HANDBOOK FOR ARIZONA COMMUNITIES
On Floodplain Management and the National Flood Insurance Program

APPENDIX N

Technical
Bulletin
Guide '99

User's Guide to Technical Bulletins

Including Key Word/Subject Index

FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

FIA-TB-0
(9/99)

TECHNICAL BULLETIN GUIDE-99

User's Guide to Technical Bulletins Including Key Word/Subject Index

The User's Guide

This User's Guide is intended to assist those using the Technical Bulletins issued by the Federal Emergency Management Agency (FEMA), Mitigation Directorate. This guide contains a Key Word/Subject Index that identifies topics contained in the Technical Bulletins regarding the National Flood Insurance Program (NFIP). Reference sources and information about ordering additional NFIP publications are also provided.

The Technical Bulletins

The Technical Bulletins provide guidance concerning the building performance standards of the NFIP, which are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulation; rather, they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the appropriate FEMA regional office (see page 6).

Comments on the Technical Bulletin Series should be addressed to:

FEMA/Mitigation Directorate
Program Policy and Assessment Branch
500 C Street, SW.
Washington, DC 20472

Copies of the Technical Bulletins can be obtained from the FEMA regional office that serves your area (see page 6). In addition, Technical Bulletins and other FEMA publications can be ordered from the FEMA Publications Service Center at 1-800-480-2520. The Technical Bulletins are also available at the FEMA web site at www.fema.gov.

It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Available Technical Bulletins

As of September 1999, the following Technical Bulletins are available:

Guide-99 User's Guide to Technical Bulletins

Provides a list of available technical bulletins, a key word/subject reference index for all the bulletins, and information about how to obtain copies of the bulletins.

1-93 Openings in Foundation Walls

Provides guidance on the NFIP regulations concerning the requirement for openings in below-Base Flood Elevation foundation walls for buildings located in Zones A, AE, A1 A30, AR, AO, and AH.

2-93 Flood-Resistant Materials Requirements

Provides guidance on the NFIP regulations concerning the required use of flood-damage resistant construction materials for building components located below the Base Flood Elevation in Special Flood Hazard Areas (both A and V zones).

3-93 Non-Residential Floodproofing – Requirements and Certification

Provides guidance on the NFIP regulations concerning watertight construction and the required certification for floodproofed non-residential buildings in Zones A, AE, A1-A30, AR, AO, and AH whose lowest floors are below the Base Flood Elevation.

4-93 Elevator Installation

Provides guidance on the NFIP regulations concerning the installation of elevators below the Base Flood Elevation in Special Flood Hazard Areas (both A and V zones).

5-93 Free-of-Obstruction Requirements

Provides guidance on the NFIP regulations concerning obstructions to flood waters below elevated buildings and on building sites in Coastal High Hazard Areas (Zones V, VE, and V1-V30).

6-93 Below-Grade Parking Requirements

Provides guidance on the NFIP regulations concerning the design of below-grade parking garages beneath buildings located in Zones A, AE, A1-A30, AR, AO, and AH.

7-93 Wet Floodproofing Requirements

Provides guidance on the NFIP regulations concerning wet floodproofing of certain types of structures located in Zones A, AE, A1-A30, AR, AO, and AH.

8-96 Corrosion Protection for Metal Connectors in Coastal Areas

Provides guidance on the need for, selection of, and use of corrosion-resistant metal connectors for the construction of buildings in coastal areas.

