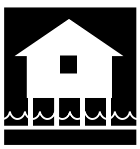
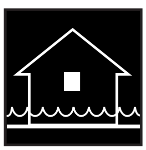
An Overview of the Retrofitting Methods

Introduction

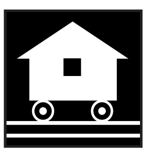
This guide describes six retrofitting methods that you should consider as you think about how to protect your house from flooding:

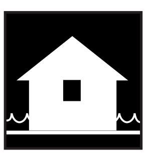
ELEVATION – Raising your house so that the lowest floor is above the flood level. You can do this in one of four ways.



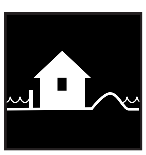
WET FLOODPROOFING – Making uninhabited portions of your house resistant to flood damage and allowing water to enter during flooding.



RELOCATION – Moving your house out of the floodplain to higher ground where it will not be exposed to flooding.



DRY FLOODPROOFING – Sealing your house to prevent flood waters from entering.



LEVEES AND FLOODWALLS – Building a floodwall or levee around your house to hold back flood water.

DEMOLITION– Tearing down your damaged house and either rebuilding properly on the same property or buying or building a house elsewhere.

This chapter describes the six methods in detail. For each method, you will find a section that explains how the method works and where it should and should not be used, lists its advantages and disadvantages, and provides a cost estimate. But first, there are some general cautions about retrofitting that you need to be aware of.

WARNING

In the areas listed below, the hazards to lives and property are usually greater than in other floodprone areas:

- Coastal High Hazard Areas (insurance Zone V, VE, and V1-V30) shown on a Flood Insurance Rate Map (FIRM) (See Figure 2-14.)
- floodways shown on a FIRM (See Figure 2-14.)
- alluvial fan flood hazard areas (Zone AO with depths and velocities) shown on a FIRM
- areas subject to flash floods
- areas subject to ice flows
- areas subject to extremely high-velocity flood flows

Modifying a house to protect it from flood damage in these areas requires extreme care and may also require complex, engineered designs. If your house is in one of these areas, you should consider relocation or demolition (as described later in this chapter and in Chapter 7) rather than any of the other retrofitting methods discussed in this guide. If you have any doubt about whether your house is in an area of unusually severe hazard, consult your local officials.

Cautions

Substantial Damage/Substantial Improvement

As noted in Chapter 2, your community's floodplain management ordinance or law includes restrictions on the types of changes that may be made to a house that has sustained **substantial damage** or that is undergoing **substantial improvement**. These restrictions prohibit or limit the use of some retrofitting measures. Two of the six methods described in this guide – dry floodproofing and levees/floodwalls – may not be used to bring a substantially damaged or substantially improved house into compliance with your community's floodplain management

NOTE

Substantial damage and **substantial improvement** are defined on page 20 and in Appendix B.

ordinance or law. Instead, in accordance, with your community's requirements, you must do one of the following:

- Move the house out of the regulatory floodplain.
- Elevate the house so that its lowest floor is at or above the Base Flood Elevation (BFE).
- Wet floodproof the areas of the house below the BFE and use them only for parking, storage, and building access.
- Demolish the house and either rebuild properly or buy a house elsewhere.

Additional restrictions apply to the use of wet floodproofing. These are described later in this chapter and in Chapter 6.

Another important floodplain management requirement concerns basements. If your house has a basement and your local officials determine that your house is substantially damaged or is being substantially improved, <u>the basement must be eliminated.</u> You can usually do this by filling it with dirt. For floodplain management purposes, the National Flood Insurance Program (NFIP) regulations define a basement as "any area of the building having its floor subgrade on all sides." Your community's floodplain management ordinance or law may include a more restrictive definition of basement.

Note that the NFIP definition of "basement" does not include what is typically referred to as a "**walkout-on-grade**" basement, whose floor would be at or above adjacent grade on at least one side of the building. Depending on your community's floodplain management ordinance or law, the requirement to eliminate the basement in a substantially damaged or substantially improved house may <u>not</u> apply to a walkout-on-grade basement. Instead, you may be able to wet floodproof the basement. However, a wet floodproofed walkout-on-grade basement may be used only for parking, storage, or building access.

Your local officials can tell you more about these restrictions and others that may be specified by local building codes and ordinances (see Chapter 4).

Flood Protection Elevation and Risk

When you retrofit your house, one of the most important things you will do is choose a level of flood protection. In other words, will you protect your house from the base flood, the 500-year flood, or some other flood? In some instances, this decision will be entirely yours; in others, it will depend largely on the regulatory requirements of your community, your state, or both.

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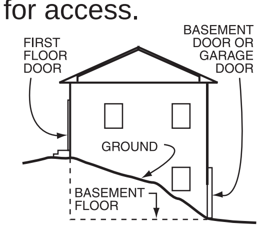
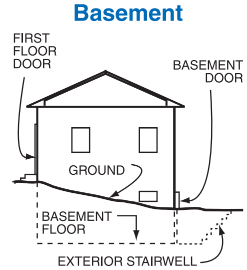
DEFINITION

Walkout-on-grade is a term commonly used to describe a basement whose floor is at ground level on at least one side of a house. The term "walkout" is used because most basements of this type have an outside door or doors (entry door, garage door, or both) at ground level (see figure). Note that a basement whose floor is below grade on all sides (a basement as defined by the NFIP regulations) may still have an outside door, but the door will be below ground level and stairs will be required for access.



Walkout-On-Grade Basement

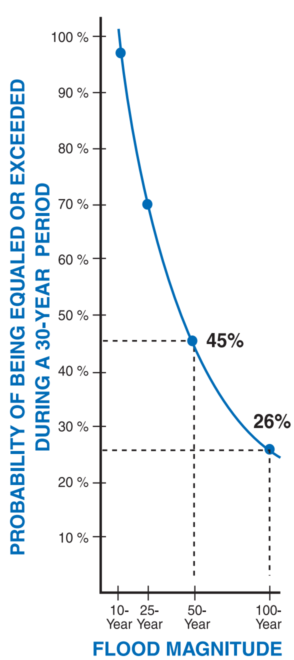


Subgrade Basement

As you will see in this chapter, different retrofitting methods protect your house in different ways. For example, when you elevate your house, you protect it by raising its lowest floor to a specified elevation. In wet floodproofing and dry floodproofing, you use flood-resistant materials, sealants, and shields to protect the part of your house below a specified elevation. When you protect your house with a levee or floodwall, the top of the levee or floodwall must be at a specified elevation. In each of these examples, the specified elevation is referred to as the Flood Protection Elevation (FPE). If flood waters rise above the FPE, your protection is either greatly diminished or eliminated.

If your house has been substantially damaged or is being substantially improved, your community's floodplain management ordinance or law will require an FPE that is at least equal to the BFE (the elevation of the 100-year flood). Communities may require a higher FPE if they wish, or they may be required to do so by State law. Some states and communities require a higher FPE by establishing freeboard requirements, as discussed in the next section. Also, even if substantial damage and substantial improvement provisions do not apply to your house, your community may still enforce regulatory requirements that would affect your choice of an FPE. Your local officials can advise you about this.

Keep in mind that community requirements are usually minimums. Although you cannot use an FPE lower than that required by your community, you are probably free to use a higher FPE if you wish to provide a greater level of flood protection. You may find that your community's floodplain management ordinance or law does not apply to your retrofitting project, in which case you may choose any FPE you wish. In either situation, your choice will be based largely on cost and risk.



In general you will find that the cost of retrofitting increases as your FPE increases. For example, protecting your house to the elevation of the 50-year flood with one of the methods described in this guide will probably cost you less than protecting it to the BFE with the same method. Although using a lower FPE may result in a less expensive retrofitting project, it exposes your house to a greater risk of flood damage. So in choosing an FPE, you must consider not only how much you are willing to pay, but also the level of risk you are willing to accept, including the potential for damage, financial loss, and emotional distress.

One way to see the relationship between FPE and risk is to look at the probabilities associated with floods of various magnitudes during a period of 30 years, the length of a standard mortgage (see graph at left). The percentages shown along the vertical scale of the graph are the probabilities that a flood will be equaled or exceeded during a 30-year period. As you can see, this probability decreases as the magnitude of the flood increases. So the probability of a flood with an elevation equal to or greater than the FPE you choose decreases as your FPE increases. For example, compare the risks associated with the 50-year flood and the base flood. If you choose an FPE equal to the elevation of the 50-year flood, the probability that a flood as high or higher than your FPE will occur during a 30-year period is 45 percent. But if you choose an FPE equal to the BFE, the probability drops to 26 percent.

Regardless of the FPE you choose or are required to use, you must realize that a larger flood is always possible and that there will always be some risk of damage. If you don't have flood insurance, you should purchase a policy; if you have flood insurance, you should maintain your policy, even if you have protected your house to or above the BFE. Once a house has been retrofitted to meet the NFIP requirements for substantially improved structures, it will probably be eligible for a significantly lower flood insurance rate.

