



7.0 Floodproofing

This guide describes two types of floodproofing: wet and dry. As its name implies, wet floodproofing allows floodwaters to enter the enclosed areas of a home. In contrast, dry floodproofing prevents the entry of floodwaters. Because both approaches rely on varying philosophies of managing flood waters, this chapter separates the approaches and mitigation methods.

7.1 Wet Floodproofing



The benefit of wet floodproofing is that, if floodwaters are allowed to enter the enclosed areas of the home and to quickly reach the same level as the floodwaters outside, the effects of hydrostatic pressure, including buoyancy, are greatly reduced. As a result, there are equalized loads imposed on the home during a flood and the likelihood of structural damage may be greatly reduced. Wet floodproofing is generally used to limit damages to enclosures below elevated buildings, walkout-on-grade basements, below-grade basements, crawlspaces, or attached garages. It is not practical for these areas to be used as living space, and, if the home is being Substantially Improved or has been Substantially Damaged, wet floodproofing can lead to NFIP compliance only if (1) the area is limited to parking, access, or storage, (2) designed to allow for automatic entry and exit of flood waters through the use of flood openings, and (3) uses only flood damage-resistant materials below the DFE.

Successful wet floodproofing involves the following:

- Ensuring that floodwaters enter and exit the home's enclosed area (for NFIP compliance, floodwaters must exit the enclosed area automatically, without the use of pumps)



WARNING

If your home is being Substantially Improved or has been Substantially Damaged, your community's floodplain management ordinance or regulations will restrict the use of wet floodproofing to attached garages and enclosed areas below the BFE that are used solely for parking, building access, or storage. For more information, refer to NFIP Technical Bulletin 7, *Wet Floodproofing Requirements* (1993).



WARNING

Non-compliant wet floodproofing a residence will *not* reduce the flood insurance premium.



NOTE

Flood damage-resistant materials are discussed later in this chapter.

- Ensuring that floodwaters inside the home rise and fall at the same rate as floodwaters outside the home
- Reducing damage caused by contact with floodwaters to areas of the home that are below the flood level
- Protecting service equipment inside and outside the home
- Relocating high-value contents stored below the DFE

This chapter describes the modifications that must be made to a home as part of a wet floodproofing project and the most important considerations for this retrofitting method. Protection of service equipment is discussed in Chapter 9.

7.1.1 Design Flood Elevation

All construction and finish materials in the areas of the home that will be allowed to flood should be resistant to damage caused by direct, and possibly prolonged, contact with flood-water. Areas used for living space typically contain floor and wall coverings and other finishing materials, furniture, appliances, and items that could be easily damaged by floodwater and expensive to clean, repair, or replace. Therefore, wet floodproofing is practical only for portions of a home that are not used for living space, such as a basement, walkout-on-grade basement, crawlspace, non-air-conditioned porch, or attached garage. As shown in Figure 7-1, the lowest floor should be at or above the DFE (including freeboard) for wet floodproofing.



NOTE

Always consult a licensed, bonded, and insured contractor before initiating a wet floodproofing project. Be sure that your contractor has experience with wet floodproofing and understands the considerations discussed in Section 7.1.

If your DFE is above the elevation of your lowest finished floor, you should consider one or more of the other retrofitting methods described in this guide, such as elevation (Chapter 5). As you review Chapter 5, note that most of the elevation methods incorporate the principles of wet floodproofing. Elevation raises the living space above the flood level and allows floodwaters to enter the enclosed areas of the home below the living space if those areas have been retrofitted for compliance.

7.1.2 Hazards

Wet floodproofing protects a home from the effects of hydrostatic pressure but not from other flood hazards, such as the hydrodynamic force of flowing water, erosion and scour, saturation of building elements, damage to contents, the impact of ice and other floodborne debris, and damage from floodborne contaminants. If you have seen evidence of these hazards in past floods in your area, or if your community officials confirm that your home may be affected by these hazards, you should consider an alternative retrofitting method, such as relocation (Chapter 6) or elevation on an open foundation (Chapter 5). Wet floodproofing a home does not change its vulnerability to damage from high winds or earthquakes.

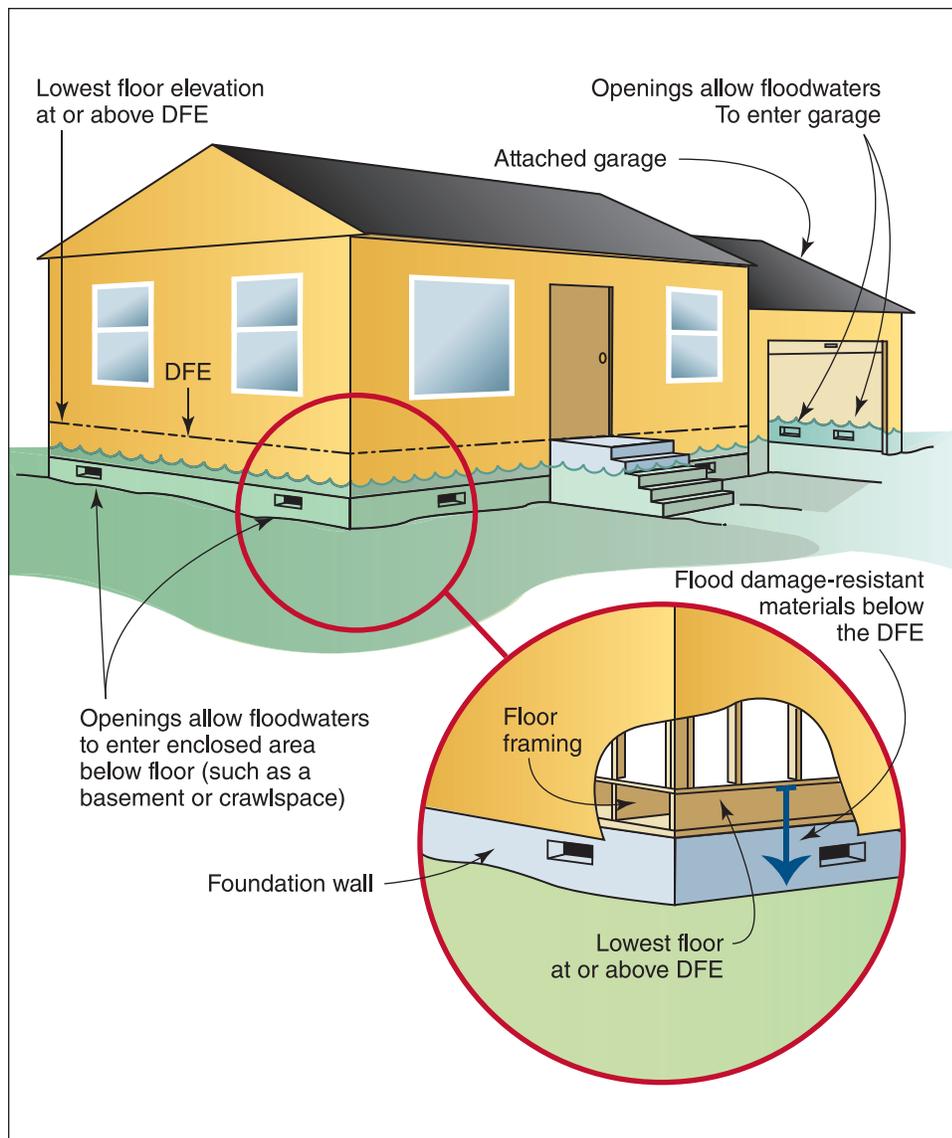


Figure 7-1. Typical wet floodproofing.

