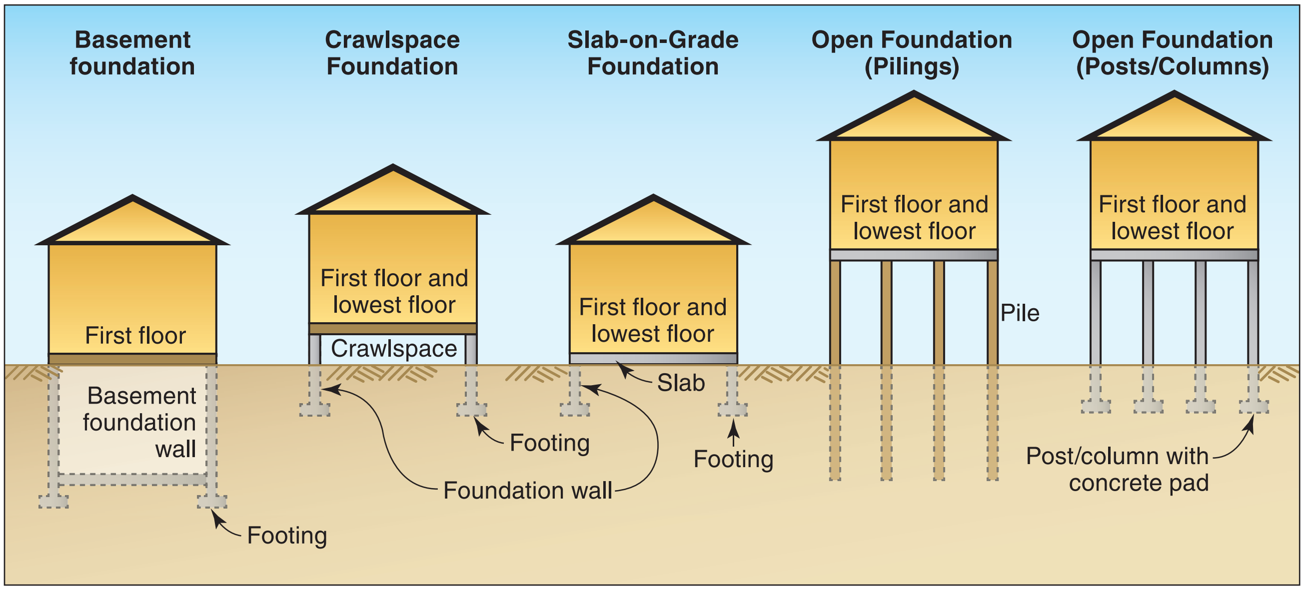


Figure 3-5. Home foundation types.

3.3 Retrofitting Methods and Costs

The following sections give an overview of the six retrofitting methods, explain how they work and where they are appropriate, and list their advantages and disadvantages. With this information, you will be ready for Chapter 4, *Deciding Which Method Is Right for Your Home.*

3.3.1 Elevation

Elevating a home to prevent floodwaters from reaching living areas is an effective retrofitting method. The goal of the elevation process is to raise the lowest floor to or above the DFE. You can do this by elevating the entire home, including the floor, or by leaving the home in its existing position and constructing a new raised floor within the home. The method used depends largely on construction type, foundation type, and flooding conditions. Chapter 5 presents more detailed information on elevation.

During the elevation process, most homes (including manufactured homes) are separated from their foundations, raised on hydraulic jacks, and held by temporary supports while a new or extended foundation is constructed below. This method works well for homes originally built on basement, crawlspace, and open foundations. As explained later in this section, the new or extended foundation can consist of continuous walls or separate piers, posts, columns, or piles.

NOTE

When you elevate your home, the existing foundation will need to be extended or demolished and rebuilt. This decision will depend on the condition of the existing foundation and its ability to carry additional loads.

CROSS REFERENCE

FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations* (FEMA. 2009), offers more detail about these foundation types and elevation.

For homes with slab-on-grade foundations, elevation can be done in one of two ways. One approach is to leave the home attached to the slab foundation and lift both together. After the home and slab are lifted, a new foundation is constructed below the slab. The other approach is to detach the home from the slab and elevate the home, leaving the slab foundation in place. After the home is lifted, a new, elevated floor is constructed.