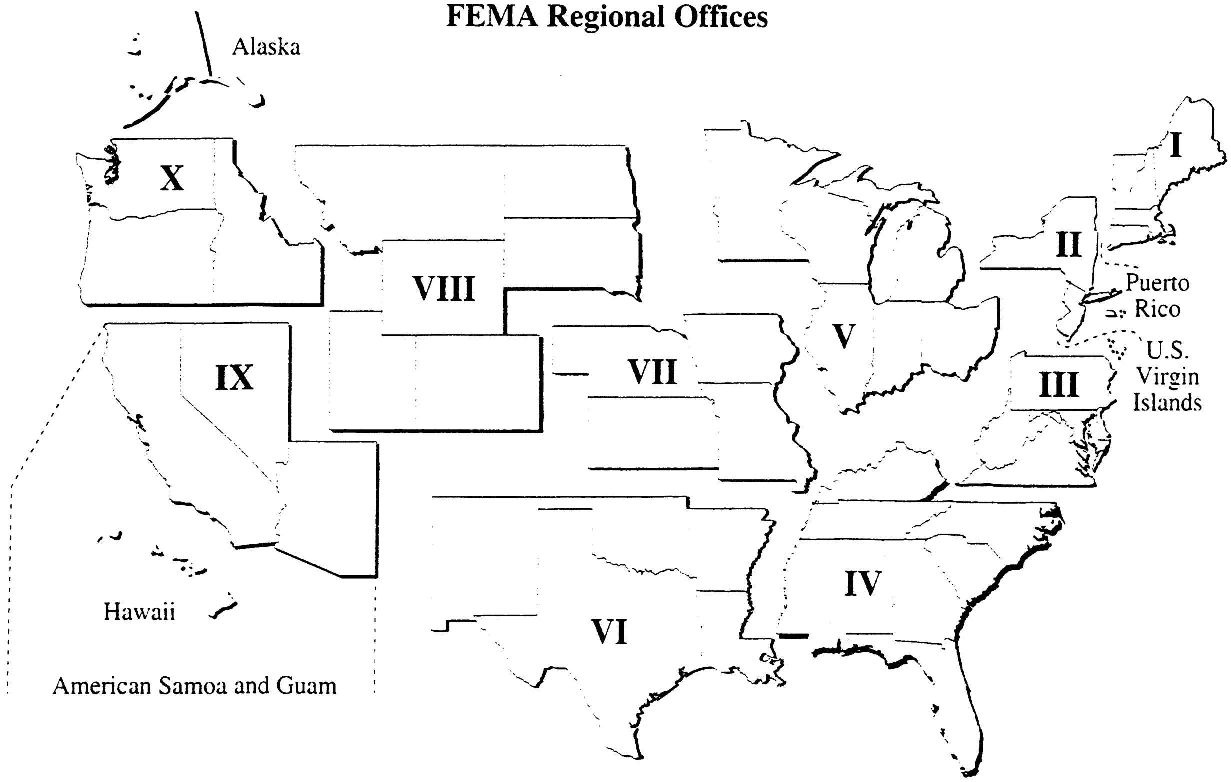
9-99 Design and Construction Guidance for Breakaway Walls Below Elevated Buildings in Coastal Areas

Provides prescriptive criteria for the design and construction of wood-frame and masonry breakaway walls compliant with NFIP regulatory requirements.

Key Word/Subject Index

This index is designed to allow the user to quickly locate key words that pertain to the subject in question. The index also cross-references issues that are addressed by more than one Technical Bulletin. For example, users of Technical Bulletin 6 (Below-Grade Parking Requirements) should also refer to Technical Bulletin 3 (Non-Residential Floodproofing — Requirements and Certification) concerning insurance rating issues.

FEMA Regional Offices



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Other Federal agencies that provide floodplain management assistance include the U.S. Army Corps of Engineers and the U.S. Natural Resources Conservation Service. For their nearest locations, please refer to your local telephone directory under "United States Government."