7.1.3 Post-Flood Cleanup

Remember that floodwater is rarely clean and may pose other safety hazards to occupants and contractors. Use caution when entering a recently flooded home; watch for structural instability or shifted contents as well as displaced animals. There are three important principles to follow when you first return to a flooded home before beginning repairs:

1. Personal Safety

Flooded buildings pose a number of health and safety risks, for both individuals who wish to maintain occupancy and those who work to repair the buildings. Eliminating hazards is the best way to protect occupants and workers; until conditions can



NOTE

If more than 10 square feet are affected by mold, you should contact a mold cleanup professional. For more information about mold prevention and remediation, visit the Center for Disease Control's (CDC's) mold Web site at <http://www.cdc.gov/mold>.

be returned to normal, anyone working in a flooded building should use appropriate personal safety equipment and take appropriate safety precautions.

Mold: The Occupational Safety and Health Administration (OSHA) Fact Sheet, *Hurricane Sandy Cleanup PPE Matrix* (OSHA-FS-3612, 2012), provides information on personal protective equipment. Anyone entering a house with visible mold growth should wear a disposable suit, rubber gloves or other hand protection, and respiratory protection. The OSHA Fact Sheet, *Mold Hazards During Hurricane Sandy Cleanup* (OSHA-FS-3619, 2012), provides information on mold.

Asbestos and Lead Paint: Asbestos in floor tile, pipe and boiler installation, and electrical wiring is common in many homes built before 1980. Breathing asbestos fibers released from building products can increase the risk of cancer and cause a number of serious lung diseases. Paint in homes constructed prior to 1978 may contain lead. If asbestos or lead paint is suspected, obtain the services of a specialist to perform material testing, and do not disturb the material until testing has been completed. If testing confirms the presence of lead, remediation should be conducted by a licensed professional in accordance with State and Federal regulations.

2. Cleaning Flood Damaged Homes to Prepare for Repair and Reconstruction

All objects that came into contact with the floodwater should be cleaned and sanitized. Water-damaged porous materials are difficult to properly clean and should be discarded.

Move out: Remove salvageable contents that were not affected by the water; dispose of all saturated porous materials, such as mattresses or upholstery.

Tear out: Remove all water-damaged interior finishes, including wet carpet and padding, curled vinyl tiles and linoleum, saturated drywall and plaster, saturated wall insulation, flooded electrical receptacles, and swollen wall paneling.

Barriers: Place plastic barriers between affected and unaffected areas of the building (typically between the first and second floors at the base of the stairs) to reduce the potential of mold spores spreading to unaffected areas.

Application of Cleaners: Cleaners are most efficiently applied using a combination of foam cleaning processes and brush cleaning, followed by pressure washing. Foam cleaning processes allow the product to stay on the surface long enough for the chemicals to kill the mold or bacteria and makes drying easier. Brushes improve decontamination of wooden studs and other surfaces by scrubbing the foam into affected surfaces. Water-damaged porous materials should be removed. Care should be taken to inspect both the front and back side of the non-flooded gypsum wall board and plaster walls for remaining dirt and mold to ensure all affected areas are cleaned.

Pressure Washing: The fastest and most efficient rinse tool, which minimizes the amount of water used to remove residual foam from wall studs, floor joists, and other surfaces, is a residential-type pressure washer set at low pressure so that the spray is a light mist.



WARNING

Although bleach is an inexpensive and convenient cleaning agent, it has many serious drawbacks when used to clean flood-impacted materials. It is not effective on porous materials, such as gypsum wall board or as a disinfectant on surfaces with residual dirt and can corrode electrical and metal components of mechanical systems. Do NOT combine chlorine bleach and ammonia, as the combination of chemicals will release vapors that can be extremely toxic or even fatal.

Cleaning Crawlspace: Removing the flooring is the simplest way to enter crawlspaces to decontaminate these areas. Solid contaminants should be removed from under the building, along with any remaining water. All exposed sides of floor joists, foundation walls, and remaining structural elements should be cleaned with cleaning foam and brushing.

Cleaning in Weather Extremes: Although cold weather poses challenges for restoring flooded buildings, it also has some advantages. Cooler weather slows down the spread of mold. However, buildings need to be warmed to 50° to 75°F to provide for worker comfort, improve the effectiveness of cleaning and sanitizing agents, and allow commercial drying equipment to operate efficiently. Mold and bacteria spread more quickly in hot and humid weather, slowing natural drying of flooded and contaminated building elements; in such circumstances, the use of drying equipment is critical to lower the moisture content of structural materials prior to rebuilding or repair.

3. Proper Drying Prior to Rebuilding

After the cleaning process has been completed, the building and any salvageable contents need to dry. Failure to allow adequate drying prior to reconstruction can trap moisture in the building, which can cause fungal growth and potential health problems. Once the electrical and HVAC systems have been restored and sanitized, the moisture content of wetted salvageable building materials should be checked to determine whether drying equipment, such as fans and dehumidifiers, is necessary.

For more information about restoring flooded buildings or initial precautions to be taken when entering flooded buildings, refer to the Hurricane Sandy Recovery Fact Sheet Number 1, *Cleaning Flooded Buildings* (FEMA. 2013a)¹.

FEMA P-942, *Hurricane Sandy in New Jersey and New York* (FEMA. 2013d) provides a comprehensive assessment of building material performance and mitigation actions appropriate to flooded homes, other structures, and infrastructure.

7.1.4 Modifications Required for Wet Floodproofing

Wet floodproofing requires a variety of modifications to your home, including its walls, construction and finishing materials, and service equipment. Consult with a design professional or licensed contractor before you make any modifications.

7.1.5 Installing Openings

The most important part of a wet floodproofing project is installing wall openings that allow the entry and exit of floodwaters. The openings must be installed in foundation walls and in garage walls as appropriate, below the expected flood level (Figure 7-2). The goal is not simply to allow the entry and exit of floodwaters, but also to ensure



CROSS REFERENCE

For more information about openings requirements for wet floodproofing, refer to NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008), and FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures* (FEMA. 2012a).



WARNING

Failure to allow adequate drying prior to reconstruction can trap moisture in the building, which can cause future fungal growth and potential health problems.