Unlike other types of construction in which elevation can be relatively straightforward, elevating slab-on-grade homes with the slab intact is technically challenging and often not feasible. When a slab-on-grade home is elevated with the slab intact, the slab, which was previously continuously supported by the soils beneath it, must function as a structural element. It must span the distance between the portions of the foundation that support the elevated home. Typically, these slabs often are either unreinforced or only lightly reinforced with welded wire fabric and are essentially non-structural. These slabs may not be able to support the loads of an elevated home. Consequently, the slab foundation should be thoroughly evaluated by a registered design professional before choosing this mitigation option.

Alternative techniques are available for masonry homes on slab-on-grade foundations. As described later in this section, these techniques do not require the lifting of the home. Instead, they involve raising the floor within the home or moving the living space to an upper story. Guidance for elevating slab-on-grade masonry homes can be found in FEMA P-347, *Above the Flood: Elevating Your Floodprone House* (FEMA. 2000).

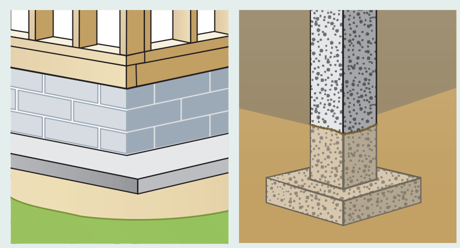
Although elevating a home can help protect it from floodwaters, you need to consider other hazards before choosing this method. Elevating the home can make it more susceptible to damage from earthquakes. In addition, both continuous wall foundations and open foundations can fail as a result of damage caused by erosion and the impact of debris carried by floodwaters. If portions of the original foundation, such as the **footings**, are used to support new walls or other foundation members, or a new second story, they must be capable of safely carrying the additional loads imposed by the new construction and the expected flood, wind, and earthquake forces.

CROSS REFERENCE

FEMA has produced a videotape titled *Best Build 3: Protecting a Flood-Prone Home*, which illustrates the retrofitting methods described in this guide (see Appendix A).

DEFINITION

A **footing** is the base of a foundation. Footings are usually made of concrete and may be reinforced with steel bars. Foundation walls are supported on continuous footings; separate foundation members, such as piers, are supported on individual footings.



NOTE

Elevation on open foundations is required by the NFIP in Zone V areas (even when the ground elevation lies above the BFE) and is strongly recommended for Coastal A Zones. Some States and communities have formally adopted open foundation requirements for Coastal A Zone construction.

Method #1: Elevating on Continuous Foundation Walls

Although this method is usually used in flood hazard areas where the risks of wave action and high-velocity flow are low (Figures 3-6 and 3-7), continuous foundation walls in low-velocity flow areas with wave action can also be susceptible to structural damage. Open foundations should be considered as a reasonable mitigation option. After the home is detached from its foundation and raised on jacks, the existing foundation is often saved and the foundation walls are extended. The new portions of the walls are usually made of masonry block or cast-in-place concrete. Although this method may be the easiest way to elevate a home, it can involve some additional construction modifications or reinforcements.

Figure 3-6. Typical cross-section of home elevated on continuous foundation walls.