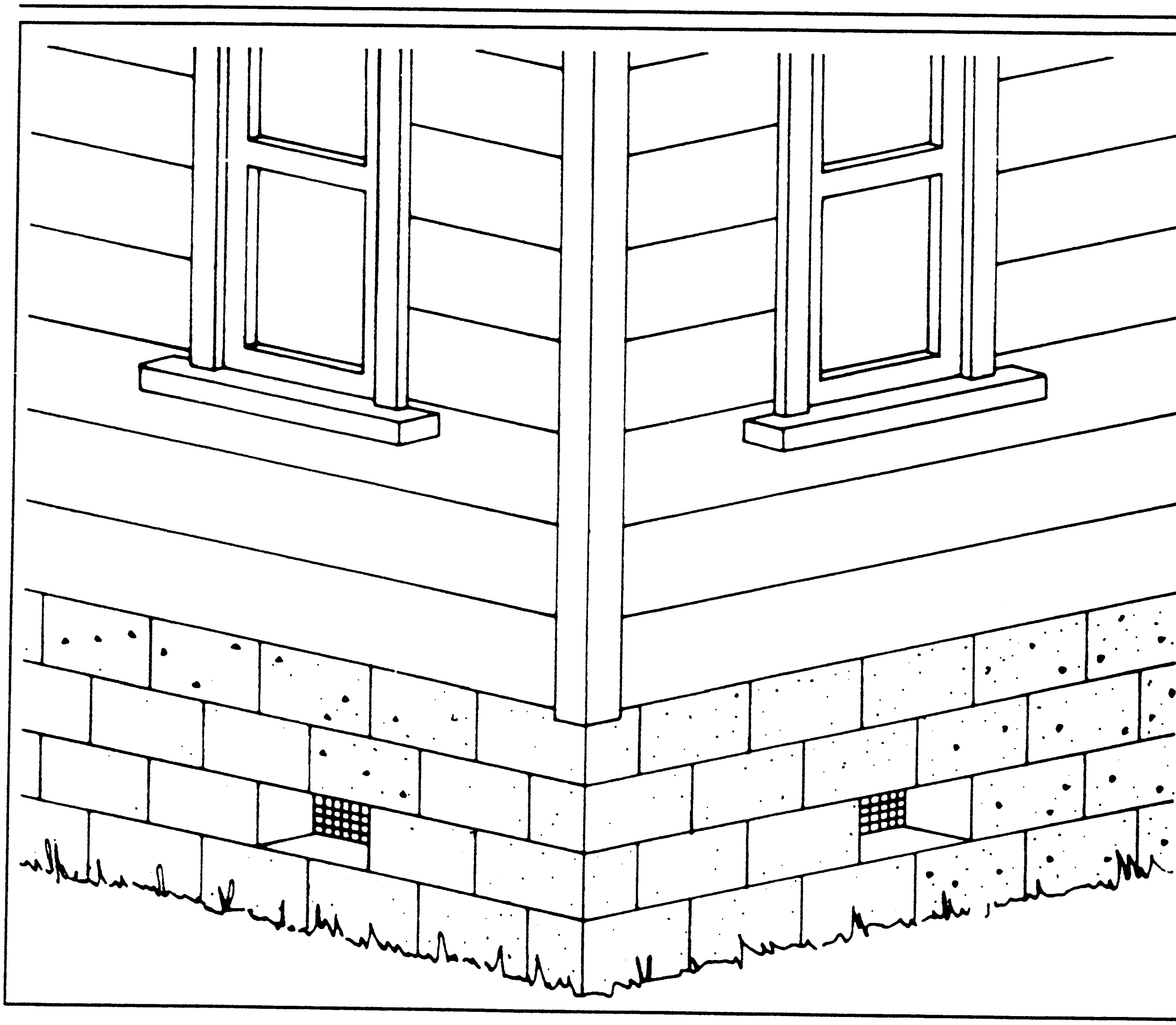
Technical Bulletin 1-93

Openings in Foundation Walls

for Buildings Located in Special Flood Hazard Areas

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
FEDERAL INSURANCE ADMINISTRATION

FIA-TB-1
(4/93)

Key Word/Subject Index:

This index allows the user to quickly locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin

Any comments on the Technical Bulletins should be directed to:

FEMA/FIA
Office of Loss Reduction
Technical Standards Division
500 C St., SW, Room 417
Washington, D.C. 20472

Technical Bulletin 1-93 replaces Technical Bulletin 85-2 (draft) "Foundation Wall Openings."

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 1-93

Openings in Foundation Walls Required for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

An important objective of the National Flood Insurance Program (NFIP) is to protect buildings constructed in floodplains from structural damage caused by flood forces. In support of this objective, the NFIP regulations include building design criteria that apply to new construction and substantial improvements of existing buildings in Special Flood Hazard Areas (SFHAs). According to these criteria, residential buildings constructed in A zones (Zones A, AE, A1-A30, AR, A0, and AH) must have their lowest floors at or above the base blood elevation (BFE). Non-residential buildings constructed in A zones must either have their lowest floors at or above the BFE or be dry floodproofed (made watertight) to or above the BFE. Residential and non-residential buildings whose lowest floors have been constructed at or above the BFE usually are elevated on piers, columns, piles, extended foundation walls, or fill. While the main portion of such a building is protected from the 100-year and lesser-magnitude floods, the foundation and any enclosures below the BFE used for parking, building access, or limited storage will be exposed to flood forces.

For buildings constructed on extended foundation walls or that have other enclosures below the BFE, these flood forces include the hydrostatic pressure of floodwaters against the foundation or enclosure walls. If the walls are not designed to withstand hydrostatic pressure, they can be weakened or can fail and the building damaged. Therefore, the NFIP regulations require that foundation and enclosure walls that are subject to the 100-year flood contain openings that will permit the automatic entry and exit of floodwaters. These openings allow floodwaters to reach equal levels on both sides of the walls and thereby lessen the potential for damage from hydrostatic pressure. The requirement for openings applies to all new and substantially improved buildings in A zones. This Technical Bulletin explains the requirement for openings and provides guidance for designing and constructing foundation and enclosure walls that include the required openings.

Extended foundation and enclosure walls below the BFE may also be threatened by hydrodynamic forces resulting from velocity flows and debris impact. The requirement for openings is intended to reduce flood damage associated with hydrostatic not hydrodynamic forces. These forces are described within this bulletin, and additional design guidance is given for buildings in areas subject to velocity flood flows, which may include debris.