¹ The fact sheet is part of FEMA's Hurricane Sandy Recovery Advisory and Fact Sheet technical series and can be downloaded at <http://www.fema.gov/hurricane-sandy-building-science-activities-resources>

that the water level inside the home rises and falls at roughly the same rate as the water level outside so that hydrostatic pressures inside and outside are continuously equalized. As shown in Figure 7-2, large differences in the interior and exterior water levels allow unequalized hydrostatic pressures and, therefore, defeat the purpose of wet floodproofing. Figure 7-3 illustrates typical enclosures with flood openings.

For equal water levels to be maintained, both the size and number of openings must be adequate. Otherwise, when floodwaters are rising and falling, water will not be able to flow into or out of the home fast enough. The number of openings required and their size will depend on the rate of rise and the rate of fall of the floodwaters (see Chapter 2) and on the size of the area that is being allowed to flood. In general, the faster the rates of rise and fall and the larger the flooded area within the home, the greater the number and size of openings required.



NOTE

If you cover wall openings with louvers or screens, keep in mind that, the more restrictive they are, the more likely they are to become clogged with debris during floods and prevent the flow of floodwaters. Make sure that any screens or louvers allow the passage of water that contains suspended sediment and other small debris. After floodwaters have receded, screens and louvers must be cleaned of any debris that may have accumulated.

Figure 7-2. Wall openings must allow floodwaters not only to enter the home, but also to rise and fall at the same rate as floodwaters outside the home.

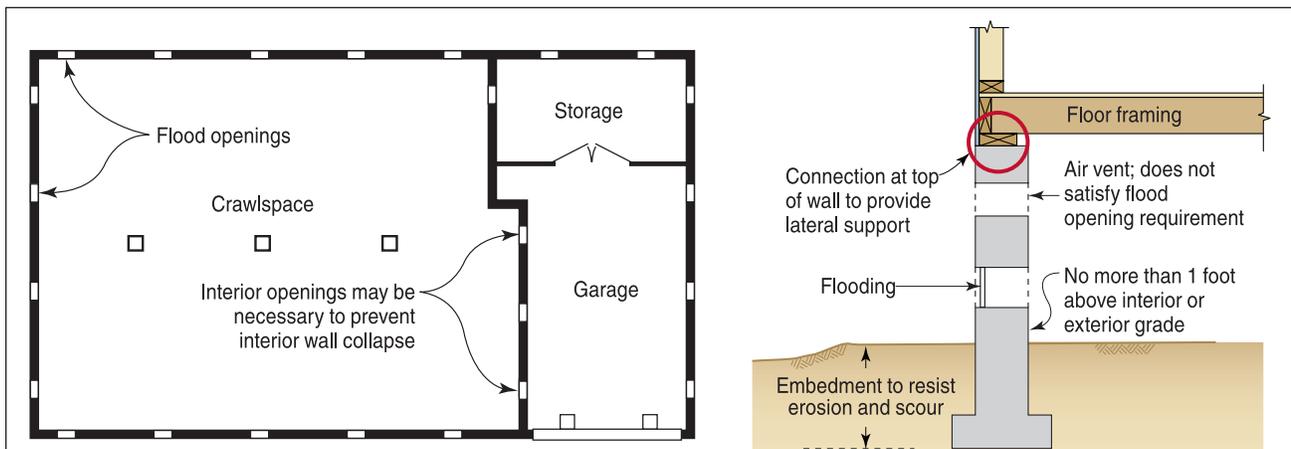
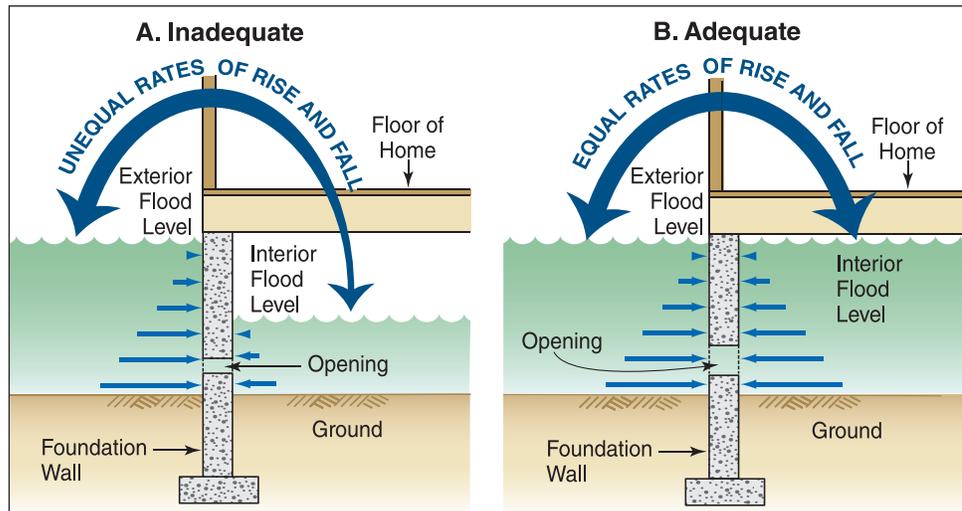


Figure 7-3. Sketch of foundation plan of home with multiple enclosed areas, each with flood openings. Typical enclosures with flood openings (Left). Flood opening in typical crawlspace foundation (Right).

If you are wet floodproofing areas below the BFE in a Substantially Improved or Substantially Damaged home, your community's floodplain management ordinance or regulation will require you to install openings in the exterior walls of all enclosed areas below the BFE (see Section 3.1.1). The minimum requirements are:

- You must provide at least two wall openings for each enclosed area—one in each of two different walls. In other words, you cannot put both openings in the same wall.
- If your home has more than one enclosed area, you must install openings in the exterior walls of each enclosed area so that floodwaters can enter directly from the outside.
- The total area (size) of all openings for each enclosed area must equal at least 1 square inch for every square foot of floor space in the enclosed area. For example, if the enclosed area is 25 feet by 40 feet (1,000 square feet), the total net area of the openings must be at least 1,000 square inches, or roughly 7 square feet. In this example, you could meet the size requirement by providing two 3½-square-foot openings or several smaller openings whose total net area equals 7 square feet.
- The bottom of each opening must be no higher than 1 foot above the higher of the exterior grade or interior grade directly below the opening.
- Floodwaters must be able to flow in and out of enclosed areas automatically. If you place louvers, screens, or other types of covers over the openings (which many homeowners do to prevent animals from entering the enclosed areas), they must not block the flow of water. Note that the area of any screens or louvers covering the openings must be subtracted from the gross opening area. Because the need for human intervention reduces the reliability of wet floodproofing, you may not install any type of electrical-, mechanical-, or manual-operated cover.
- Flood openings must be entirely below the BFE.

FEMA developed these requirements to provide homeowners with a straightforward means of determining where and how to install wall openings without the aid of an engineer or design professional. The requirements provide a margin of safety for wet floodproofed homes subject to flooding with rates of rise and fall as high as 5 feet per hour. If you wish to install openings that do not meet one or more of the requirements listed above, your design must be certified by a registered engineer or other licensed design professional and approved by your local officials. See FEMA's NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008), for more information about openings requirements.