Freeboard

Freeboard is an additional amount of height included in the FPE to provide a factor of safety. If you are protecting your house by elevating it, wet floodproofing it, dry floodproofing it, or building a levee or floodwall, you should include a minimum of 1 foot of freeboard in your FPE, even if your community does not require you to do so. For example, if you are elevating your house to protect it from the base flood, your FPE should be equal to the BFE plus 1 foot.

Freeboard is needed because of uncertainties regarding expected flood elevations. These uncertainties exist for several reasons, but the two primary reasons are limitations of the analytical methods used in floodplain studies and potential effects of future **watershed** development, such as the construction of buildings and roads.

FEMA and all other agencies that perform floodplain studies use a variety of standard engineering methodologies to determine flood frequencies and flood elevations. These methods involve the use of historical data, field measurements, and assumptions and judgments, all of which can affect the accuracy of the results. Some amount of uncertainty regarding the results is therefore unavoidable, and the potential for flood elevations higher than those expected should always be accounted for in retrofitting.

DEFINITION

The **watershed** of a stream is the geographic area that contributes surface water, from rain or melting snow, to that stream.

Development in a watershed can increase the size and frequency of floods in that watershed. In general, watershed development reduces the amount of open ground available to absorb water from rain and melting snow and therefore increases the amount of water that makes its way into streams. As a result, in a developing watershed, an amount of rainfall that might have caused minor floods in the past may cause larger floods, and higher elevations, in the future.

FEMA's floodplain studies are based on the watershed conditions existing at the time the studies are performed. They do not account for potential increases in watershed development or any other changes that might affect the sizes of future floods. The reason for this approach is that one of the primary purposes of Flood Insurance Studies (FISs) and FIRMs is to provide the technical basis for an insurance rate structure. Therefore, the flood hazards must be shown as they are, not as they might be. Also, attempting to predict the level of future watershed development in every study and determine the effects not only would be extremely difficult but also would require additional assumptions and judgments that could increase uncertainty. In many watersheds, however, some amount of development is inevitable. So, providing freeboard is a prudent means of protecting against the increased flood elevations that may result.

Human Intervention

Retrofitting methods fall into two general categories: those that depend on **human intervention**, which are referred to as "active" methods, and those that do not, which are referred to as "passive" methods. For example, a continuous floodwall around your house does not require human intervention. But what if you have to include an opening for your car? A floodwall with an opening will protect your house only if you can close the opening before flooding occurs. So your floodwall will have to be fitted with a gate (or some other type of closure mechanism), and every time flooding threatens, you will have to be warned far enough in advance that you can close the gate in time.

The need for adequate warning time and human intervention makes active methods less reliable than passive methods. So you should try to avoid active methods when you choose a retrofitting method for your house. If your retrofitting project includes active methods, you must have a plan that describes what actions you will take to make the measures work properly and when you will take those actions.

DEFINITION

Human intervention is any action that a person must take to enable a flood protection measure to function as intended. This action must be taken every time flooding threatens.

WARNING

Some communities may restrict or prohibit the use of active retrofitting methods for flood protection.

Other Considerations

Retrofitting methods that are properly designed and applied have several advantages over other types of damage reduction methods. Individual homeowners can undertake retrofitting projects on their own – they do not have to wait for, or depend on, government-sponsored flood control projects. Retrofitting also may be the best means of protection for a homeowner whose house is in an area where a large flood control project, such as a dam, levee, or major waterway improvement, is not feasible, warranted, or appropriate. But you should keep the following in mind whenever you consider a retrofitting project:

- Communities participating in the NFIP require permits for all development within the regulatory floodplain. Under your community's floodplain ordinance or law, any manmade changes to buildings and other structures are considered "development." These changes include improvements and repairs of existing buildings and other structures. Also, communities usually require building permits for many of the activities associated with the retrofitting methods described in this guide. In communities that have adopted a floodplain ordinance or law, health code, and building code, the permits required by these ordinances, laws, and codes may be issued separately or as one combined permit. You may need a permit for the following:

    1. Modifying your existing house or building a new house on a flood-free site. Even if your community does not require a building permit, it may require something similar, such as a special permit to regulate floodplain development.

    2. Moving a house on public rights-of-way. If you relocate your house, you will probably need such a permit, not only from your community but also from your state and from any other communities and states the house will pass through on its way to the new site.

    3. Demolishing a damaged house and restoring the site after demolition, including grading, planting vegetative cover, capping and abandoning utilities, and removing or securing underground septic and fuel storage tanks.

  You may wish to obtain the permits necessary for your retrofitting project yourself or arrange for your retrofitting contractor or design professional to obtain them. But remember, you must have the necessary permits in hand before you begin your project. As discussed in Chapter 4, your local officials are the best source of information about State and local permit requirements.

- In addition to meeting the requirements of the NFIP and local codes and floodplain management ordinances, you must comply with the requirements of all other applicable codes, ordinances, and regulations, such as those dealing with building setbacks and wetlands. Again, your local officials are the best source of information about these requirements.
- If your retrofitting project will involve financial assistance from a Federal agency and your property is 50 years old or older, you must work with that agency to ensure that your project complies with the National Historic Preservation Act (16 U.S.C. 470). The act requires that before releasing any Federal assistance, the agency determine whether the property is eligible for inclusion in the National Register of Historic Places and if so, whether your project will have any effect on the property. This requirement may not apply in some emergency situations or if the agency has made prior arrangements with historic preservation officials. For more information, contact your State Historic Preservation Office (Appendix E).
- Most retrofitting measures should be designed and constructed by experienced professionals such as contractors, engineers, and architects. Using professionals helps you make sure that the work is done properly, that code and regulatory requirements are met, and that once completed, the retrofitting measures will work properly.
- Most retrofitting measures cannot be simply installed and forgotten. You will need to periodically inspect and maintain them to be sure that they will continue to work over time, especially if they require human intervention.
- Even though retrofitting will help protect your house from flooding, you should never remain in your house during flooding. Stay informed about flooding conditions by monitoring local radio and television stations. You must be prepared to evacuate when necessary.
- Elevating your house properly may reduce your flood insurance rate. Relocating a house to a site outside the regulatory floodplain eliminates the flood insurance purchase requirement and significantly reduces the cost of flood insurance for an owner who wishes to purchase a policy. Buying flood insurance is strongly recommended, even when it is not required.

Construction Terminology

In the remainder of this guide, you will find many references to common types of house construction, such as frame or masonry, and common types of house foundations, such as slab-on-grade or crawlspace. Even if you are already familiar with these and other house construction terms, take a minute to review the following information before you move to the descriptions of the retrofitting methods.

Construction Type

The most common house construction types are as follows (see Figure 3-1):

frame – walls constructed of wood or light-gage metal studs, with wood, vinyl, or aluminum siding

masonry veneer – frame walls with a non-structural, decorative, exterior layer of brick, stone, or concrete block instead of siding

masonry – walls constructed of brick or concrete block

modular home – frame house assembled on-site from separate sections manufactured elsewhere

manufactured home – prefabricated frame house constructed on a transportable frame

Some houses consist of combinations of two or more of these construction types.

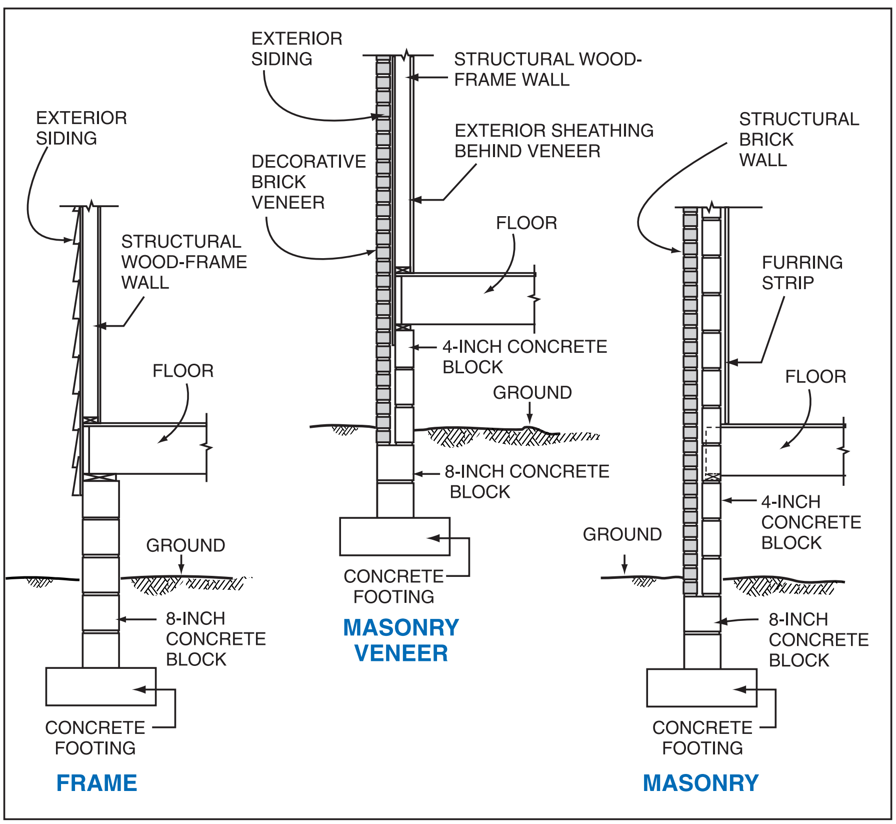


Figure 3-1
Typical cross sections of three common construction types: frame, masonry veneer, and masonry. The foundation shown here for all three construction types consists of concrete blocks and a concrete footing. The same construction types are also found on basement and slab-on-grade foundations (see next section).

