervention to evacuate contents from the flood-prone area
Costs less than other measures	Results in a structure that is wet on the inside and possibly contaminated by sewage, chemicals, and other materials borne by floodwaters and may require extensive cleanup
Does not require extra land	Does not eliminate the need to evacuate during floods
Reduces the physical, financial, and emotional strains that accompany flood events	May make the structure uninhabitable for some period after flooding
	Limits the use of the floodable area
	May require ongoing maintenance
	May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems
	Requires care when pumping out basements to avoid foundation wall collapse

NFIP = National Flood Insurance Program

1.3.5 Floodwalls and Levees

Another retrofitting approach is to construct a barrier between the structure and source of flooding. There are two basic types of barriers: floodwalls and levees. They can be built to any height, but are usually limited to 4 feet for floodwalls and 6 feet for levees due to cost, aesthetics, access, water pressure, and space. Local zoning and building codes may also restrict use, size, and location.

> **NOTE**
>
> Generally, residential floodwalls are only cost-beneficial at providing protection up to 4 feet and levees up to 6 feet, including 1 foot of freeboard.

Floodwalls are engineered barriers designed to keep floodwaters from coming into contact with the structure. Floodwalls can be constructed in a wide variety of shapes and sizes, but are typically built of reinforced concrete and/or masonry materials.

A floodwall can surround an entire structure or, depending on the flood levels, site topography, and design preferences; it can also protect isolated structure openings such as doors, windows, or basement entrances. Floodwalls can be designed as attractive features to a residence, utilizing decorative bricks or blocks, landscaping, and garden areas, or they can be designed for utility at a considerable savings in cost.

Figure 1-11 shows a schematic of a home protected by a floodwall and a levee.

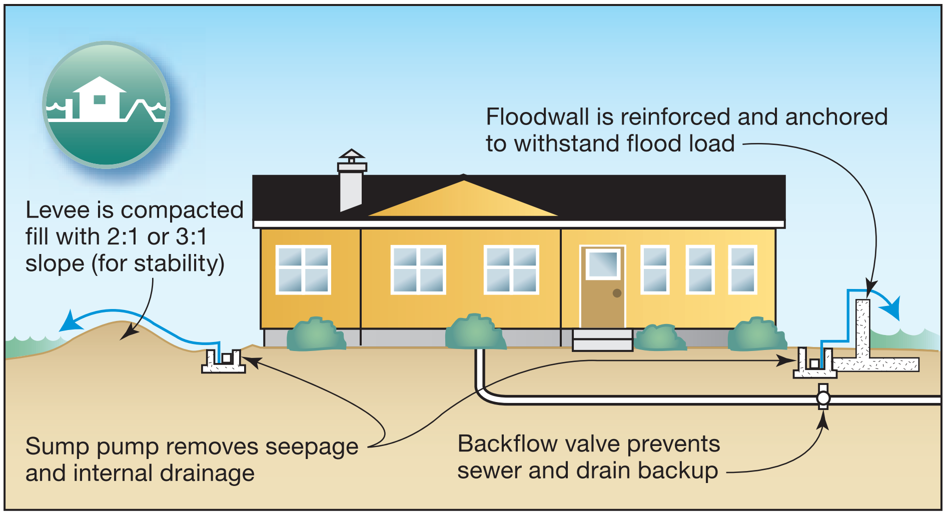


Figure 1-11. Structure protected by floodwall and levee

Because their cost is usually greater than that of levees, floodwalls would normally be considered only on sites that are too small to have room for levees or where flood velocities may erode earthen levees. Some owners may believe that floodwalls are more aesthetically pleasing and allow preservation of site features, such as trees. Figure 1-12 shows a home protected by a levee.

> **WARNING**
>
> While floodwalls and levees are allowed under NFIP regulations, they do not make a non-compliant structure compliant with the NFIP.

A levee is typically a compacted earthen structure that blocks floodwaters from coming into contact with the structure. To be effective over time, levees must be constructed of suitable materials (i.e., impervious soils) and with correct side slopes for stability. Levees may completely surround the structure or tie to high ground at each end.

Figure 1-12. Home protected by a levee

Levees are generally limited to homes where floodwaters are less than 5 feet deep. Otherwise, the cost and the land area required for such barriers usually make them impractical for the average owner.