7.1.6 Protecting the Underside of Elevated Buildings

The undersides of elevated coastal buildings are typically covered with vinyl or aluminum soffits or plywood sheathing to protect insulation and metal floor system connectors. The undersides of these buildings are often damaged by high hurricane force winds, allowing water to be driven into the building. Lost paneling or sheathing can become wind-borne debris, increasing the risk of damage. How the space below the building is designed and built is determined by local floodplain regulations and building codes, which may include fire resistant-rated building materials, depending on the use of the underneath space (parking, storage areas).

Underside materials should meet flood damage-resistant requirements outlined in NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008), and local code requirements, including fire resistance requirements where applicable. In coastal areas, make sure to use corrosion-resistant fasteners to secure the underside materials. Wind loads based on wind speed maps for the area where the building is located must be included in the underbuilding wind protection assembly design. To ensure the assembly is effective, a licensed engineer or architect should prepare the design in accordance with Hurricane Isaac Recovery Advisory 1 (see Cross Reference).

7.1.7 Using Flood Damage-Resistant Materials

In the areas below the anticipated flood level, any construction and finishing materials that could be damaged by floodwaters must be either removed or replaced with flood damage-resistant materials as required by your community's floodplain management ordinance or regulations. Vulnerable materials include gypsum wall board (also called dry wall), blown-in and fiberglass batt insulation, carpeting, and non-pressure-treated wood and plywood. Flood damage-resistant materials are those that can be inundated by floodwaters with little or no damage. They include such materials as concrete, stone, masonry block, ceramic and clay tile, pressure-treated and naturally decay-resistant lumber, epoxy-based paints, and metal. In addition to resisting damage from floodwaters and their contaminants, these materials are relatively easy to clean after floodwaters recede.

Table 7-1 lists materials that are acceptable and unacceptable for use in wet floodproofing projects. NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008), offers more complete guidance on materials that can and cannot be used to wet floodproof an area below the DFE. Consult a design professional before selecting materials to wet floodproof any areas in your home.



CROSS REFERENCE

For more information about flood damage-resistant materials, refer to NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008). This bulletin includes a detailed list of common floor, wall, and ceiling materials categorized according to their applicability for use in areas subject to inundation by floodwaters.



CROSS REFERENCE

For more information about openings protecting the underside of elevated buildings, refer to Hurricane Isaac Recovery Advisory 1, *Minimizing Wind and Water Intrusion by Covering the Underside of Buildings* (FEMA, 2012c).

Table 7-1. Flood Damage-Resistant Materials

Material Type	Acceptable	Unacceptable
Structural Flooring Materials	<ul style="list-style-type: none"> • Concrete • Naturally decay-resistant lumber • Pressure-treated plywood 	<ul style="list-style-type: none"> • Engineered wood or laminate flooring • Oriented-strand board (OSB)
Finish Flooring Materials	<ul style="list-style-type: none"> • Clay tile • Ceramic or porcelain tile • Terrazzo tile • Vinyl tile or sheets 	<ul style="list-style-type: none"> • Engineered wood or laminate flooring • Carpeting • Wood flooring
Structural Wall and Ceiling Materials	<ul style="list-style-type: none"> • Brick face, concrete, or concrete block • Cement board / fiber-cement board • Pressure-treated plywood • Solid, standard structural lumber (2x4) • Non-paper-faced gypsum board 	<ul style="list-style-type: none"> • Fiberglass insulation • Paper-faced gypsum board • OSB
Finish Wall and Ceiling Materials	<ul style="list-style-type: none"> • Glass blocks • Metal cabinets or doors • Latex paint 	<ul style="list-style-type: none"> • Wood cabinets and doors • Non-latex paint • Particleboard cabinets and doors • Wallpaper

7.1.8 Protecting Service Equipment

When you wet floodproof a home, you should also protect the service equipment below the anticipated flood level, both inside and outside the home in accordance with NFIP requirements. Service equipment includes utility lines, heating ventilation and air conditioning (HVAC) equipment, ductwork, hot water heaters, and large appliances. Chapter 9 describes a variety of methods you can use to protect interior and exterior service equipment.

7.2 Dry Floodproofing



Dry floodproofing involves completely sealing the exterior of a building to prevent the entry of floodwaters. Unlike wet floodproofing (Section 7.1), which allows water to enter the building through wall openings, dry floodproofing seals all openings below the flood level and relies on the walls of the building to keep water out. Even if your home is dry floodproofed, water can still seep through small openings in the sealant system or through the gaskets of shields that are protecting openings (doors and windows). Internal drainage systems, utilizing sump pumps, are required to remove any water that has seeped through and to remove water collected from any necessary underdrain systems in the below-grade walls and floor of the home.

Because the walls are exposed to floodwaters and the pressures they exert, dry floodproofing is practical only for homes with walls constructed of masonry or poured concrete and only where flood depths are low (typically no more than 2 to 3 feet). Successful dry floodproofing involves the following:

- Sealing the exterior walls of the home
- Covering openings below the flood level
- Protecting the interior of the home from seepage
- Protecting service equipment outside the home

The following sections discuss the most important considerations regarding dry floodproofing and describe the modifications that must be made to a home as part of a dry floodproofing project. Protection of service equipment is discussed in Chapter 9.

7.2.1 Considerations

Flood Depth

The primary consideration in dry floodproofing, and the one that imposes the greatest limitations on the application of this method, is the effect of hydrostatic pressure. Because dry floodproofing prevents water from entering the home, the external hydrostatic pressure exerted by floodwaters is not countered by an equal force from water inside the home (see Chapter 2). This external pressure results in two significant problems: heavy unequalized loads on the walls of the home and buoyancy, or uplift force, which acts on the entire home.

When water rises against a wall, it pushes laterally against the wall. As the depth of water increases, so does this force, as indicated by the arrows in Figure 7-4. Tests performed by the USACE² indicated that, on a test subject, the maximum allowable flood depth for masonry and masonry veneer walls was approximately 3 feet. In these tests, walls exposed to greater depths of water either collapsed or suffered serious structural damage. These tests only addressed flood loads on the house and did not expose the house to wind loads. Additionally, the tests represented one flood event and the test procedures did not address the impact of similar flood loads on the longevity of the house or its ability to resist future flood events. Masonry veneer is not allowed by design standards to be considered as a material to resist lateral loads, such as flood loads. Houses should not be considered resistant to increased or high loads (such as lateral loads from floodwaters) because of the presence of a masonry veneer alone.



WARNING

Dry floodproofing cannot be used to bring a Substantially Improved or Substantially Damaged home into compliance with the requirements of your community's floodplain management ordinance or regulation. In addition, dry floodproofing measures can fail during larger flood events.



WARNING

The flood depth limits discussed here are provided as general guidelines only. Before you attempt to dry floodproof your home, a design professional, such as a structural engineer, must inspect it to determine whether it is structurally sound and able to resist increased flood loads expected as a result of dry floodproofing. Design professionals familiar with dry floodproofing techniques and technologies should design the dry floodproofing system so that the building's load capacities can be properly addressed.