For buildings in V zones (Zones V, VE, and V1-V30), more stringent design and construction requirements have been established for the portions of the buildings below the BFE. For information on V-zone design and construction requirements, refer to the NFIP regulations, the Technical Bulletin series, and FEMA's "Coastal Construction Manual."

NFIP Regulations

The NFIP regulations require that all enclosures below the BFE in A zones be designed to allow for the automatic equalization of hydrostatic forces during a flood event. Section 60.3(c)(5) of the NFIP regulations states that a community shall:

> ***"Require, for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access, or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters."***

As stated in the regulations, buildings in A zones that are substantially damaged and/or substantially improved must meet all the NFIP requirements for new construction, including the openings requirement. All design plans for substantial improvements to buildings in A zones must be thoroughly reviewed by the community to ensure compliance with the openings requirement. Further information on substantial damage and substantial improvement may be found in the FEMA publication "Answers to Questions About Substantially Damaged Buildings."

> It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Guidance for Non-Engineered Foundation Openings

Each of the following four design criteria must be met for new and substantially improved A-zone buildings that have enclosed areas below the BFE with openings not designed and certified by a design professional:

1. There must be a minimum of two openings on different sides of each enclosed area. If a building has more than one enclosed area, each area must have openings on exterior walls to allow floodwater to directly enter.

2. The total area of all openings must be at least 1 square inch for each 1 square foot of enclosed area.

3. The bottom of each opening can be no more than 1 foot above the adjacent grade.
4. Any louvers, screens, or other opening covers must not block or impede the automatic flow of floodwaters into and out of the enclosed area.

Types of Buildings Affected

In all cases, any enclosed area below the BFE is subject to flood forces and must be equipped with exterior wall openings in accordance with the NFIP regulations, either at the time of initial construction or, if the building is being substantially improved, at the time of improvement. The only exception to this requirement is floodproofed non-residential buildings that are engineered and meet stringent watertight construction requirements. For further information on this topic, refer to Technical Bulletin 3, "Non-Residential Floodproofing — Requirements and Certification."

Buildings Elevated on Solid Foundation Walls

When a building is elevated on solid foundation walls, an enclosed area is often created below the lowest floor. All foundation enclosures below the BFE must have openings that meet NFIP criteria. Figure 1 shows an example of a properly placed foundation opening. As discussed previously, screens, louvers, or other covers that allow floodwaters to flow freely into the enclosed area may be placed over the openings to keep out vermin and weather.

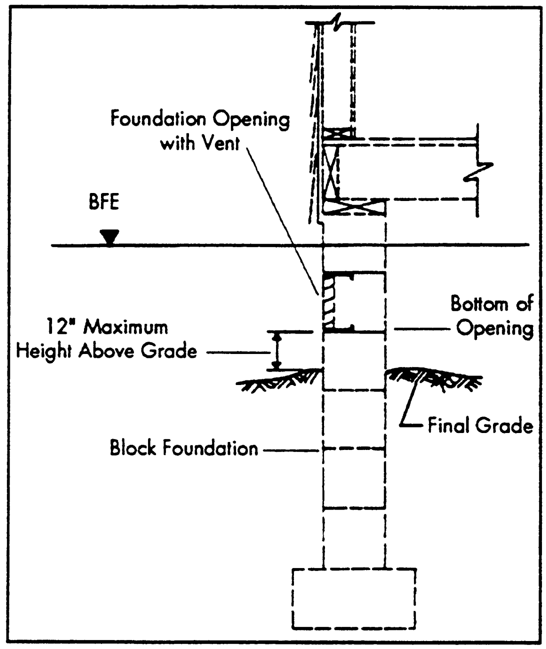


Figure 1. Opening for Solid Foundation Wall

Care must be taken when placing fill dirt around the outside of the foundation. The resulting enclosed area may be considered a basement under the NFIP. A basement is defined as any area of a building having a floor (finished or unfinished) that is subgrade (below grade) on all sides. The NFIP regulations do not permit a residential building in an SFHA to have a basement whose lowest floor (including basement) is below the BFE.