DEFINITION

Concrete poured into forms at the construction site is referred to as **cast-in-place**.

Foundation Type

Most houses of the construction types listed above are built on the following types of foundations (see Figure 3-2):

basement – with masonry or **cast-in-place** concrete walls

crawlspace – with masonry or cast-in-place concrete walls

slab-on-grade – either (1) a slab with a masonry or concrete foundation or (2) a thickened slab (see Figure 5-5 in Chapter 5)

open foundation – usually concrete or masonry piers, but sometimes wood, concrete, or metal posts, columns, or pilings

Some houses are built on more than one type of foundation. Various combinations of basement, crawlspace, and slab-on-grade foundations are common. Manufactured homes are occasionally installed on basement or crawlspace foundations but are more often supported either by stacks of concrete blocks or by foundation systems designed specifically for manufactured homes.

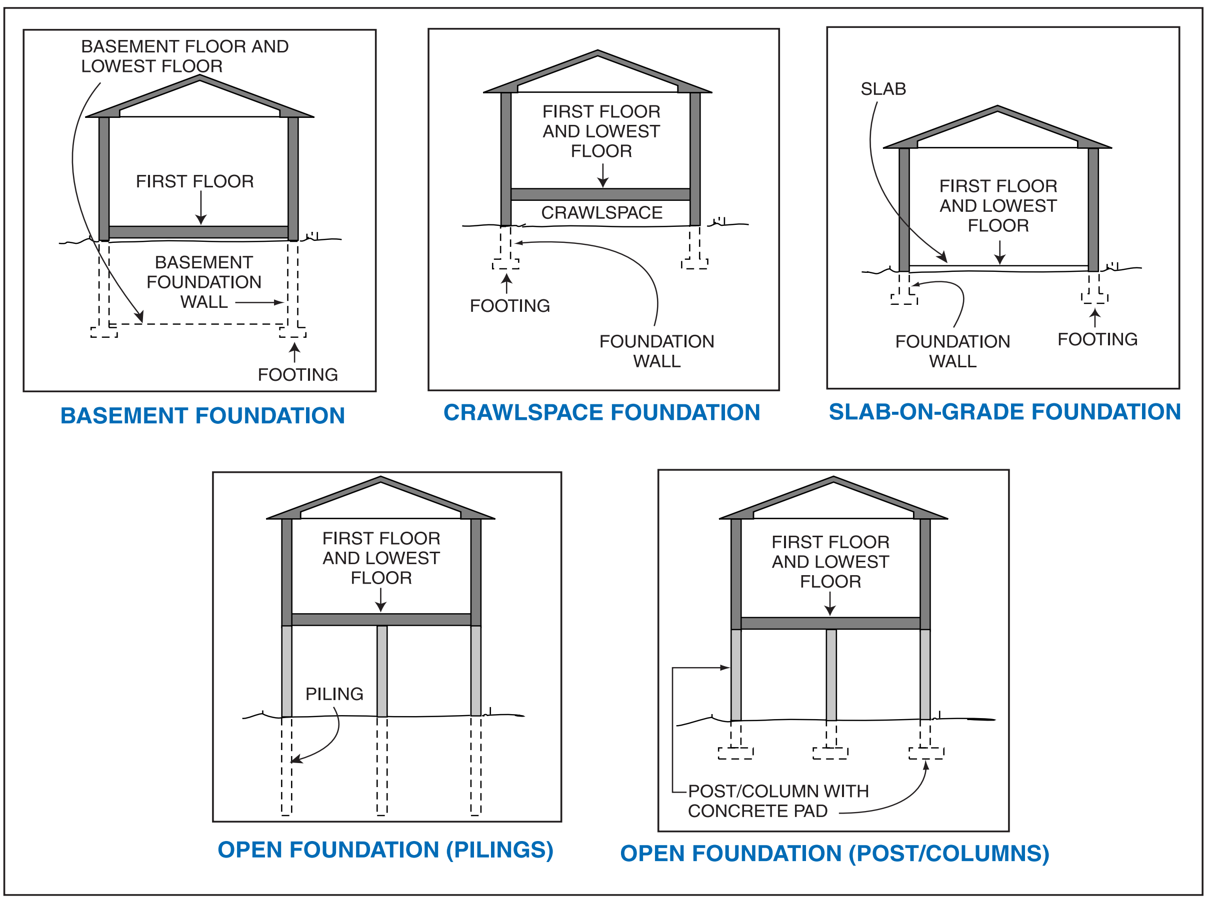
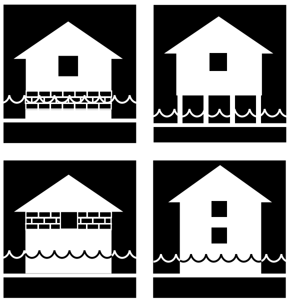


Figure 3-2 ***House foundation types.***

Retrofitting Methods and Costs

The following sections describe the retrofitting methods, explain how they work and where they are appropriate, list their advantages and disadvantages, and provide cost estimates. With this information, you will be ready for Chapter 4, *Deciding Which Method Is Right for Your House*.



Elevation (Chapter 5)

Elevating a house to prevent flood waters 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 FPE. You can do this by elevating the entire house, including the floor, or by leaving the house in its existing position and constructing a new, elevated floor within the house. The method used depends largely on construction type, foundation type, and flooding conditions.

During the elevation process, most houses (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 houses originally built on basement, crawlspace, and open foundations. As explained later in this section, the new or extended foundation can consist of either continuous walls or separate piers, posts, columns, or pilings.

A variation of this method is used for houses on slab-on-grade foundations. In these houses, the slab forms both the foundation and the floor of the house. Elevating these houses is easier if the house is left attached to the slab foundation and both are lifted together. After the house and slab are lifted, a new foundation is constructed below the slab.

Alternative techniques are available for masonry houses on slab-on-grade foundations. As described later in this section, these techniques do not require the lifting of the house. Instead, they involve raising the floor within the house or moving the living space to an upper story.

Although elevating a house can help protect it from flood waters, you need to consider other hazards before choosing this method. The walls

WARNING

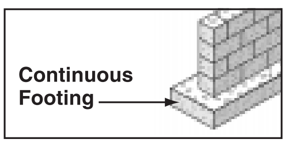
The cost estimates in this chapter are provided only as guidelines that can help you choose a retrofitting method. They are based on 1998 national averages that may need to be adjusted for local economic conditions. Be sure to get a complete, written cost estimate from your contractor and design professional before you begin any retrofitting project (see Chapter 4).

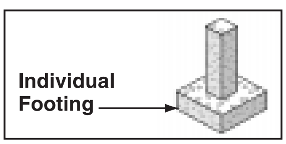
NOTE

FEMA has produced a videotape entitled *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.





and roof of an elevated house may be more susceptible to wind forces because they are higher and more exposed. Elevating the house also causes it to become “top heavy” and therefore more susceptible to the overturning forces of 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 flood waters. 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.

Elevating on Continuous Foundation Walls

This method is normally used in flood hazard areas where the risks of wave action and high-velocity flow are low. After the house is raised, the existing foundation is often saved and the existing foundation walls are extended. The new portions of the walls are usually made of masonry block or cast-in-place concrete. Although it may seem to be the easiest way to elevate a house, this method may involve some complications.

Depending on the size of your house, 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 house. The original footings may have to be replaced with larger footings. It may also be necessary to reinforce both the footings and the foundation walls with steel bars.

As explained in Chapter 2, unequalized hydrostatic pressure exerted by flood waters can collapse walls regardless of the construction materials used. If flood waters are expected to be more than about a foot deep, openings must be installed in the foundation walls so that water can flow into and out of any enclosed area below the newly elevated house. When the water levels on both sides of the foundation walls are the same, the hydrostatic pressure is equalized. If you are elevating your house in connection with repairs of substantial damage or as part of a substantial improvement, your community’s floodplain management ordinance or law will require that you install openings in all areas below the BFE.