² The test results are documented in the following reports published by the USACE National Flood Proofing Committee: *Flood Proofing Tests – Tests of Materials and Systems for Flood Proofing Structures*, August 1988; *Systems and Materials to Prevent Floodwaters from Entering Buildings*, May 1985; *Structural Integrity of Brick-Veneer Buildings*, 1978; *Tests of Brick-Veneer Walls and Closures for Resistance to Floodwaters*, May 1978.

Hydrostatic pressure is exerted not only by floodwater, but also by soils saturated by floodwaters. As a result, basement walls can be subjected to pressures much greater than that from 3 feet of water alone (Figure 7-4). These pressures can easily cause basement walls to buckle inward or collapse (Figure 2-8). For this reason, dry floodproofing in basements is strongly discouraged. In fact, your community's floodplain management ordinance or regulation does not allow basements in Substantially Improved or Substantially Damaged homes to be dry floodproofed.

As shown in Figure 7-4, water and saturated soils also push up from below the home. The buoyancy force resulting from flood depths of over 3 feet can separate a dry floodproofed home from its foundation and buckle concrete slab floors in dry floodproofed slab-on-grade homes.

The degree of danger posed by buoyancy depends on the flood depth, the type of soil at the home site, how saturated the soil is, the duration of the flood, whether the home has a drainage collection and disposal system, and how well that system works. Only an experienced engineer can evaluate these factors.



CROSS REFERENCE

For additional information about dry floodproofing techniques, refer to NFIP Technical Bulletin 3, Non-Residential Floodproofing – Requirements and Certification (1993), and FEMA P-259, Principles and Practices for Retrofitting Flood-Prone Residential Structures (2012).

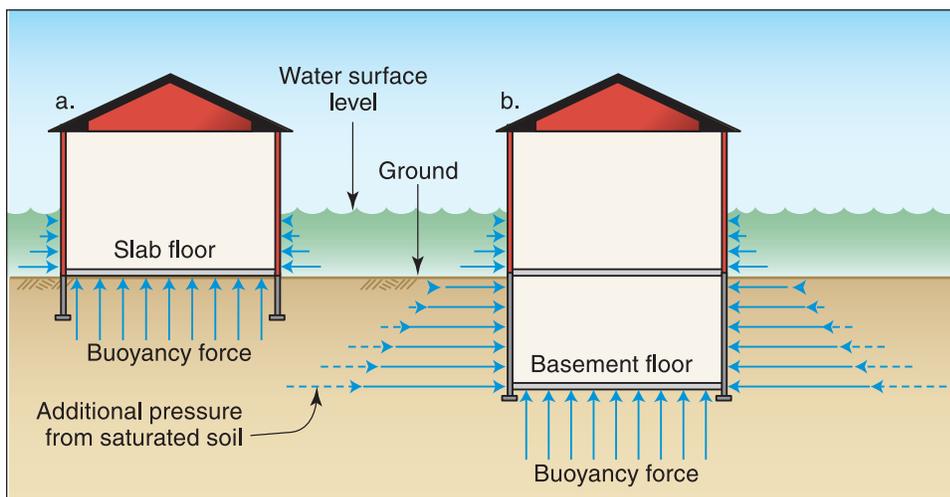


Figure 7-4. The lateral and buoyancy force resulting from the same depth of flooding is much less on a home without a basement (a) than on a home with a basement (b). The pressure on basement walls is caused by water and saturated soils.

Flow Velocity, Erosion and Scour, Debris Impact, and Wave Action

Dry floodproofing does not protect a home from the hydrodynamic force of flowing water, erosion and scour, the impact of ice and other floodborne debris, or wave action. If your home is located in an area subject to any of these hazards, consider an alternative retrofitting method, such as elevation on an open foundation (Section 5.2.3) or relocation (Section 6.1). Dry floodproofing a home does not change its vulnerability to damage from high winds or earthquakes.

Flood Duration

Flood duration is an important consideration because the potential for seepage through and deterioration of the materials used to seal the home increase with the length of time that the home is exposed to flooding. Also, the longer the duration, the greater the likelihood that the soil beneath and adjacent to the home will become fully saturated and add to the loads on the walls and floor (Figure 7-4). Additionally, most dry floodproofing methods depend on sump pumps to address water that has leaked into the house, and those pumps require electricity to

run. Although some sump pumps have battery backups, these backups typically only last a few hours, so a generator system may also be required for long-duration flooding. If your home is in an area where floodwaters remain high for days, weeks, or even months at a time, consider an alternative retrofitting method, such as elevation or relocation.

Human Intervention

Dry floodproofing systems almost always include components that have to be installed or activated each time flooding threatens. One example is a flood shield placed across a doorway. For this reason, dry floodproofing is not an appropriate retrofitting method in areas where there is little or no flood warning or where, for any other reason, the homeowner will not be able or willing to install shields or other components before floodwaters arrive.

Post-Flood Cleanup

Remember that floodwaters are rarely clean. They usually carry sediment, debris, and even corrosive or hazardous materials, such as solvents, oil, sewage, pesticides, fertilizers, and other chemicals. The walls of a dry floodproofed home will be exposed to whatever is in the floodwaters. Cleaning up a dry floodproofed home after a flood may, therefore, involve not only removing mud and debris from around the home, but also decontaminating or disinfecting walls and other exterior surfaces. Hurricane Sandy Fact Sheet 1, Cleaning Flooded Buildings (FEMA, 2013a), provides some guidance on cleaning up following a flood.

7.2.2 Modifications Required for Dry Floodproofing

Dry floodproofing involves the use of sealants and shields, the installation of a drainage system, and the protection of service equipment.

Sealants

Except for some types of high-quality concrete, most wall materials are not impervious to water. Therefore, sealants must be applied to the walls of a dry floodproofed home to prevent leakage. Prior to applying a sealant, a structural engineer must determine whether the walls can resist the loads. Flexible sealants are compounds (such as asphalt coatings) or materials (such as polyethylene film) that are applied directly to the outside surface of the home walls. Sealants must also be applied to all structural joints, such as the joint between the walls and a slab floor, and to any other openings below the flood level, such as those where utility lines enter the home through the walls or floor. Some of these sealants are designed to be applied to the outside of the wall, while others can be applied to the inside of the walls. Which sealant is appropriate will depend on the manufacturer's recommendations and the access to the wall surfaces or structural joints.

Sealants that can be applied to outside walls include cement- and asphalt-based coatings and clear coatings, such as epoxies and polyurethanes. Cement- and asphalt-based coatings are often the most effective, but they can change the appearance of the wall (Figure 7-5). The aesthetic advantage of many exterior treatments is lost when these coatings are applied over them. Clear coatings do not change the appearance of the wall, but are less effective

Figure 7-6 shows one method of sealing masonry walls with an asphalt-based coating that does not detract from their appearance. In this method, a new masonry veneer is added to the existing veneer after the coating is applied.