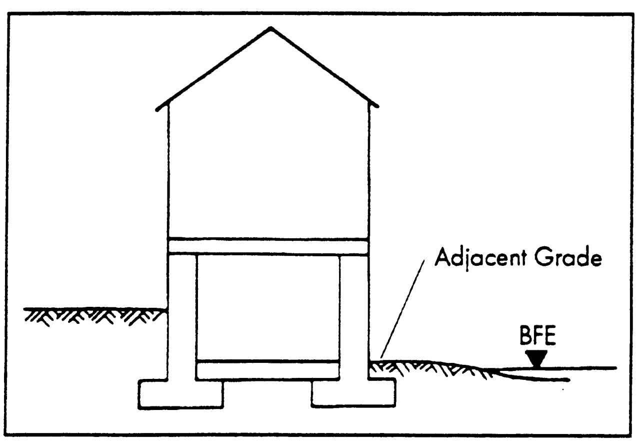


Figure 2. Compliant Grading for a Walkout Basement

To meet the NFIP requirements, fill placed around foundation walls must be graded so that the grade inside the enclosed area is equal to or higher than the adjacent grade outside the building on at least one side of the building (as illustrated in Figure 2). If the grade inside the foundation walls is above the BFE, openings are not required.

Buildings in Hazardous Velocity Areas

In coastal A zones, or in riverine A zones where flood velocities exceed 5 feet per second, fast-flowing floodwaters can exert considerable pressure on solid foundation walls. This hydrodynamic pressure, as described in the following section, may destroy a building's foundation. In such areas, foundations that allow floodwaters to flow freely beneath the building should be considered. Foundations such as piles, piers, or columns will provide the appropriate level of safety to a building located in a hazardous velocity area, if properly embedded and anchored. See the discussion of hydrodynamic pressure for design guidance.

Buildings in A-zone floodplains with velocity floodwaters may have breakaway walls constructed in areas below the BFE. Compliant foundation openings are required in breakaway walls in A zones.

Buildings with Attached Garages

Any new or substantially improved residential building constructed in an A zone must have its lowest floor at or above the BFE. Many of these buildings have structurally attached garages with floor slabs below the BFE. Because such a below-BFE attached garage is an enclosed area below the BFE, openings are required either in the exterior walls of the garage or in the garage doors themselves in order to meet the NFIP openings criteria (see Figure 3). Openings are required because they prevent flood damage to the garage and subsequently to the structurally attached residence. Garage doors without openings specifically designed to allow for the free flow of floodwaters do not meet the openings requirement. The human intervention necessary to open garage doors when flooding threatens is not an acceptable means of meeting the openings requirement. Gaps that may be present between the door segments and between the garage door and the garage door jamb do not guarantee the automatic entry and exit of floodwaters. Therefore, openings are required either in the exterior walls of the enclosed area or in the garage doors themselves. Openings in garage doors must either meet the non-engineered openings requirements or be certified by a design professional.

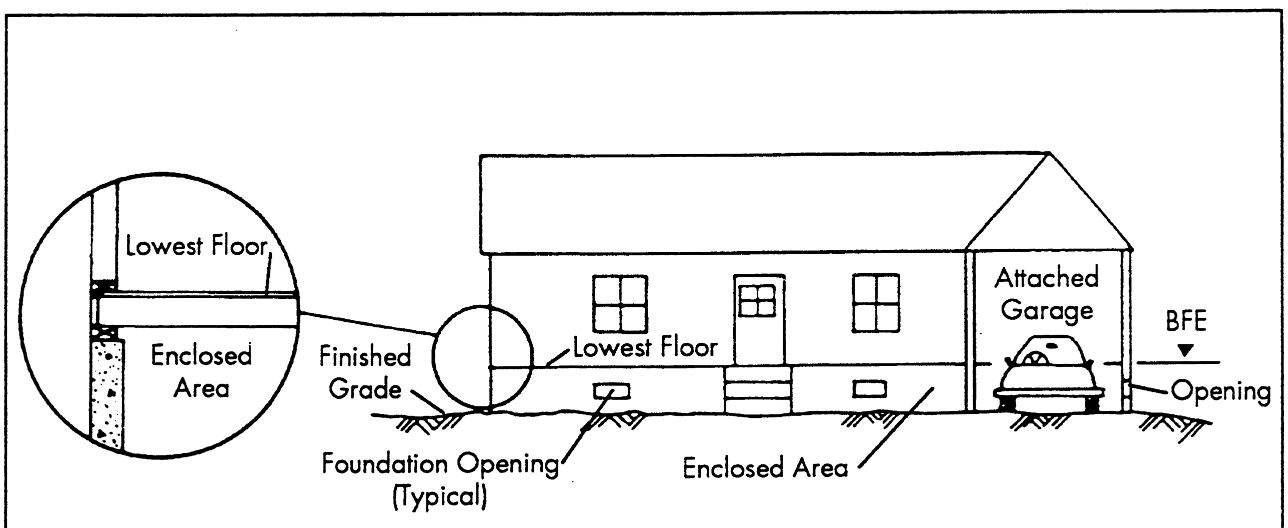


Figure 3. Compliant Residential Building Built on Solid Foundation Walls With Attached Garage

Flood Insurance Implication

If a below-BFE attached garage does not have proper openings, the Elevation Certificate prepared for the building must identify the elevation of the garage floor slab as the lowest floor (reference level) of the building. This may result in flood insurance premiums significantly higher than those that would have applied if the garage had proper openings.