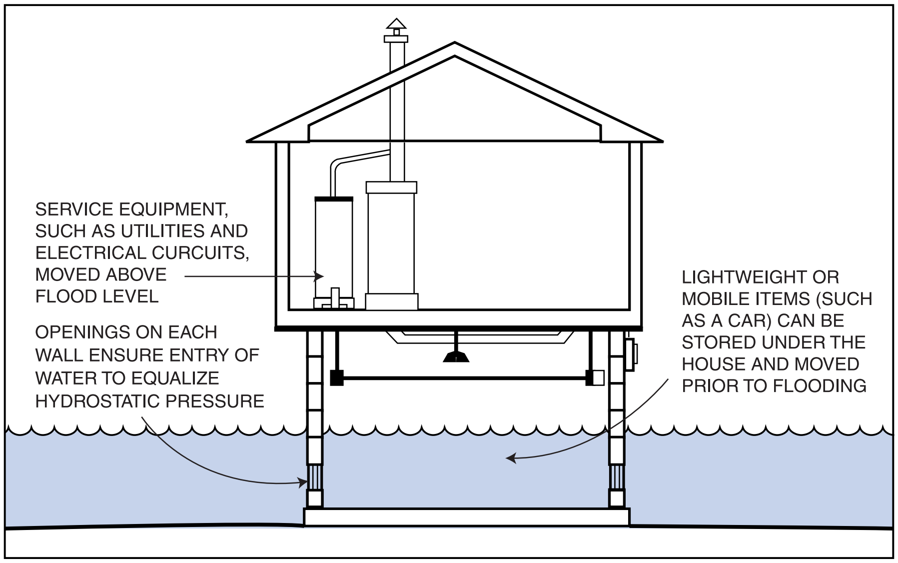


Figure 3-3
Typical cross-section of house elevated on continuous foundation walls.

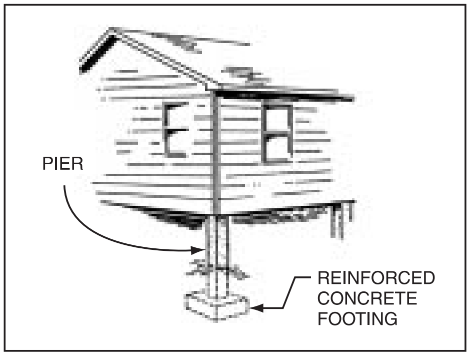
Figure 3-4
Retrofitted house elevated on extended continuous foundation walls.

WARNING

If you elevate a house that has been substantially damaged or is being substantially improved, your community's floodplain management ordinance or law will not allow you to have a basement, as defined under the NFIP. The NFIP regulations define a basement as "any area of the building having its floor subgrade on all sides." If your house has such a basement, you will be required to fill it in as part of any elevation project. Note that the NFIP definition of basement does not include what is typically referred to as a "walkout-on-grade" basement, whose floor would be at or above the adjacent grade on at least one side.

Elevating on Open Foundations

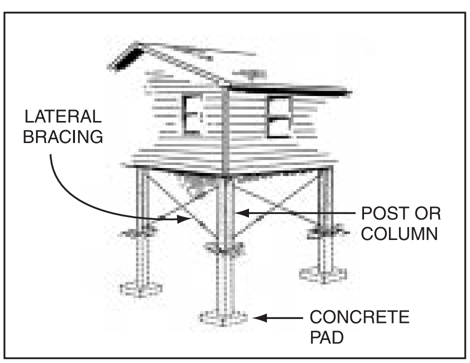
Unlike continuous foundations, open foundations consist of individual vertical structural members that support the house only at key points. Because they present less of an obstacle to flood flows than continuous walls, open foundations can be used where the risks of wave action and high-velocity flood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



House elevated on piers.

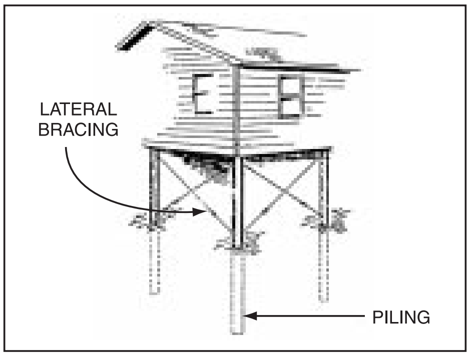
Piers. The most common type of open foundation is a pier foundation. Piers are built with masonry block or are made of cast-in-place concrete. The bottom of each pier sits on a concrete footing. Pier foundations are used in conventional construction; they are not just a means of elevating a floodprone house. In conventional use, they are designed primarily for vertical loading – to hold the weight of the house. They are not normally designed to resist large horizontal forces – such as those associated with moving flood water, 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.

If you decide to elevate your house on a pier foundation, you should expect your contractor to reinforce the piers and footings with steel rods and to tie the piers to the footings so they will not separate under flood or other forces. Adequate connections between the piers and the house are also necessary so that the house and foundation will resist lateral loads from flood, wind, and earthquake and uplift from buoyancy.



House elevated on posts or columns.

Posts or columns. Posts (also referred to as columns) are usually made of wood or steel. They are generally square but may also be round. Posts and columns are set in holes, and their ends are encased in concrete, or supported on concrete pads (as in the figure). After posts or columns are set, the holes are filled with concrete, dirt, gravel, or crushed stone. Unlike piers, which are designed to act as independent supports, posts and columns usually must be connected to each other with bracing. The bracing may consist of wood, steel rods, or guy wires. The type you choose is usually determined by cost, flood conditions, expected loads, the availability of materials, and local construction practice. Like piers, posts and columns are generally used where the risks of wave action and high-velocity flow are low to moderate.



House elevated on pilings.

Pilings. Pilings are usually made of wood, but steel and **precast concrete** are also common in some areas. Pilings are similar to posts, but instead of being set in holes, they are driven into the ground or **jetted** in with high-pressure streams of water. Also, pilings are embedded deeper in the ground than either piers or posts. As a result, piling foundations are less susceptible to the effects of high-velocity flow, waves, debris impact, erosion, and scour than the other types of open foundations. Pilings 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 pilings will enable them to resist the loads that are expected to act on them.

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

DEFINITION

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

DEFINITION

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

DEFINITION

Cribbing usually consists of a framework of criss-crossed timbers that provides temporary structural support.

Figure 3-5
This coastal house in Florida was elevated on pilings so that it would be less vulnerable to damage from coastal flooding.

Elevating by Extending the Walls of the House or Moving the Living Space to an Upper Floor

For masonry houses on slab-on-grade foundations, two alternative elevation methods are available. One is to remove the roof, extend the walls of the house upward, replace the roof, and build a new, elevated floor at the FPE. This technique works best where the floor needs to be raised less than 4 feet to reach the FPE. The elevated 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 area between it and the old slab is left open and becomes a crawlspace.

The second technique is to abandon the entire lower floor, or lower enclosed area, of the house and move the living space to an existing or newly constructed upper story. This technique works best for multi-story houses where the FPE 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, storage, or building access.

These techniques, like the others, have their limitations. The portions of the house below the FPE will be exposed to flooding and must therefore be made of flood-resistant materials. That is why this method is generally applicable only to masonry houses. A frame house would be much more easily damaged by flooding. The area below the FPE cannot be used for living space; it may be used only for parking, storage, or building access. 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 the next section for a discussion of wet floodproofing).

Figure 3-6
The owner of this floodprone house in south Florida decided to build a new frame second story on top of his masonry first story. The new second story is well above the BFE.

Table 3.1

ADVANTAGES AND DISADVANTAGES OF ELEVATION

ADVANTAGES	DISADVANTAGES
• **Elevation to or above the BFE allows a substantially damaged or substantially improved house to be brought into compliance with your community's floodplain management ordinance or law.** • Elevation reduces the flood risk to the house and its contents. • Except where a lower floor is used for storage, elevation eliminates the need to move vulnerable contents to areas above the water level during flooding. • Elevation often reduces flood insurance premiums. • Elevation techniques are well-known, and qualified contractors are often readily available. • Elevation does not require the additional land that may be needed for the construction of floodwalls or levees. • Elevation reduces the physical, financial, and emotional strain that accompanies floods.	• Cost may be prohibitive. • The appearance of the house may be adversely affected. • Access to the house may be adversely affected. • The house must not be occupied during a flood. • Unless special measures are taken, elevation is not appropriate in areas with high-velocity flows, waves, fast-moving ice or debris flow, or erosion. • Additional costs are likely if the house must be brought into compliance with current code requirements for plumbing, electrical, and energy systems. • Potential wind and earthquake loads must be considered.

NOTE

As discussed under Financial Assistance for Retrofitting in Chapter 2, the cost of elevating a substantially damaged house may be an eligible flood insurance claim under Increased Cost of Compliance (ICC) coverage.

Adding a new second story to a single-story house 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.

Approximate Costs

The costs shown in Table 3.2 are for elevating frame and masonry houses a total of 2 feet. The costs for extending utilities and adding or extending staircases are included. The costs shown for elevating frame and masonry houses on existing slab-on-grade foundations are based on the assumption that the house is raised with the existing slab attached.

Table 3.2

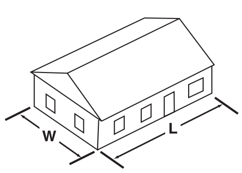
COST OF ELEVATING A HOUSE 2 FEET

CONSTRUCTION TYPE	EXISTING FOUNDATION	RETROFIT	COST (per square foot of house footprint)
FRAME (For frame house with brick veneer on walls, add 10 percent)	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$17
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation[1]	$47[1]
MASONRY	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$47[1]
	Basement, Crawlspace, or Slab-on-Grade	Extend Existing Walls 2 Feet and Create New Elevated Living Area	$35

[1] Price shown is for raising the house with the slab attached.

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 <u>not</u> equal to the total square footage of all the floors in the house.