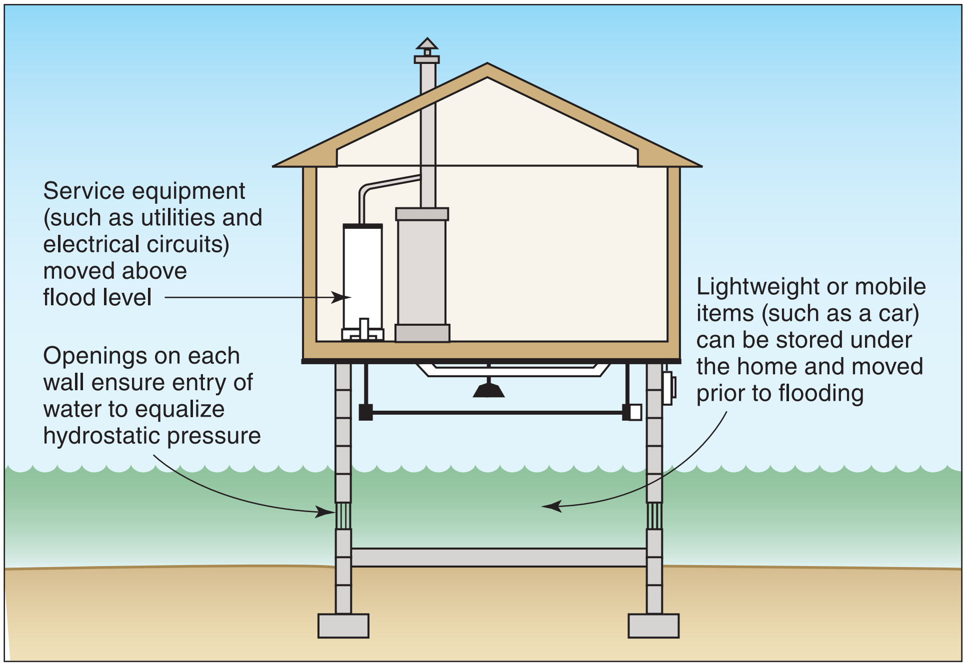


Figure 3-7. Before (left) and after (right) photos of a retrofitted home elevated on extended continuous foundation walls.

Depending on the size of your home, the amount of elevation, and the magnitude of the potential environmental loads (such as those from floods, wind, earthquakes, and snow), your contractor may have to modify or reinforce the footings and foundation walls to ensure the structural stability of the home. The original footings may have to be replaced with ones that have a higher capacity for environmental loads. Both the footings and the foundation walls may need to be reinforced with steel bars.

This type of foundation creates what is referred to under the NFIP as an "enclosure." The enclosure must be constructed of flood damage-resistant materials, have all service equipment elevated above the DFE, and be used only for parking, access, or storage. NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (FEMA. 2008), defines a "flood [damage]-resistant material" as "any building product [material, component, or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage."

"Prolonged contact" means at least 72 hours, and "significant damage" means any damage requiring more than cosmetic repair. Technical Bulletin 2 provides a detailed list of appropriate flood damage-resistant materials and also classifies flood damage-resistance of materials as acceptable or unacceptable based on water resistance and ability to be cleaned.

The enclosure must also be constructed with openings to allow equalization of hydrostatic pressure to comply with NFIP and building code requirements. As explained in Chapter 2, unequalized hydrostatic pressure exerted by floodwaters can collapse walls, regardless of the construction materials used. The NFIP may require that openings be installed in the foundation walls so that water can flow into and out of any enclosed area below the newly elevated home. NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (FEMA. 2008), provides guidance on the NFIP regulations concerning openings in foundation walls. When the water levels on both sides of the foundation walls are the same, the hydrostatic pressure is equalized. If you are elevating your home as part of a Substantial Improvement or in connection with repairs of Substantial Damage, your community's floodplain management ordinance, regulation, or provisions of the building code will require that you install openings in all areas below the BFE. Consult your local officials about local requirements for openings.

Method #2: Elevating on Open Foundations

Unlike continuous foundations, open foundations consist of individual vertical structural members that support the home only at key points. Because they present less of an obstacle to flood flows than continuous walls, open foundations can be used in areas where there are risks of wave action and high-velocity flood. Most open foundations consist of piers, posts, columns, or piles.

Piers. Piers (or columns) are commonly built with masonry block or are made of cast-in-place concrete (Figure 3-8). Piers can be made from wood and steel as well. The bottom of each pier sits on a concrete footing. Pier foundations are used in conventional construction; they are not just a means of elevating a flood-prone home. In conventional use, they are designed primarily for vertical loading—to hold the weight of the home. They are not normally designed to resist large horizontal forces, such as those associated with moving floodwaters, waves, impacts from floodborne debris, wind, and earthquakes. As a result, pier foundations are generally used where the risks of wave action and high-velocity flow are low to moderate and the potential for earthquakes is low.