An alternative to using coatings is to temporarily wrap the entire lower part of the home in polyethylene film when flood conditions threaten. This alternative is sometimes referred to as the “wrapped home” technique. The cross-section view in Figure 7-7 shows how this technique works. There must be at least several hours of warning time in order to properly deploy this method. The use of a flood wrapping system should be considered temporary and largely an emergency solution to a flooding problem.



Figure 7-5. Example of an exterior application of a spray-applied asphalt membrane (left – courtesy of GMX, inc.) and an interior application of a fiber reinforced polymer wrap (right).

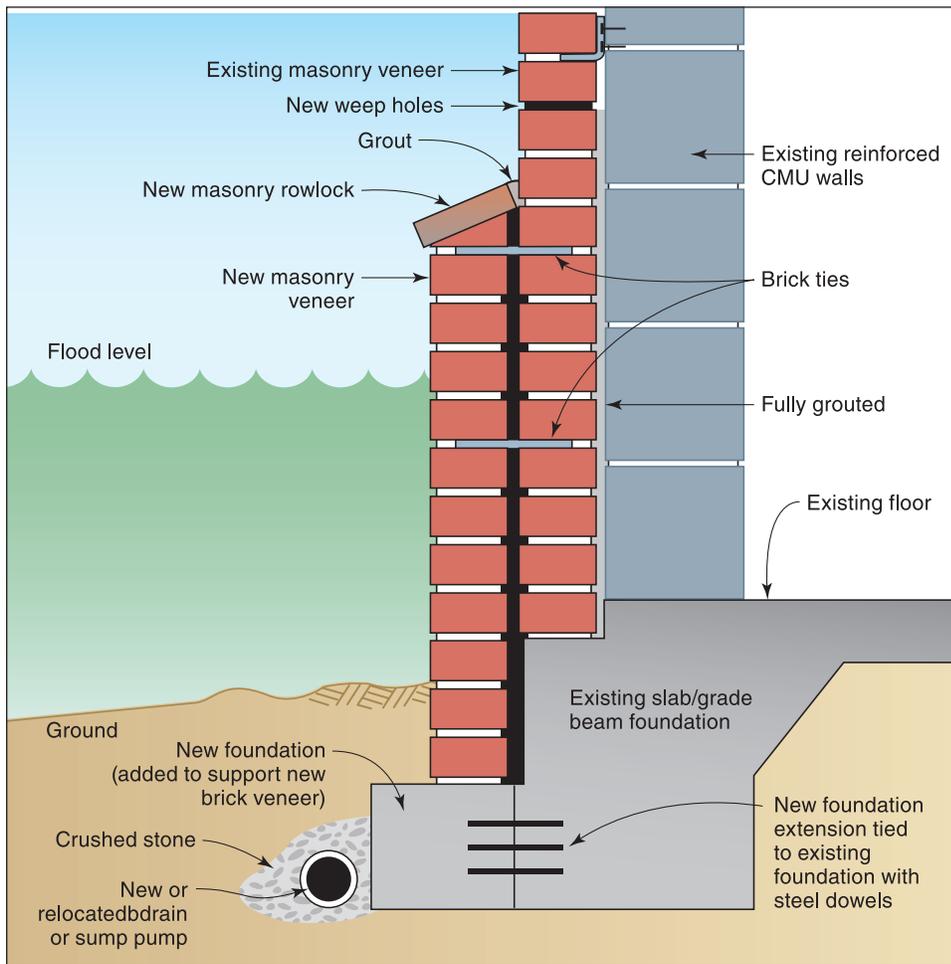


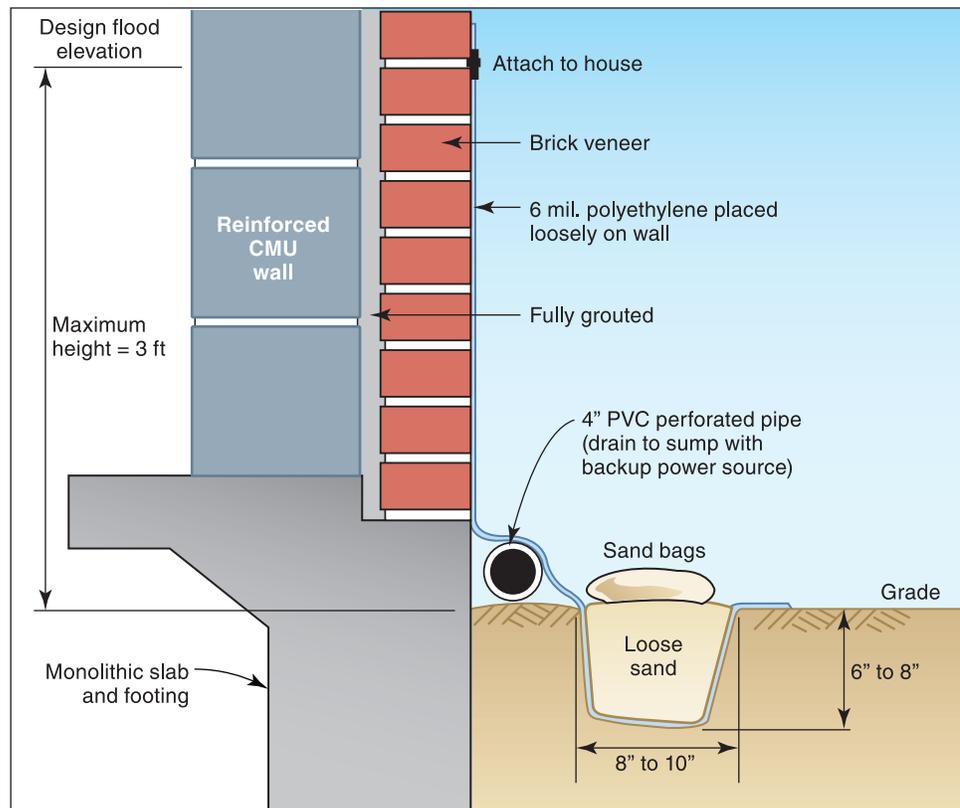
Figure 7-6. A way to seal an existing brick-faced wall is to add an additional layer of brick with a seal in between. Please note that weep holes (drainage) and wick drains are moved up to prevent moisture from getting inside the walls.

Polyethylene film is not a strong material; it cannot withstand water pressure on its own and can be punctured fairly easily. As a result, the following requirements must be met when the wrapped home technique is used:

- The manufacturer’s literature must demonstrate applicability of the film to the home’s building materials. Rely on actual test results, if available.
- The installation must be carried out very carefully. Even a small hole in the film will leak under the pressure of floodwaters.
- The film must be applied directly against the walls of the home so that the walls, rather than the film, provide the resistance to water pressures. This may require strengthening the walls of the home and openings, such as doors.
- Where the film covers doorways and other openings, it must be backed by framed plywood panels that are braced to resist water pressures.
- A temporary drainage system must be provided to collect and dispose of any water that leaks through holes in the film. (Drainage systems are discussed later in this section.)
- The duration of flooding should be less than 12 hours and the flood depth adjacent to the home should not exceed 1 foot.