Footprint = L x W

You can estimate the cost of elevating more than 2 feet by adding $0.75 per square foot of house **footprint** for each additional foot of elevation up to 8 feet. For elevations greater than 8 feet, add $1.00 per square foot for each additional foot of elevation.

Occasionally, slab-on-grade houses are raised without the slab. Although this method can be less expensive than raising the house with the slab, it involves detaching the house from the slab and requires extensive alterations to interior and exterior walls. As a result, raising the house without the slab is usually done only when the house has been severely damaged by a flood, fire, or other catastrophe.

The cost of abandoning an existing lower level will depend on whether the house 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 are **flood-resistant**. The cost would be approximately $5 - $10 per square foot of building footprint. This method is well-suited to a house with a walkout-on-grade basement, which can be wet floodproofed and used for parking, storage, or building access. Adding a new frame upper level and raising the roof to accommodate the new level would cost approximately $40 - $50 per square foot depending upon the amount of interior finishing.

NOTE

See Chapter 6 for a discussion of **flood-resistant materials.**

SAMPLE COST ESTIMATE

It may be helpful to consider an example in which a 40-foot by 25-foot frame house with brick veneer walls is elevated a total of 4 feet on continuous foundation walls.

Footprint= 40 feet x 25 feet = 1,000 square feet

Cost of elevating 2 feet =
$17 per square foot of footprint = **$17,000**

Cost of elevating 2 additional feet =
2 x $0.75 per square foot of footprint = **$1,500**

Total = $18,500 + 10% for brick veneer =
$18,500 + $1,850 = $20,350 or
$20.35 per square foot of house footprint

Wet Floodproofing (Chapter 6)

Wet floodproofing a house is modifying the uninhabited portions of the house (such as a crawlspace or an unfinished basement) so that flood waters will enter but not cause significant damage to either the house or its contents. The purpose of allowing water into portions of the house is to ensure that the interior and exterior hydrostatic pressures will be equal. Allowing these pressures to equalize greatly reduces the likelihood of wall failures and structural damage. Wet floodproofing is often used when all other retrofitting methods are either too costly or are not feasible. But it is practical in only a limited number of situations.

Because wet floodproofing allows flood waters to enter the house, all construction and finishing materials below the FPE must be resistant to flood damage. For this reason, wet floodproofing is practical only for portions of a house that are not used for living space, such as a basement as defined by the NFIP regulations, a walkout-on-grade basement, crawlspace, or attached garage. It would not be practical for most slab-on-grade houses, in which the living space is at or very near the ground level. Whether or not wet floodproofing is appropriate for your house will depend on the flood conditions, the FPE you have selected, the design and construction of your house, and whether your house has been substantially damaged or is being substantially improved.

If you are considering wet floodproofing, keep the following in mind:

- Your house should have space above the FPE in which you can temporarily store items that could be damaged by flood waters.
- If your furnace, water heater, or other service equipment is below the FPE, it must be protected as well. You may be able to do this by moving the equipment to another floor, elevating it, or protecting it in place. (An example of protection in place is surrounding a furnace with an interior floodwall -- see Chapter 8).
- Any construction and finishing materials below the FPE that are not **flood-resistant** must be removed or replaced with materials that are flood-resistant.
- If a flood occurs, you will not be able to live in your house as long as flood waters remain inside.
- Wet floodproofing does nothing to alleviate the threat of damage from high-velocity flood flow and wave action.

WARNING

If your house has been substantially damaged or is being substantially improved, your community's floodplain management ordinance or law will restrict your use of wet floodproofing to attached garages and enclosed areas below the BFE that are used solely for parking, storage, or building access. For more information, consult your local officials or refer to FEMA's Technical Bulletin 7-93, *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas.*

NOTE

See Chapter 6 for a discussion of **flood-resistant materials.**

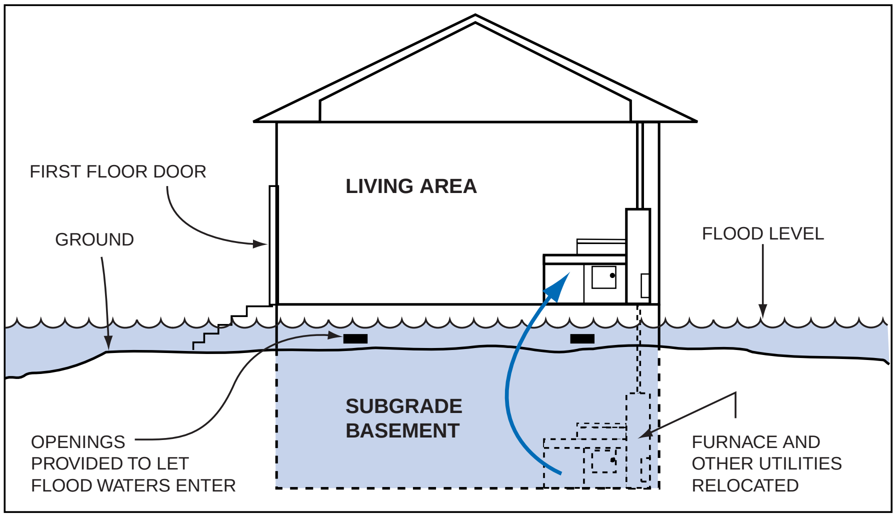


Figure 3-7 ***A house with a wet floodproofed subgrade basement. (If this house were substantially damaged or substantially improved, the basement would have to be filled in; see the Warning at right.)***

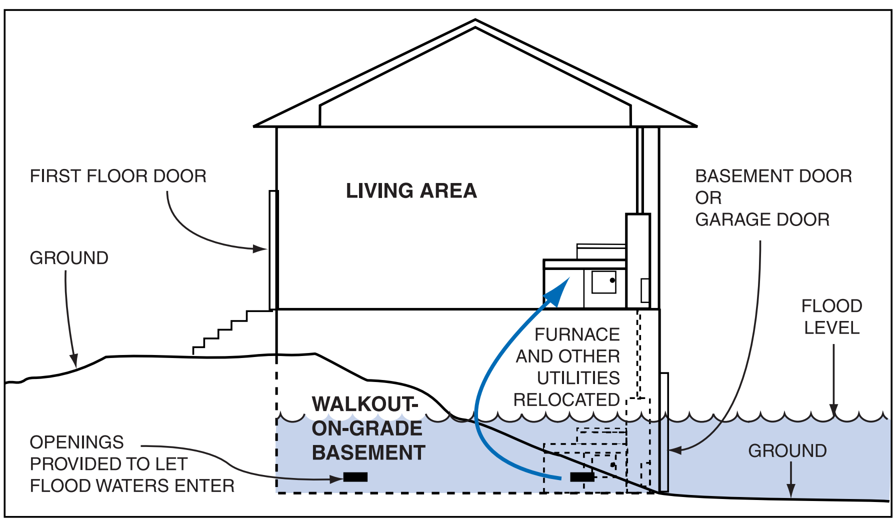


Figure 3-8 ***A house with a wet floodproofed walkout-on-grade basement.***

WARNING

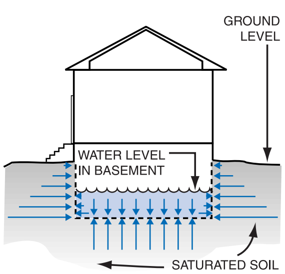
If you wet floodproof a house that has been substantially damaged or is being substantially improved, your community's floodplain management ordinance or law will not allow you to have a basement, as defined under the NFIP. The NFIP regulations define a basement as "any area of the building having its floor subgrade on all sides." If your house has such a basement, you will be required to fill it in as part of any wet floodproofing project. Note that the NFIP definition of basement does not include what is typically referred to as a "walk-out-on-grade" basement, whose floor would be at or above grade on at least one side.

Table 3.3 **ADVANTAGES AND DISADVANTAGES OF WET FLOODPROOFING**

ADVANTAGES	DISADVANTAGES
• No matter how small the effort, wet floodproofing can, in many instances, reduce flood damage to a house and its contents. • Because wet floodproofing allows internal and external hydrostatic pressures to equalize, the loads on walls and floors will be less than in a dry floodproofed house (discussed later in this section). • Costs for moving or storing contents (except basement contents) after a flood warning is issued are covered by flood insurance in some circumstances. • Wet floodproofing measures are often less costly than other types of retrofitting. • Wet floodproofing does not require the additional land that may be needed for floodwalls and levees (discussed later in this section). • The appearance of the house is usually not adversely affected. • Wet floodproofing reduces the physical, financial, and emotional strain that accompanies floods.	• **Wet floodproofing may be used to bring a substantially damaged or substantially improved house into compliance with your community's floodplain management ordinance or law <u>only</u> if the areas of the house below the BFE are used solely for parking, storage, or building access.** • Preparing the house and its contents for an impending flood requires human intervention and adequate warning time. • The house will get wet inside and possibly be contaminated by sewage, chemicals, and other materials borne by flood waters. Extensive cleanup may be necessary. • The house must not be occupied during a flood, and it may be uninhabitable for some time afterward. • It will be necessary to limit the uses of the floodable area of the house. • Periodic maintenance may be required. • Pumping flood waters out of a wet floodproofed basement too soon after a flood may lead to structural damage (see the Warning at left). • Wet floodproofing does nothing to minimize the potential damage from high-velocity flood flow and wave action.