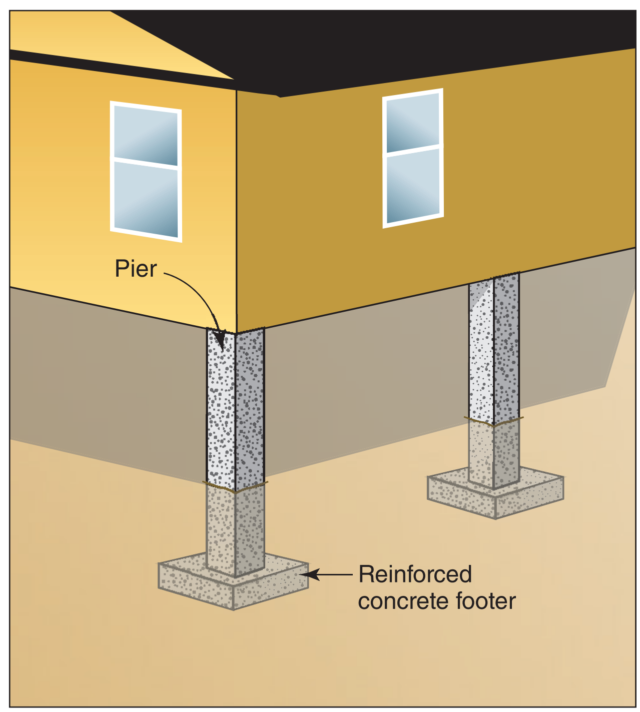


Figure 3-8. Home elevated on reinforced concrete piers.

If you decide to elevate your home on a pier foundation, you should expect your contractor to reinforce the piers and footings with steel reinforcing bars and to connect the piers to the footings so they will not separate under flood or other forces. Adequate connections between the piers and the home are also necessary so that the home and foundation will resist lateral loads from floods, winds, and earthquakes, and uplift from buoyancy.

Posts. Posts are usually made of wood or steel (Figure 3-9). They are generally square but may also be round. Posts are set in holes, and their ends are encased in concrete, or supported on concrete pads (as in the figure). After posts are set, the holes are filled with concrete, dirt, gravel, or crushed stone.

Posts can be connected to each other with bracing made of wood, steel rods, or guy wires. The type is usually determined by cost, flood conditions, expected loads, the availability of materials, and local construction practice. Like piers, posts are generally used where the risks of wave action and high-velocity flow are low to moderate.

One primary difference between piers, and posts is the dimension of the element – piers are larger in cross section because they usually are CMU (concrete masonry unit) or concrete block and are usually shorter than posts. Posts are braced together because they are usually taller and more slender with less stability than piers.

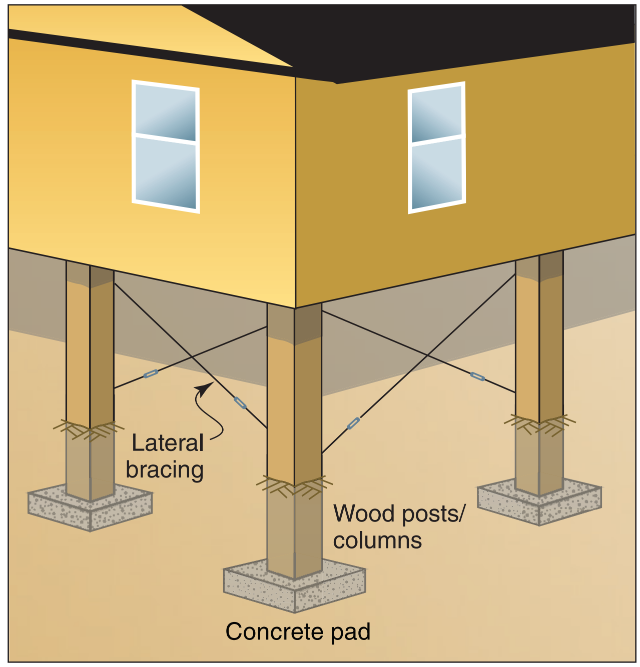


Figure 3-9. Home elevated on posts

Piles. Piles are usually made of wood, but fiber-reinforced polymer, steel, or **precast** concrete piles are also common in some areas (Figure 3-10). Piles are similar to posts but, instead of being set in holes, they are driven into the ground or jetted in with streams of water. Also, piles are embedded deeper in the ground than either piers or posts. As a result, pile foundations are less susceptible to the effects of high-velocity flow, waves, debris impact, erosion, and scour than the other types of open foundations. Piles differ from piers and posts also in that they do not rest on footings. Instead they are driven until they rest on a solid support layer, such as bedrock, or until they are embedded deep enough that the friction between the ground and the piles will enable them to resist the loads that are expected to act on them.