Guidance for Engineered Openings

In situations where it is not feasible or desirable to meet the openings criteria stated previously, a design professional (registered engineer or architect) may design and certify openings. This section provides guidance for such engineered designs. For openings not meeting all four requirements for non-engineered openings listed on pages 2 and 3, certification by a registered professional engineer or architect is required. Such certification must be submitted to, and kept on file by, the community. These certifications must assure community officials that the openings are designed in accordance with accepted standards of practice. A certification may be affixed to the design drawings or submitted separately. It must include appropriate certification language, and the name, title, address, signature, type of license, license number, and professional seal of the certifier. Figure 4 is an example of an acceptable certification.

____
Project Name

I, ____________________ do hereby certify that the opening(s) designed for installation in the aforementioned building will allow for the automatic equalizing of hydrostatic flood forces on exterior walls by allowing for the automatic entry and exit of floodwater during floods up to and including the base (100-year) flood.

____________________ Signature
__________ Date

____________________ Title

____________________ Type of Licence
__________ Licence Number

____________________ Address

PROFESSIONAL SEAL

Figure 4. Example of Openings Certificate

Calculation of Flood Forces

Floodwaters can impose both hydrostatic and hydrodynamic forces on floodprone buildings. Hydrostatic pressure is the force that water at rest exerts on any submerged object, including a floodprone building. Hydrostatic pressure is capable of collapsing, moving, and severely damaging most types of buildings. In many floods, hydrostatic pressure is the most prevalent cause of damage. Hydrodynamic pressure is the force exerted on a vertical obstruction (foundation wall) by flowing water and debris.

Hydrostatic pressure on an enclosed area above grade can be calculated by multiplying the specific weight of water (62.4 pounds per cubic foot) by the height of the water on the surface being analyzed. The application of the force generated by hydrostatic pressure is always perpendicular (normal) to the surface in question. In the case of a submerged object, this means that hydrostatic forces act in two ways. First, the force will act laterally (see Figure 5), which can result in collapse of walls or movement of the entire building off its foundation. Second, the force will act vertically (the vertical force is also known as buoyancy, see Figure 6), which can result in the building being lifted from its foundation or floor system.