WARNING

After flood waters recede from the area around a house with a wet floodproofed basement, the homeowner will usually want to pump out the water that filled the basement during the flood. But if the soil surrounding the basement walls and below the basement floor is still saturated with water, removing the water in the basement too quickly can be dangerous. As the water level in the basement drops, the outside pressure on the basement walls and floor becomes greater than the inside pressure (see figure). As a result, the walls can collapse and the floor can be pushed up or cracked.



DEFINITION

The **lowest adjacent grade (LAG)** is the lowest ground surface that touches any of the exterior walls of your house.

Wet floodproofing is generally less expensive than the other flood protection methods described in this guide. Table 3.4 shows approximate costs per square foot of building footprint for wet floodproofing houses on basement and crawlspace foundations to heights of 2, 4, and 8 feet. In a house with a basement, this height is measured from the basement floor (but see warning on page 47). In a house with a crawlspace, this height is measured from the **lowest grade adjacent to the house**. The costs shown include those for adding wall openings for the entry and exit of flood waters, installing pumps, rearranging or relocating utility systems, moving large appliances, and making it easier to clean up after flood waters recede. The costs shown for basements in Table 3.4 are valid only for unfinished basements. Wet floodproofing a finished basement would require that all non-flood-resistant finishing materials be permanently removed or replaced with flood-resistant materials. As a result, wet floodproofing costs for finished basements would be higher than those shown below and would vary depending on the amount of finishing to be removed or replaced.

Table 3.4

COST OF WET FLOODPROOFING

CONSTRUCTION TYPE	HEIGHT OF WET FLOODPROOFING (in feet above basement floor or LAG[1])	EXISTING FOUNDATION	COST (per square foot of house footprint)
FRAME OR MASONRY	2	Basement[2]	$1.70
		Crawlspace	$1.30
	4	Basement[2]	$3.50
		Crawlspace	$3.25
	8	Basement[2]	$10.00
		Crawlspace	NA[3]

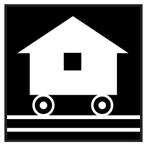
[1] House with basement: feet above basement floor; house with crawlspace: feet above LAG
[2] Unfinished
[3] A house would almost never have a crawlspace 8 feet high, which is nearly the height of a full story.

SAMPLE COST ESTIMATE

It may be helpful to consider an example in which a 40-foot by 25-foot house on a crawlspace foundation is wet floodproofed to a height of 4 feet above grade.

Footprint= 40 feet x 25 feet = 1,000 square feet

Total cost of wet floodproofing 4 feet =
$3.25 per square foot of house footprint = $3,250



Relocation (Chapter 7)

Moving your house to high ground, outside the flood hazard area, is the most effective of the retrofitting methods described in this guide. Retrofitting literature commonly refers to this method as relocation. When space permits, you may even be able to move your house to another location on the same piece of property.

Relocating a house usually involves jacking it up and placing it on a wheeled vehicle, which delivers it to the new site. The original foundation cannot be moved, so it is demolished and a new foundation is built at the new site. The house is installed on the new foundation and all utility lines are connected. Relocation is particularly appropriate in areas where the flood hazard is severe, such as where flood conditions are characterized by one or more of the following:

- deep water
- short warning time
- high flow velocity
- long duration
- high rates of rise and fall
- wave action
- high debris potential

Relocation is also appropriate for homeowners who want to be free of worries about damage from future floods that may exceed a selected FPE.

Although similar to elevation, relocation requires additional steps that usually make it more expensive. These include moving the house, buying and preparing a new site (including building the new foundation and providing the necessary utilities), and restoring the old site (including demolishing the old foundation and properly capping and abandoning old utility lines).

Houses of all sizes and types can be relocated, either as a unit or in segments. One-story frame houses are usually the easiest to move, particularly if they are built on a crawlspace or basement foundation that provides easy access to the floor framing. Masonry houses can also be moved, but usually with more difficulty and at a higher cost.

Professional house movers can advise you about the things you need to consider in deciding whether to relocate. The structural soundness of your house will have to be checked. Also, you may need to find a place where you can store furniture and other belongings temporarily. In most instances, however, the contents of your home may remain in the house while it is being moved. And keep in mind that there must be a clear route to the new site. Narrow roads, restrictive overpasses, and bridges with low weight limits may make it impossible for your house to be moved to the new site. Also, many states and communities have requirements that govern the transport of houses and other buildings on public rights-of-way.

ADVANTAGES AND DISADVANTAGES OF RELOCATION

Table 3.5

ADVANTAGES	DISADVANTAGES
• **Relocation allows a substantially damaged or substantially improved house to be brought into compliance with your community's floodplain management ordinance or law.**	• Cost may be prohibitive.
• Relocation significantly reduces flood risk to the house and its contents.	• A new site (preferably outside the flood hazard area) must be located and purchased.
• Relocation can either eliminate the need to purchase flood insurance or reduce the amount of the premium.	• The floodprone lot on which the house was located must be sold or otherwise disposed of.
• Relocation techniques are well-known, and qualified contractors are often readily available.	• Additional costs are likely if the house must be brought into compliance with current code requirements for plumbing, electrical, and energy systems.
• Relocation reduces the physical, financial, and emotional strain that accompanies flood events.	

The Table 3.6 shows approximate costs per square foot of house footprint for relocating houses of different types. The costs include those for moving the house, building a new foundation at the new site, installing the house on the new foundation, and hooking up all utilities. The costs shown are based on the assumption that the house will be moved less than 5 miles and installed on the same type of foundation as it originally had.

Table 3.6

WARNING

The relocation costs shown here are for a 1,000-square-foot house. Because relocation costs do not increase proportionally with the size of a house, the cost per square foot of moving a larger house may be less than that shown here.

COST OF RELOCATING

CONSTRUCTION TYPE	EXISTING FOUNDATION	COST (per square foot of house **footprint**)
FRAME (For frame house with brick veneer on walls, add 10 percent)	Basement	$32
	Crawlspace	$27
	Slab-on-Grade	$51
MASONRY	Basement	$49
	Crawlspace	$32
	Slab-on-Grade	$61

The costs shown in Table 3.6 do not include the cost of restoring the old site, which would be approximately $12 per square foot of building footprint regardless of construction type or foundation type. Also not included is the cost of any new property that must be purchased.

NOTE

As discussed in Financial Assistance for Retrofitting in Chapter 2, the cost of relocating a substantially damaged house may be an eligible flood insurance claim under ICC coverage.

SAMPLE COST ESTIMATE

It may be helpful to consider an example in which a 40-foot by 25-foot frame house with masonry veneer on a basement foundation is relocated to a site less than 5 miles away and installed on the same type of foundation.

Footprint= 40 feet x 25 feet = 1,000 square feet

Cost of relocating=
$32 per square foot of footprint = **$32,000**

Additional cost for masonry veneer =
$32,000 x 10% = **$3,200**

Additional cost for site restoration =
$12 per square foot of footprint = **$12,000**

Total cost of relocation =
$47,200 or
$47.20 per square foot of house footprint

Dry Floodproofing (Chapter 7)

In some situations, a house can be made watertight below the FPE, so that flood waters cannot enter. This method is called “dry floodproofing.” Making the house watertight requires sealing the walls with waterproof coatings, impermeable membranes, or supplemental layers of masonry or concrete. Also, doors, windows, and other openings below the FPE must be equipped with permanent or removable shields, and backflow valves must be installed in sewer lines and drains. The flood characteristics that affect the success of dry floodproofing are flood depth, flood duration, flow velocity, and the potential for wave action and floodborne debris.

WARNING

Dry floodproofing may <u>not</u> be used to bring a substantially damaged or substantially improved house into compliance with your community’s floodplain management ordinance or law.

Flood depth is important because of the hydrostatic pressure that flood waters exert on walls and floors. Because water is prevented from entering a dry floodproofed house, the exterior pressure on walls and floors is not counteracted as it is in a wet floodproofed house (see the discussion on pages 12 and 13). The ability of house walls to withstand the pressure exerted by flood waters depends partly on how the walls are constructed. Typical masonry and masonry veneer walls, without reinforcement, can usually withstand the pressure exerted by water up to about 3 feet deep. When flood depths exceed 3 feet, unreinforced masonry and masonry veneer walls are much more likely to crack or collapse. An advantage of masonry and masonry veneer walls is that their exterior surfaces are resistant to damage by moisture and can be made watertight relatively easily with sealants. In contrast, typical frame walls are likely to fail at lower flood depths, are more difficult to make watertight, and are more vulnerable to damage from moisture. As a result, wet floodproofing is not recommended for houses with frame walls.