Home wrap systems require secure connections at both the top and bottom of the wrap. The actual loads imposed vertically on the wrap are difficult to determine because they can vary depending on the quality of the installation. Voids or weak spots left from poor construction may force the wrap to carry the weight of the water and should be avoided.

Figure 7-7. In the “wrapped home” method, the lower portion of the home is protected with a temporary layer of polyethylene film. As shown, a temporary drainage line is also required.



The following should be considered in the selection of a top-of-wall connection system:

- A clamping system that uniformly supports the wrap. A small spacing on the connections and a connection system with some rigidity on the outside of the wrap can provide this needed support.
- The existing wall construction can vary widely. Part of the connection may need to be a permanent part of the wall.



WARNING

Wrap systems may be affected by freeze-thaw cycles. Careful installation in accordance with manufacturer instructions and evaluation of performance in frozen climates is advisable.

Anchoring a wrap into the ground at the base of a wall is the most important link in the wrap system (see Figure 7-7). The following recommendations should be followed during selection of a system:

- A drain line between the wrap and the building is usually required to remove any water that leaks through the wrap or seeps through the soil under the anchor.
- As with the top-of-wall connection, wrap forces are difficult to determine. Details that have worked in the past and that are compatible with the building and the selected wrapping system should be followed.
- The end of the wrap should be buried at least below the topsoil layer. Additional ballast may be needed (e.g., sandbags, stone) to prevent wrap movement in a saturated and/or frozen soil condition.
- The product literature for the wrap material and applicable codes and standards should be reviewed and followed.

Before selecting a wrapping system, make sure that the manufacturer's literature addresses the following issues.

- Are any chemicals used or stored around the home or onsite that could damage the wrapping system? Evaluate adjacent properties to identify any potential chemicals that could damage a wrap system.
- How should the wrapping system be repaired and approximately how much additional wrapping material is required for each repair? Understanding whether the wrapping material can be repaired under flood conditions or if it must be dry for a proper repair to be made is important.

Shields

Shields are flood barriers placed over openings in walls such as doorways and windows. Shields can be made of several materials, depending on the size of the opening to be covered, and should include gaskets along their edges. When flood depths are expected to reach the maximum allowable 2 to 3 feet, shields for openings wider than approximately 3 feet must be made of strong materials such as heavy-gauge aluminum or steel plates (Figure 7-8); shields for lesser depths and smaller openings can be made of lighter materials. Because of the potential risk of a shield failing, a structural engineer must assist with the design of the shields and evaluate the entire dry floodproofing system. The engineer may also determine that the walls to which the shield is attached need to be strengthened to carry the flood loads associated with the shield.

Because permanently blocking all doors and other openings would be impractical, shields are usually placed temporarily, after flood warnings are issued. Most residential shields are light enough that they can be stored in the home and, when needed, brought out and bolted in place or secured in permanently installed brackets or tracks (Figure 7-9). Although rare for residential applications, some larger, heavier shields may have to be permanently installed on hinges or rollers so that they can be opened and closed easily.

Figure 7-8. Heavy-gauge metal shield over sliding glass door opening.

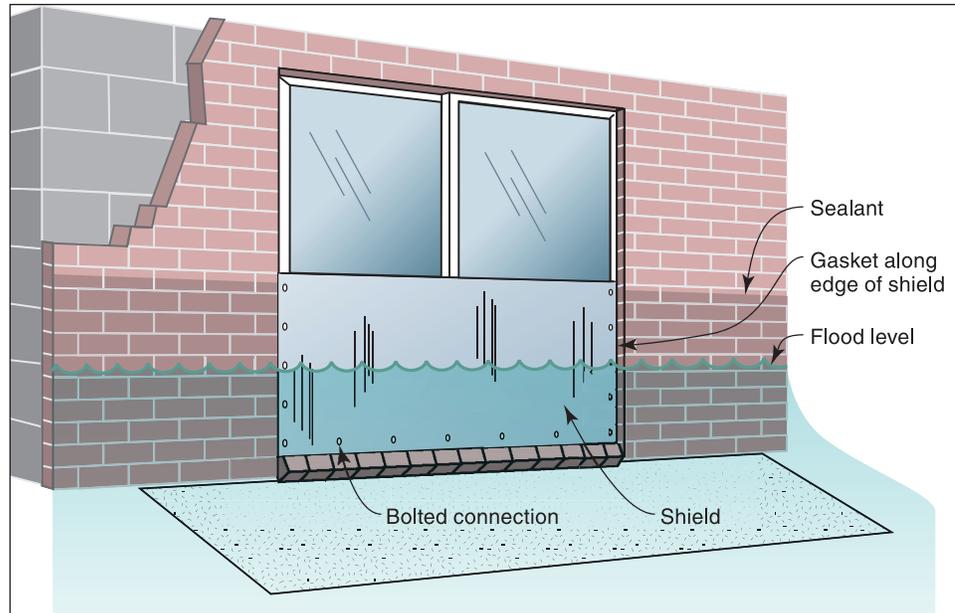
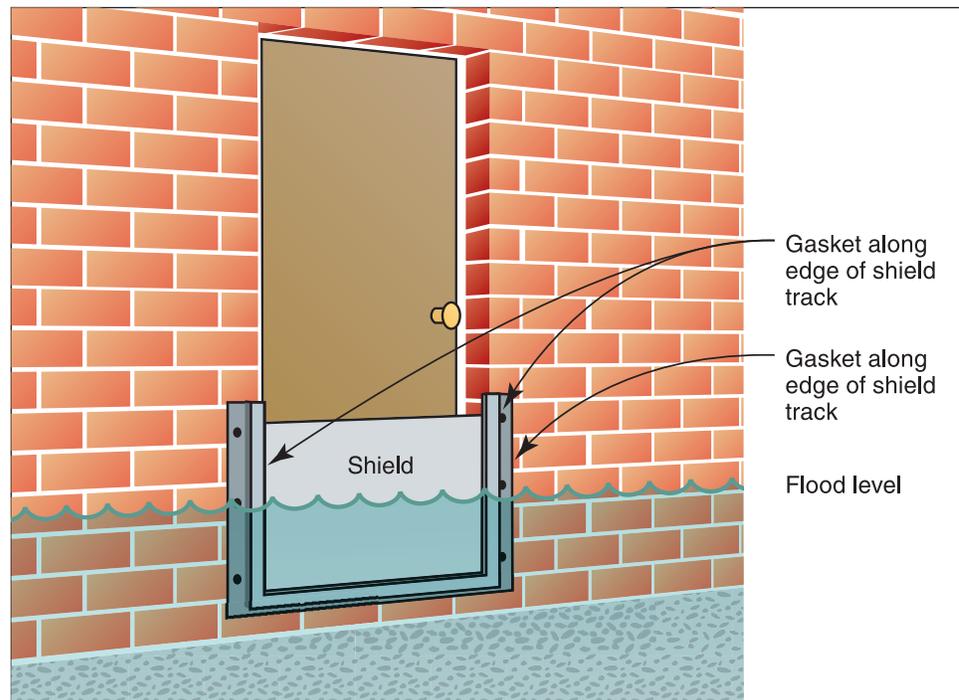


Figure 7-9. Light-gauge metal shield held in place by permanently installed tracks.