DEFINITION

Concrete materials such as posts, beams, and blocks that are brought to the construction site in finished form are referred to as **precast**.

Jetting is a process in which the hole for the installation of a pile is made by a high-pressure stream of water from a nozzle attached to the bottom of the pile.

Cribbing usually consists of a framework of crisscrossed timbers that provides temporary structural support.

Because driving and **jetting** piles requires bulky, heavy construction machinery, an existing home must normally be moved off its existing foundation and set on **cribbing** until the operation is complete. As a result, elevating a home by placing it on a pile foundation will usually require more space and cost more than elevating with another type of foundation. Pile foundations are used primarily in areas where other elevation methods are not feasible, such as where floodwaters are deep and the risks of wave action and high-velocity flow are great. For example, pile foundations are used extensively in oceanfront areas exposed to high-velocity flow, waves, and high winds (Figure 3-11).

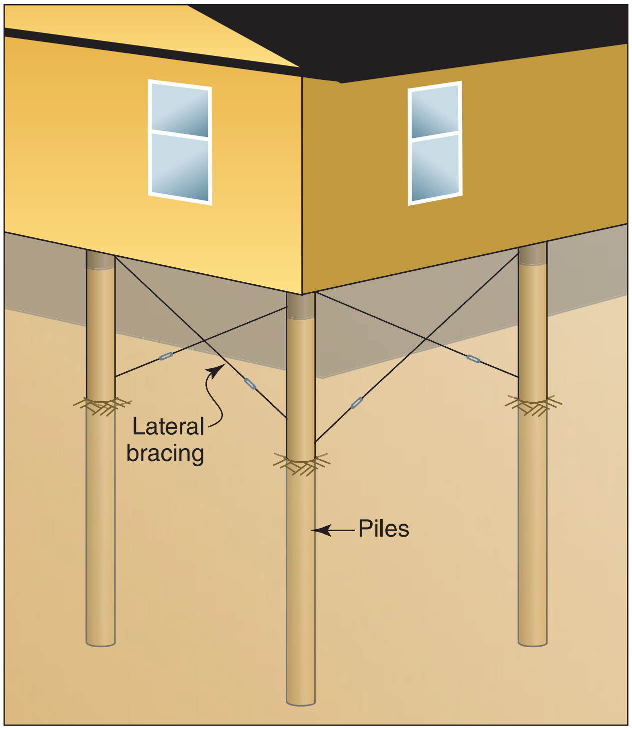


Figure 3-10. Home elevated on piles.

Figure 3-11. Example of well-elevated and embedded pile foundation tested by Hurricane Katrina. Note adjacent building failures (Dauphin Island, AL, 2005).

Methods #3 and #4: Elevating by Extending the Walls of the Home or Moving the Living Space to an Upper Floor

For masonry homes on slab-on-grade foundations, two alternative elevation methods are available. One is to remove the roof, extend the walls of the home upward, replace the roof, and build a new, raised floor at the DFE (Figure 3-12). This technique works best where the floor needs to be raised less than 4 feet to reach the DFE. The floor can be either a new slab or a new wood-framed floor. For a new slab, fill dirt is placed on top of the old slab and the new slab is built on top. If a new wood-framed floor is built, the space between it and the old slab is left open and becomes a crawlspace (and must be retrofitted with openings to allow floodwaters in the crawlspace).

CROSS REFERENCE

As discussed in Section 2.6, the cost of elevating a Substantially Damaged home may be eligible for a flood insurance claim under ICC coverage.

Figure 3-12. The owner of this flood-prone home in south Florida decided to build a new wood-framed second story on top of the masonry first story. The new second story is well above the BFE.

The second technique is to abandon the entire lower floor, or lower enclosed area, of the home and move the living space to an existing or newly constructed upper story. This technique works best for multi-story homes where the DFE is more than 4 feet above the level of the lower floor. The abandoned lower floor or enclosed area is then used only for parking, building access, or storage.