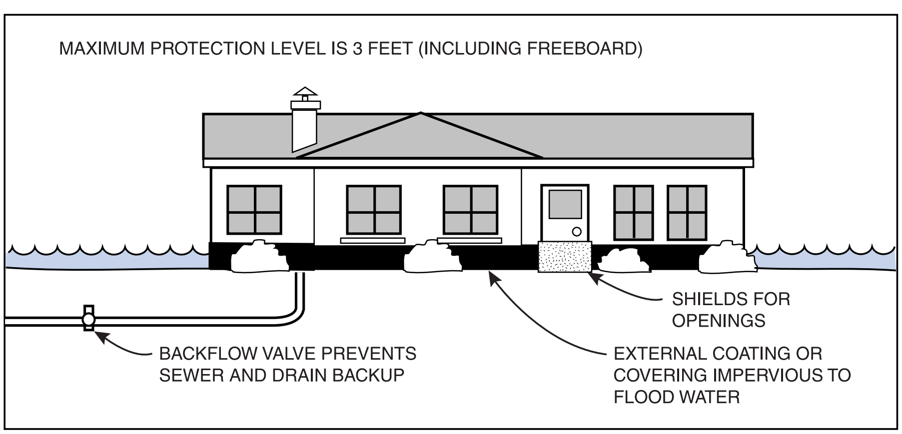


Figure 3-9
A typical dry floodproofed house.

ADVANTAGES AND DISADVANTAGES OF DRY FLOODPROOFING

Table 3.7

ADVANTAGES	DISADVANTAGES
• Dry floodproofing reduces the flood risk to the house and its contents. • Dry floodproofing may be less costly than other retrofitting methods. • Dry floodproofing does not require the additional land that may be needed for levees and floodwalls (discussed later in this chapter). • Dry floodproofing reduces the physical, financial, and emotional strain that accompanies floods.	• **Dry floodproofing may not be used to bring a substantially damaged or substantially improved house into compliance with your community's floodplain management ordinance or law.** • Ongoing maintenance is required. • Flood insurance premiums are not reduced for residential structures. • Installing temporary protective measures, such as flood shields, requires human intervention and adequate warning time. • If the protective measures fail or the FPE is exceeded, the effect on the house will be the same as if there were no protection at all. • If design loads are exceeded, walls may collapse, floors may buckle, and the house may even float, potentially resulting in more damage than if the house were allowed to flood. • The house must not be occupied during a flood. • Flood shields may not be aesthetically pleasing. • Damage to the exterior of the house and other property may not be reduced. • Shields and sealants may leak, which could result to damage to the house and its contents. • Dry floodproofing does nothing to minimize the potential damage from high-velocity flood flow and wave action.

WARNING

Because dry floodproofing requires human intervention, you must be willing and able to install all flood shields and carry out all other activities required for the successful operation of the dry floodproofing system. As a result, not only must you be physically capable of carrying out these activities, you must be home or able to go home in time to do so before flood waters arrive.

Even if masonry or masonry veneer walls are reinforced to withstand the pressure of deeper water, the effects of buoyancy must be considered. The buoyancy force exerted by water greater than 3 feet deep is often great enough to crack a slab floor or push it up. For this reason, dry floodproofing usually is not appropriate method of protecting a house from flooding over 3 feet deep.

Duration of flooding is critical because most sealing systems will begin to allow some amount of seepage after prolonged periods of exposure to water. If your house is in an area where flood waters remain high for days, you should use a different retrofitting method. Areas with a risk of high-velocity flood flow, wave action, or both are not appropriate locations for dry floodproofing. Either condition may render dry floodproofing totally ineffective and cause severe damage.

Dry floodproofing is not recommended for houses with basements. Saturated soils pressing against basement walls can damage them or cause them to fail. The buoyancy force exerted by saturated soils below the basement can cause the basement floor to fail or even push the entire house up.

Sealant systems, especially those that rely on membranes and coatings, can be punctured by ice and other types of debris. If your house is in an area where flood waters are known to carry debris, you should select a different retrofitting method.

The Table 3.8 shows approximate costs for individual components that make up a dry floodproofing system.

WARNING

Even concrete block and brick walls should not be dry floodproofed above a height of 3 feet, unless an engineering analysis has been performed which shows that the walls will withstand the expected hydrostatic and hydrodynamic loads and debris impact forces. The effects of buoyancy on slab floors must also be considered.

COST OF DRY FLOODPROOFING

Table 3.8

COMPONENT	COST	PER
Sprayed-on Cement (above grade)[1]	$3.30	Square Foot of Wall Area Covered
Asphalt (two coats on foundation below grade)[1, 2]	$1.10	Square Foot of Wall Area Covered
Waterproof Membrane (above grade)[1]	$1.10	Square Foot of Wall Area Covered
Drainage Line Around Perimeter of House	$31	Linear Foot
Plumbing Check Valve	$620	Lump Sum
Sump and Sump Pump (with backup battery)	$1,000	Lump Sum
Metal Flood Shield	$73	Square Foot of Shield Surface
Wood Flood Shield	$23	Square Foot of Shield Surface

[1]Cement, asphalt, and membrane are alternative sealant methods.
[2]Does not include the cost of excavation

As you can see from the table, the total cost for dry floodproofing a house will depend largely on the size of the house, FPE, types of sealant and shield materials used, number of plumbing lines that have to be protected by check valves, and number of openings that have to be covered by shields.

SAMPLE COST ESTIMATE

It may be helpful to consider an example in which a 40-foot by 25-foot masonry house on a slab-on-grade foundation is dry floodproofed to a height of 2 feet above the lowest floor. The house is assumed to have two doors below the FPE and to require three plumbing check valves and one sump pump.

Perimeter of house = 40 feet + 25 feet + 40 feet + 25 feet =
130 feet
Protected wall area = 130 feet x 2 feet high = 260 square feet
Cost of waterproof membrane = $1.10 x 260 square feet = **$286.00**

Width of doors to be protected = 3 feet per door x 2 = 6 feet
Protected door area = 6 feet x 2 feet high = 12 square feet
Cost of wood door shields = $23 x 12 square feet = **$276.00**

Cost of perimeter drainage line = 130 feet x $31 per square foot =
$4,030
Cost of three plumbing check valves = $620.00 x 3 = **$1,860**
Cost of one sump pump = **$1,000**

Total cost of dry floodproofing =
$7,452.00 or
$7.45 per square foot of house footprint

Levees and Floodwalls (Chapter 7)

Levees and floodwalls are types of flood protection barriers. A levee is typically a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both. When these barriers are built to protect a house, they are usually referred to as “residential,” “individual,” or “on-site” levees and floodwalls. The practical heights of these levees and floodwalls are usually limited to 6 feet and 4 feet, respectively. These limits are the result of the following considerations:

- As the height of a levee or floodwall increases, so does the depth of water that can build up behind it. Greater depths result in greater water pressures, so taller levees and floodwalls must be designed and constructed to withstand the increased pressures. Meeting this need for additional strength greatly increases the cost of the levee or floodwall, usually beyond what an individual homeowner can afford.
- Because taller levees and floodwalls must be stronger, they must also be more massive, so they usually require more space than is likely to be available on an individual lot. This is especially true of levees.

WARNING

Levees and floodwalls may not be used to bring a substantially damaged or substantially improved house into compliance with your community’s floodplain management ordinance or law.

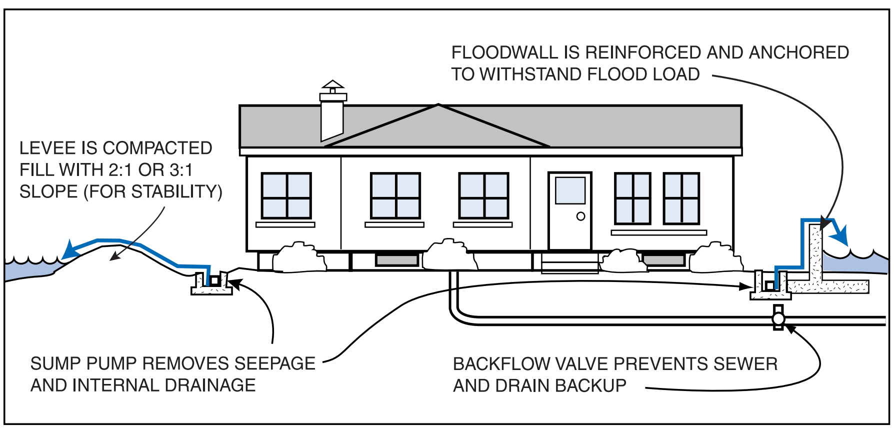


Figure 3-10
House protected by levee (left) and floodwall (right).

Both levees and floodwalls should provide at least 1 foot of **freeboard**. For example, if you are building a levee to protect your house from the base flood, the top of the levee should be 1 foot above the BFE.

NOTE

Freeboard is explained on page 31.

For a levee to be effective over time, it must be constructed of soils that cannot be easily penetrated by flood waters, it must have proper side slopes for stability, and it must be periodically inspected and maintained. In areas where high flow velocities could erode the surface of a levee, the side of the levee exposed to flood water is usually protected with a covering of rock, referred to as riprap, or with other erosion-resistant material. Levees can surround a house, or they may be built only across low areas and tied into existing high ground.

Figure 3-11
House protected by levee, which holds back the flood waters shown in the lower half of the photograph. Note that the levee ties in to high ground created by the road embankment.