Companies that specialize in flood protection devices can provide custom-fitted flood shields. Usually, these commercial shields are made of heavy-duty materials, and some are equipped with inflatable or other types of gaskets that help eliminate leaks. Gaskets left exposed to the elements can rapidly decay. Gasket materials should be stored indoors and checked periodically for tears or decay. A faulty gasket can allow floodwaters to get past the gasket, nullifying any of the other floodproofing techniques.

An alternative to using shields is to permanently seal openings. For example, a low-level window can be removed or raised and the opening bricked up or filled with glass block (Figure 7-10).

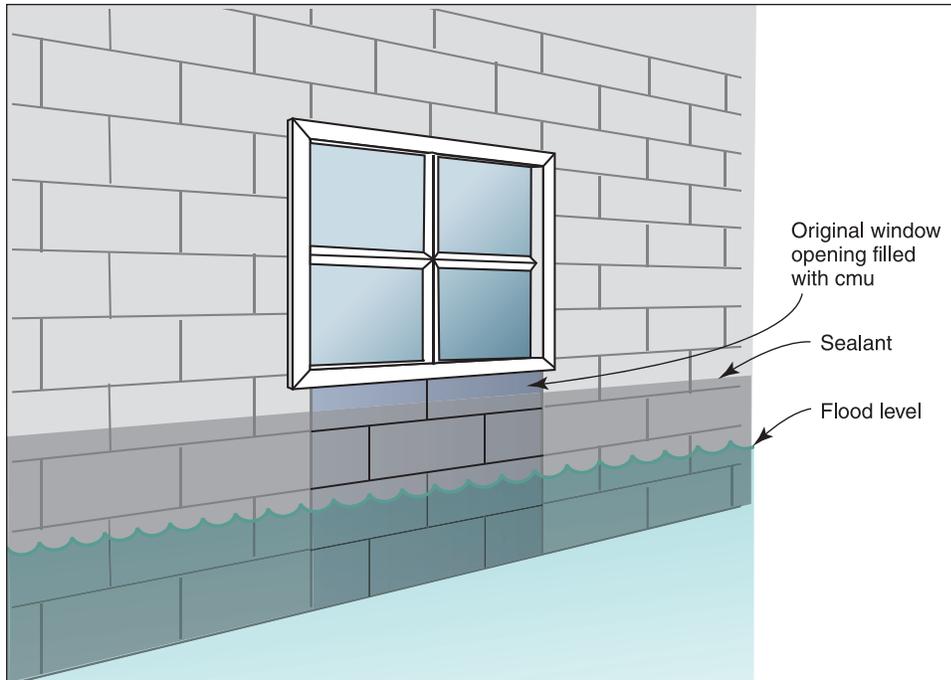


Figure 7-10. Low window raised approximately 2 feet and original opening filled with brick.

Drainage Systems

Sealants and shields provide the bulk of the protection in dry floodproofing, but they may permit some leakage, especially during floods of longer duration and when damaged by debris. They also do not protect against “**underseepage**,” water that migrates downward along the sealed wall and then under the foundation. For these reasons, a dry floodproofed home must have a drainage system that will remove any water that enters the home through leaks in sealants and shields and any water that accumulates at the base of the foundation. Depending on the permeability of the soils around and under the home, the drainage system may also have to be designed to reduce buoyancy forces.



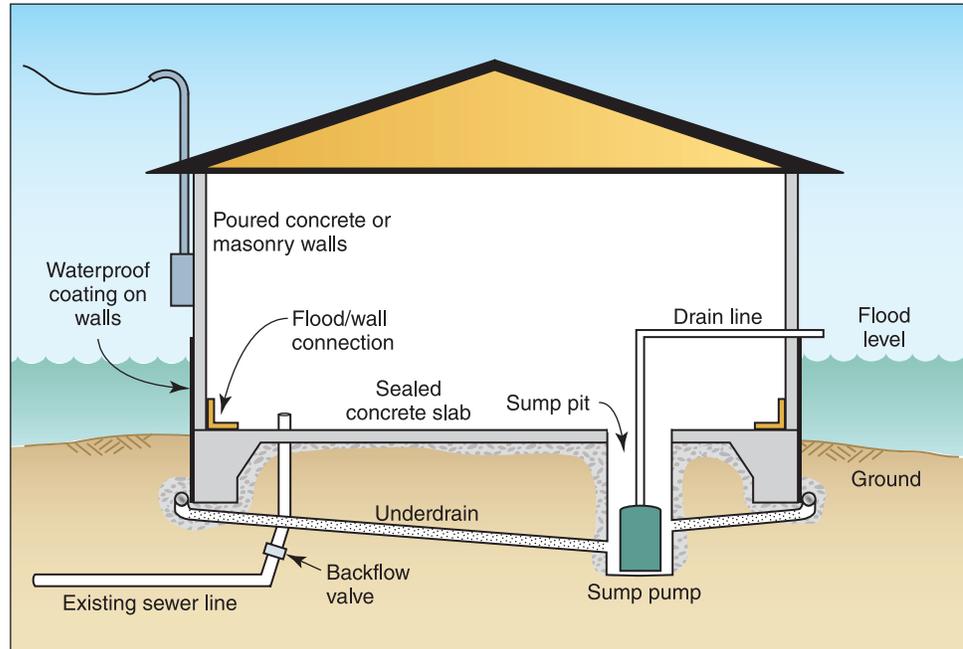
DEFINITION

Underseepage is water that migrates downward along the sealed walls of a home and then under the foundation.

An adequate drainage system includes drains along the base of the foundation and under the floor. The drains consist of perforated pipe surrounded by crushed stone. The pipes collect water that seeps through the ground and channel it to a central collection point equipped with a sump pump. This system is shown in Figure 7-11. The sump pump must have sufficient capacity to handle the inflow of water and must have an emergency power source, such as a portable generator, so that it will continue to operate if conventional electric service is disrupted. Depending on soil conditions, seepage rates may exceed the maximum discharge rates of standard sump pumps.

Drainage systems should be designed and laid out based upon several factors, such as the design flood depth, soil conditions, and the construction methods and materials of the area to be protected. These factors will also affect the size of the sump pump and the requirements for a backup power source. Because of the complexity of these designs and the potential consequences of a system failure, seek the input of a design professional familiar with dry floodproofing systems.

Figure 7-11. Drainage system for a dry floodproofed home.



Protecting Service Equipment

Dry floodproofing a home will not protect service equipment outside the home. Examples of service equipment typically found outside the home are utility lines, air conditioning compressors, heat pumps, and fuel storage tanks. Chapter 9 discusses the protection of service equipment.