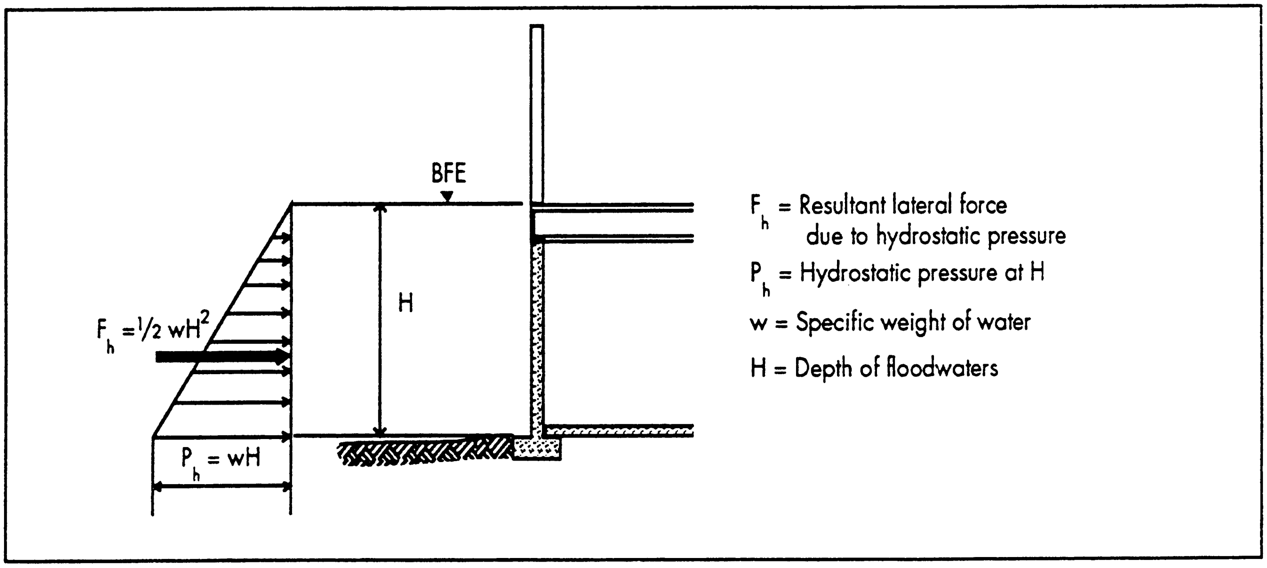


Figure 5. Lateral Hydrostatic Force and Pressure

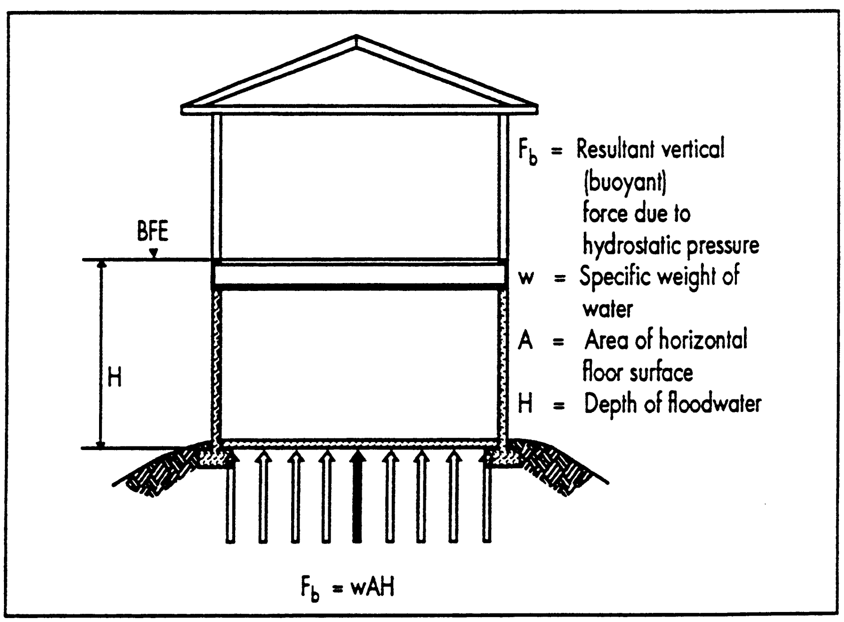


Figure 6. Buoyancy Force

To describe hydrostatic pressure in more technical terms:

The hydrostatic pressure, P_h, at a specific location on a structure is:

$P_h = wH$

where: P_h is the pressure in pounds per square foot

w is the specific weight of water, 62.4 pounds per cubic foot

H is the depth from the surface of the water to the location in question (generally from BFE to bottom of foundation wall)

The lateral force resulting from hydrostatic pressure is:

The resultant lateral (horizontal) force against the surface is:

$F_h = \frac{1}{2}P_hH = \frac{1}{2}wH^2$

where: F_h is the lateral force in pounds per linear foot of surface

Describing the hydrostatic vertical force (buoyancy) in more technical terms:

The buoyant (vertical) hydrostatic force acting against a horizontal surface such as a floor slab is:

$F_b = wAH$

where: F_b is the total buoyant force in pounds

w is the specific weight of water, 62.4 pounds per cubic foot

A is the area of the horizontal surface in square feet

H is the depth of the building below the flood level

As shown in the following table, hydrostatic pressure, whether it affects a building laterally or vertically, increases rapidly as floodwater depths increase:

Height, H (in feet)	1	2	3	4	5	6	7	8
Pressure, P_h (in pounds per square foot)	62	125	187	250	312	374	437	499

Hydrodynamic pressure is exerted on all vertical surfaces of obstructions, such as building foundations, by the impact of velocity water and debris. Depending upon site-specific flood characteristics and the strength of the foundation, hydrodynamic pressure can overload and destroy a building's foundation. The openings criteria are intended to equalize hydrostatic pressure and are not intended to minimize hydrodynamic pressure on the foundation. Hydrodynamic pressure must be considered in the design of any foundation system where velocity waters or the potential for debris flow exists. If flood velocities are excessive (greater than 5 feet per second), foundation systems other than solid foundation walls should be considered, so that obstructions to damaging flood flows are minimized. Safe foundations in such locations include pile, post, column, and pier foundations. These types of foundation systems are appropriate for A zones in coastal environs subject to waves and velocity floodwaters, as well as in riverine floodplains subject to velocity floodwaters (velocities greater than 5 feet per second) and areas subject to debris flows and ice floes. In areas with high-velocity floodwaters, it is advisable to construct any enclosures below the BFE using the breakaway wall specifications described in FEMA's "Coastal Construction Manual." As stated previously, breakaway walls in A zones must have openings compliant with NFIP regulatory requirements so that hydrostatic pressures are equalized during low-level flood events.