WARNING

Special design considerations are necessary when levees or floodwalls are built to protect a house with a basement. Even though the surface water is kept from coming into contact with the house, the soil below the levee or floodwall and around the house can become saturated, especially during floods of long duration. The resulting pressure on basement walls and floors can cause them to crack buckle, or even collapse (see page 133).

A floodwall can surround a house, or, depending on flood depths, site topography, and design preferences, it can protect isolated openings such as doors, windows, and basement entrances, including entry doors and garage doors in walkout-on-grade basements. When built with decorative bricks or blocks or as part of garden areas, floodwalls can become attractive architectural or landscaping features. But they can also be built solely for utility, usually at a much lower cost.

Because a floodwall is made of concrete or masonry rather than compacted earth, it is more resistant to erosion than a levee and generally requires less space than a levee that provides the same level of protection. But floodwalls are usually more expensive. As a result, floodwalls are normally considered only for sites where there is not enough room for a levee or where high flow velocities may erode a levee. Also, some homeowners prefer floodwalls because they can be more aesthetically pleasing and allow for the preservation of existing site features, such as trees.

As shown in Figure 3-10, an interior drainage system, including a sump pump, must be installed in the area protected by a levee or floodwall. The purpose of the system is to remove rainwater trapped inside the protected area and, during flooding, to remove water that enters through seepage or infiltration. It also may be necessary to include an opening in a levee or floodwall that will provide access for a car or other vehicle. All openings must be equipped with closures similar to those used in dry floodproofing.

ADVANTAGES AND DISADVANTAGES OF LEVEES AND FLOODWALLS

Table 3.9

ADVANTAGES	DISADVANTAGES
• The house and the area around it will be protected from inundation, and no significant changes to the house will be required. • Flood waters cannot reach the house or other structures in the protected area and therefore will not cause damage through inundation, hydrodynamic pressure, erosion, scour, or debris impact. • The house can be occupied during construction of levees and floodwalls. • Levees and floodwalls reduce the flood risk to the house and its contents. • Levees and floodwalls reduce the physical, financial, and emotional strain that accompanies flood events.	• **Levees and floodwalls may not be used to bring a substantially damaged or substantially improved house into compliance with your community's floodplain management ordinance or law.** • Cost may be prohibitive. • Periodic maintenance is required. • Human intervention and adequate warning time are required to close any openings in a levee or floodwall. • If a levee or floodwall fails or is overtopped by flood waters, the effect on the house will be the same as if there were no protection at all. • An interior drainage system must be provided. • Local drainage can be affected, possibly creating or worsening flood problems for others. • The house must not be occupied during a flood. • Access to the house may be restricted. • Levees and floodwalls do not reduce flood insurance rates. • Floodplain management requirements may make levees and floodwalls violations of codes and/or regulations. • A large area may be required for construction, especially for levees. • Hydrostatic pressure on below-ground portions of a house may still be a problem, so levees and floodwalls are not good retrofitting methods for houses with basements.

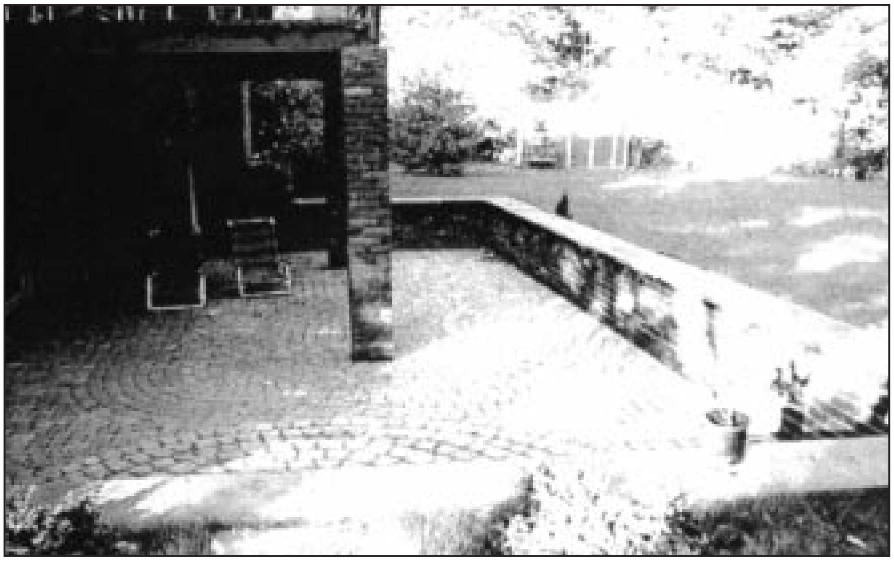


Figure 3-12
House protected by a floodwall designed as a landscaping feature.

The following tables show approximate costs for levees and floodwalls of various heights and for additional levee and floodwall components that may be needed.

Table 3.10

COSTS OF LEVEES AND FLOODWALLS

COMPONENT	COST (per linear foot)
Levee – 2 feet above ground	$37
Levee – 4 feet above ground	$69
Levee – 6 feet above ground	$115
Floodwall – 2 feet above ground	$85
Floodwall – 4 feet above ground	$124

Table 3.11

COSTS OF ADDITIONAL LEVEE AND FLOODWALL COMPONENTS

COMPONENT	COST	PER
Levee Riprap	$31	Cubic Yard
Interior Drainage System	$4,200	Lump Sum
Closure (each)	$73	Square Foot of Closure Area
Seeding of disturbed areas	$0.05	Square foot of Ground Area

NOTE

The costs for levee construction can vary greatly depending on the distance between the construction site and the source of the fill dirt used to build the levee. The greater the distance that fill dirt must be hauled, the greater the cost.

Demolition (Chapter 7)

Demolition, as a retrofitting method, is tearing down a damaged house and either rebuilding properly somewhere on the same property or moving to a house on other property, outside the regulatory floodplain. This retrofitting method may be the most practical of all those described in this guide when a house has sustained extensive damage, especially severe structural damage.

Whether you rebuild or move, you must tear down your damaged house and then restore the site. Site restoration usually involves filling in a basement, grading, and landscaping. As a result, you will probably need the services of a demolition contractor. The contractor will disconnect and cap all utility lines at the site and then raze the house with a bulldozer or other heavy equipment. If you decide to rebuild on the old site or somewhere else on the same property, your construction contractor may be able to do the demolition and site restoration work as part of the house construction.

Remember, all demolition, construction, and site restoration work must be done according to the regulatory requirements of your community. Permits may be required for all or part of this work. If you decide to rebuild on the site of your old house, you must rebuild properly, which means ensuring that the lowest floor of your new house is at or above the FPE. You can do this by elevating your new house on an extended foundation as described in the *Elevation* section in this chapter or on compacted fill dirt. If your property includes an alternative building site outside the regulatory floodplain, a better approach is to build on that site, where you can use standard construction practices, including the construction of a basement. Remember, if you rebuild on the existing site, within the regulatory floodplain, your community's floodplain management ordinance or law will not allow your new house to have a basement (as defined by the NFIP regulations).

The advantages and disadvantages of demolition vary depending on which of the following three options you choose:

1. rebuilding on the existing site
2. rebuilding on an alternative, flood-free site elsewhere on your existing property
3. moving to a house on other property, outside the regulatory floodplain

The advantages and disadvantages of option 1 are same as those listed in Table 3.1 for the elevation method (see page 43). The advantages and disadvantages of options 2 and 3 are the same as those listed in Table 3.5 for the relocation method (see page 51), with the following exceptions: If you choose option 2, you will avoid the need to buy new property and dispose of your existing property.

NOTE

As discussed in *Financial Assistance for Retrofitting* in Chapter 2, the cost of demolishing a substantially damaged house may be an eligible flood insurance claim under ICC coverage.

If you decide to demolish your damaged house and rebuild somewhere on your existing property (option 1 or 2 above), your costs will be those for tearing down the damaged house, building the new house, reconnecting utility lines, and restoring the site around the new house. If you decide to move to a house outside the regulatory floodplain (option 3), your costs will be those for tearing down the damaged house, buying or building a house elsewhere, capping and abandoning the old utility lines, and restoring the old site.

The cost of tearing a house down, which is not a complex or difficult job, will be almost entirely for the disposal of the resulting debris. This cost can vary widely depending on the amount of debris, whether it can be buried at the demolition site or must be hauled to a licensed disposal site, and whether a dumping fee is required at the disposal site. The major costs associated with the demolition method will be for building or buying a house and will therefore depend on how and where you build or on the type of house you buy. Be sure to get a complete cost estimate before you begin a demolition project.

Summary

To protect your house from flooding, you may be able to use one or more of the retrofitting methods described in this chapter. However, as noted in this chapter, some retrofitting methods are probably inappropriate for your house, and some may not be allowed by your state or community. Also, if the substantial damage and substantial improvement requirements do not apply to your house, you may be faced with decisions about the level of protection you are willing to pay for and the level of risk you are willing to accept.

Chapter 4 will help you decide on a method. Then, depending on your decision, you can move on to Chapter 5, 6, or 7 for a detailed look at your preferred method.