Special design considerations must be taken into account when floodwalls or levees are used to protect homes with basements because they are susceptible to seepage that can result in hydrostatic and saturated soil pressure on foundation elements.

NOTE

Provisions for closing access openings must be included as part of the floodwall or levee design.

The costs of floodwalls and levees can vary greatly, depending on height, length, availability of construction materials, labor, access closures, and the interior drainage system. A levee could be constructed at a lower cost if the proper fill material is available nearby.

Table 1-5 provides advantages and disadvantages associated with protecting a home with a floodwall or a levee.

Table 1-5. Advantages and Disadvantages of Floodways and Levees

Advantages	Disadvantages
Protects the area around the structure from inundation without significant changes to the structure	Does not satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance
Eliminates pressure from floodwaters that would cause structural damage to the home or other structures in the protected area	May fail or be overtopped by large floods or floods of long duration
Costs less to build than elevating or relocating the structure	May be expensive
Allows the structure to be occupied during construction	Requires periodic maintenance
Reduces flood risk to the structure and its contents	Requires interior drainage
Reduces the physical, financial, and emotional strains that accompany flood events	May affect local drainage, possibly resulting in water problems for others
	Does not reduce flood insurance premiums
	May restrict access to structure
	Requires considerable land (levees only)
	Does not eliminate the need to evacuate during floods
	May require warning and human intervention for closures
	May violate applicable codes or regulations

NFIP = National Flood Insurance Program

1.4 Considerations When Retrofitting

Appropriately applied retrofitting measures have several advantages over other damage reduction methods. Individual owners can undertake retrofitting projects without waiting for government action to construct flood control projects. Retrofitting may also provide protection in areas where large structural projects, such as dams or major waterway improvements, are not feasible, warranted, or appropriate. Some general considerations when implementing a retrofitting strategy include:

- Substantial damage or improvement requirements under the NFIP, local building codes, and floodplain management ordinances render some retrofitting measures illegal.
- Codes, ordinances, and regulations for other restrictions, such as setbacks and wetlands, should be observed.
- Retrofitted structures should not be used nor occupied during conditions of flooding.
- Most retrofitting measures should be designed and constructed by experienced professionals (engineers, architects, or contractors) to ensure proper consideration of all factors influencing effectiveness.
- Most retrofitting measures cannot be installed and forgotten. Maintenance must be performed on a scheduled basis to ensure that the retrofitting measures adequately protect the structure over time.
- Floods may exceed the level of protection provided in retrofitting measures. In addition to implementing these protective measures, owners should consider continuing (and may be required to purchase) flood insurance. In some cases, owners may be required by lending institutions to continue flood insurance coverage.
- When human intervention is most often needed for successful flood protection, a plan of action must be in place and an awareness of flood conditions is required.

1.5 Retrofitting Process

A good retrofitting project should follow a careful path of exploration, fact finding, analysis, detailed design, and construction steps as depicted in Figure 1-13. The successful completion of a retrofitting project will require a series of homeowner coordination and design input meetings. Ultimately, the homeowner will be living with the retrofitting measure, so every effort should be made to incorporate the homeowner's concerns and preferences into the final product. The primary steps in the overall process are shown in Figure 1-13 and discussed in the following steps.

> **NOTE**
>
> Within each of these steps, homeowners are involved in providing input into the evaluations, analyses, decisions, and design concepts to ensure that the final product meets their requirements. Finally, maintenance of the constructed retrofitting measure is the responsibility of the homeowner.

Step 1. Homeowner Motivation: The decision to consider retrofitting options usually stems from having experienced or witnessed a flooding event in or near the structure in question; having experienced substantial damage from a flood or an event other than a flood; or embarking on a substantial improvement, which requires adherence to local floodplain regulations. The homeowner may contact other homeowners, community officials, contractors, or design professionals to obtain information on retrofitting techniques, available technical and financial assistance, and other possible options.

Step 2. Parameters of Retrofitting: The goal of this step is to conduct the necessary field investigations, regulatory reviews, and preliminary technical evaluations to select applicable and technically feasible retrofitting techniques that warrant further analysis.