These techniques, like the others, have their limitations. The portions of the home below the DFE will be exposed to flooding and must, therefore, be made of flood damage-resistant materials. That is why this method is applicable to masonry homes rather than frame homes, which would be much more easily damaged by flooding. The area below the DFE cannot be used for living space; it may be used only for parking, building access, or storage. In addition, all appliances and utilities must be moved to the upper floor. Also, openings must be cut into the walls of the lower floor to allow water to enter during flooding so that the hydrostatic pressure on the walls will be equalized. In essence, the lower floor is wet floodproofed (see Section 3.4.1).

Adding a new second story to a single-story home may require that the foundation be strengthened so that it can support the additional load. You must consult an engineer if you plan to use this method. The second story can be frame or masonry (to match the lower floor). The method you choose will depend on the advice of your engineer, cost, appearance, the availability of materials and experienced contractors, and the risks of other natural hazards such as hurricanes and earthquakes.

Table 3-1 presents the advantages and disadvantages of elevation.

The relative costs shown in Table 3-2 are for elevating frame, masonry veneer, and masonry homes of various foundation types. The costs for extending utilities and adding or extending staircases are included. The costs shown for elevating frame, masonry veneer, and masonry homes on existing slab-on-grade foundations are based on the assumption that the home is raised with the existing slab attached.

Table 3-1. 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 • Reduces flood risk to the structure and its contents • Eliminates the need to relocate vulnerable items above the flood level during flooding • Often reduces flood insurance premiums • Uses established techniques • Can be initiated quickly because qualified contractors are often readily available (unless project is implemented immediately after a disaster) • Reduces the physical, financial, and emotional strains that accompany flood events • Does not require the additional land that may be needed for floodwalls or levees	• May be cost-prohibitive • May adversely affect the structure's appearance • May adversely affect access to the structure • Cannot be used in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion, unless special measures are taken • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems • Requires consideration of forces from wind and seismic hazards and possible changes to building design

NFIP = National Flood Insurance Program; BFE = base flood elevation

Table 3-2. Relative Costs of Elevating a Home

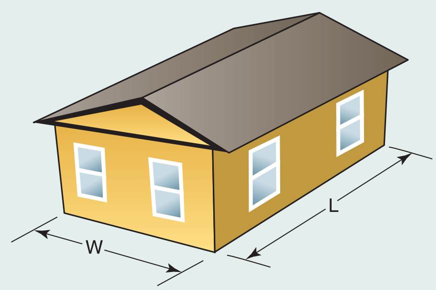
Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame	Basement, crawlspace, or open foundation	Elevate on continuous foundation walls or open foundation	Lowest
Frame with masonry veneer		Elevate on continuous foundation walls or open foundation	
Load bearing masonry		Extend existing walls and create new elevated living area	
Frame	Slab-on-grade	Elevate on continuous foundation walls or open foundation	
Frame with masonry veneer		Elevate on continuous foundation walls or open foundation	
Load bearing masonry		Elevate on continuous foundation walls or open foundation	Highest

Occasionally, slab-on-grade homes are raised without the slab. Although this method can be less expensive than raising the home with the slab, it involves detaching the home from the slab and requires extensive alterations to interior and exterior walls.

The cost of abandoning an existing lower level will depend on whether the home already has an upper level that can be used for living space. If an upper level is available, abandoning the lower floor would involve primarily elevating or relocating utilities, adding openings in the lower-level walls, and ensuring that all construction materials below the BFE are flood damage resistant. This method is well-suited to a home with a walkout-on-grade basement, which can be wet floodproofed and used for parking, building access, or storage. The cost of adding a new frame upper level and raising the roof to accommodate the new level would vary, depending upon the amount of interior finishing and other factors.

DEFINITION

The footprint of a house is the land area it covers (see figure). This area is equal to the length of the house multiplied by its width. Note that the footprint is not necessarily equal to the total square footage of the house.



Footprint = L x W

3.3.2 Relocation and Demolition

Relocation is the retrofitting measure that can offer the greatest security from future flooding. It involves moving an entire structure to another location, usually outside the floodplain. Relocation as a retrofitting measure not only relieves anxiety about future flooding, but also offers the opportunity to reduce future flood insurance premiums. Demolition is tearing down a damaged home. A new compliant home can be rebuilt on site, rebuilt on another property, or the owner can simply move in to another structure elsewhere. These retrofitting methods are discussed below.