Step 3. Determination of Hazards: This step involves the detailed analysis of flood, flood-related, and non-flood-related hazards and the evaluation of specific sites and structures to be retrofitted.

Step 4. Benefit-Cost Analysis: This step is critical in the overall ranking of technically feasible retrofitting techniques, and it combines an objective economic analysis of each retrofitting measure considered with any subjective decision factors introduced by the homeowner or others.

Step 5. Design: During this phase, specific retrofitting measures are designed, construction details developed, cost estimates prepared, and construction permits obtained.

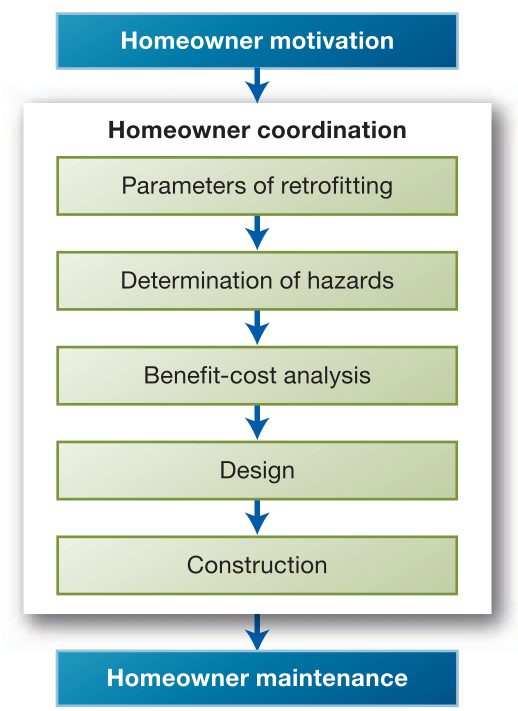
NOTE

You can download the newest version (Version 4.5.5) of the BCA software free of charge from the Web site: http://www.fema.gov/government/grant/bca.shtm#1.

Step 6. Construction: Upon final design approvals, a contractor is selected and the retrofitting measure is constructed.

Step 7. Operation and Maintenance: The development of a well-conceived operation and maintenance plan is critical to the overall success of the project.

Figure 1-13.
Primary steps in retrofitting process



1.5.1 Other Retrofitting Guides

When considering retrofitting a structure, it is important to approach the retrofitting method selection and design process with a multi-hazard perspective. Improvements to a building that are made to increase resistance to the effects of natural hazards should focus on those items that will potentially return the largest benefit to the building owner. If the existing building is considered inadequate to resist natural hazard loads, retrofit improvements should be considered for the following building elements:

- Decks and porches
- Exterior metal (handrails, connectors, etc.)
- Windows and doors
- Foundation
- Exterior equipment
- Roof
- Siding

All relevant hazards to the home need be considered. FEMA has several other retrofit publications available:

- NFIP Technical Bulletins 1 through 11 (available at http://www.fema.gov/plan/prevent/floodplain/techbul.shtm)
- FEMA P-312, *Homeowner's Guide to Retrofitting* (FEMA, 2009a)
- FEMA 232, *Homebuilder's Guide to Earthquake-Resistant Design and Construction* (FEMA, 2006a)
- FEMA 347, *Above the Flood: Elevating Your Floodprone House* (FEMA, 2000a)
- FEMA P-348, *Protecting Building Utilities from Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems* (FEMA, 1999a)
- FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* (FEMA, 2000b) later replaced by ASCE 41-06, *Seismic Rehabilitation of Existing Buildings* (ASCE, 2006)
- FEMA P-499, *Home Builder's Guide to Coastal Construction* (FEMA, 2010a)
  - Technical Fact Sheet Number 9.1: "Repairs, Remodeling, Additions, and Retrofitting – Flood"
  - Technical Fact Sheet Number 9.2: "Repairs, Remodeling, Additions, and Retrofitting – Wind"
- FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (FEMA, 2010b)

Chapter 15 of FEMA P-55, *Coastal Construction Manual* (FEMA, 2011) also discusses retrofit options and solutions for different hazards, as well as the importance of retrofitting with a multi-hazard perspective.

An engineer or design professional should be consulted to ensure that a retrofit project for one hazard type will not impede the structure's resistance to other types of natural hazards.