Design Criteria for Engineered Openings

Engineered openings that allow floodwaters into an enclosure for the purpose of equalizing hydrostatic pressures shall be designed using the following criteria:

- The difference between the exterior and interior floodwater levels should not exceed 1 foot at any time during the flood event. Greater differences can result in excessive hydrostatic pressures and structural damage to the enclosure walls.
- The arrangement of the openings must be capable of equalizing the hydrostatic pressures associated with the "worst-case" rate of rise of floodwaters. Historical flooding information should be used to determine rate of rise. A rate of rise of 5 feet per hour was assumed in the development of the NFIP non-engineered openings design criteria.
- Because of the large amount of debris associated with flooding and because openings will often be equipped with some form of vermin screen to meet applicable building codes, there is a high probability that openings may be obstructed during a flood. For this reason, a substantial safety factor is needed. Standard engineering practice is to use a safety factor of 5 in similar life/safety situations involving potential structural failure; therefore, a safety factor

of 5 was incorporated into the calculations that follow. Openings on the sides of the building facing the primary direction of velocity flow will add an additional safety factor; however, such openings will tend to be blocked with debris sooner than other openings.

- At least two openings must be included to provide for a safety factor against debris blockage. This safety factor is enhanced when openings are located on at least two different sides of the enclosed area. This will allow for more even filling and emptying of the enclosed area and will also reduce the risk of debris being forced against an opening and blocking it.

The first step in determining the total net area required for openings is to calculate the flow rate per square foot of enclosed area, which is based on the rate of rise of the floodwaters. The assumed worst-case rate of rise is 5 feet per hour per square foot of area, or about 0.1 foot per minute. To convert this to gallons per minute per square foot of enclosed area, multiply by a conversion factor of 7.5 gallons per cubic foot. The needed flow rate into the enclosure per square foot of area is then (0.1 foot per minute) times (7.5 gallons per cubic foot), or 0.8 gallon per minute per square foot of enclosed area. The second step is outlined below.

To determine the total net area of the openings, A, needed to permit the above flow rate, the formula is:

$$Q = 38.0cA(p)^{.5}$$

Solving for area A and multiplying by a factor of safety:

$$A = \frac{Q}{38.0\ cp^{.5}}\ (FS)$$

where:

	A	is the net area of openings required, in square inches
	Q	is the flow rate per square foot, which is 0.8 gallon per minute
	c	is the coefficient of discharge, which is assumed to be 0.2
	p	is the pressure, which for one square foot of differential is 62.4 pounds per square foot, or 0.4 pound per square inch
	FS	is the factor of safety, which is 5

Therefore:

$$A = \frac{0.8}{38.0 \times 0.2 \times 0.6}\ (5)$$

= about 1.0 square inch of opening per square foot of enclosed area.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because it was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on a mutual agreement between the federal government and communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to community residents provided that the participating community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's Flood Insurance Rate Maps.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Natural Hazards Branch of the appropriate FEMA regional office. The "User's Guide to Technical Bulletins" lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse — the form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning openings in foundation walls:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2. "Coastal Construction Manual," FEMA, February 1986, FEMA-55.

3. "Colorado Floodproofing Manual," Colorado Department of Natural Resources, Water Conservation Board, October 1983.

4. "Design Manual for Retrofitting Flood-Prone Residential Structures," FEMA, September 1986, FEMA-114.

5. "Elevated Residential Structures," FEMA, May 1986, FEMA-54.

6. "Elevating Flood-Prone Buildings: A Contractor's Guide," Illinois Department of Transportation, Division of Water Resources, 1985.

7. "Flood Proofing Regulations," U.S. Army Corps of Engineers, March 1992, EP 1165-2-314.

8. "Flood Proofing Systems and Techniques," U.S. Army Corps of Engineers, December 1984.

9. "Foundation Analysis and Design," Second Edition, Joseph E.Bowles, McGraw-Hill Book Co., New York.

Glossary

Base flood — The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area — An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources.

Federal Emergency Management Agency (FEMA) — The independent federal agency that, in addition to carrying out other activities, oversees the administration of the National Flood Insurance Program.

Federal Insurance Administration (FIA) — The component of FEMA directly responsible for administering the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) — The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Floodprone area — Any land area susceptible to being inundated by floodwater from any source.

Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial damage — Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

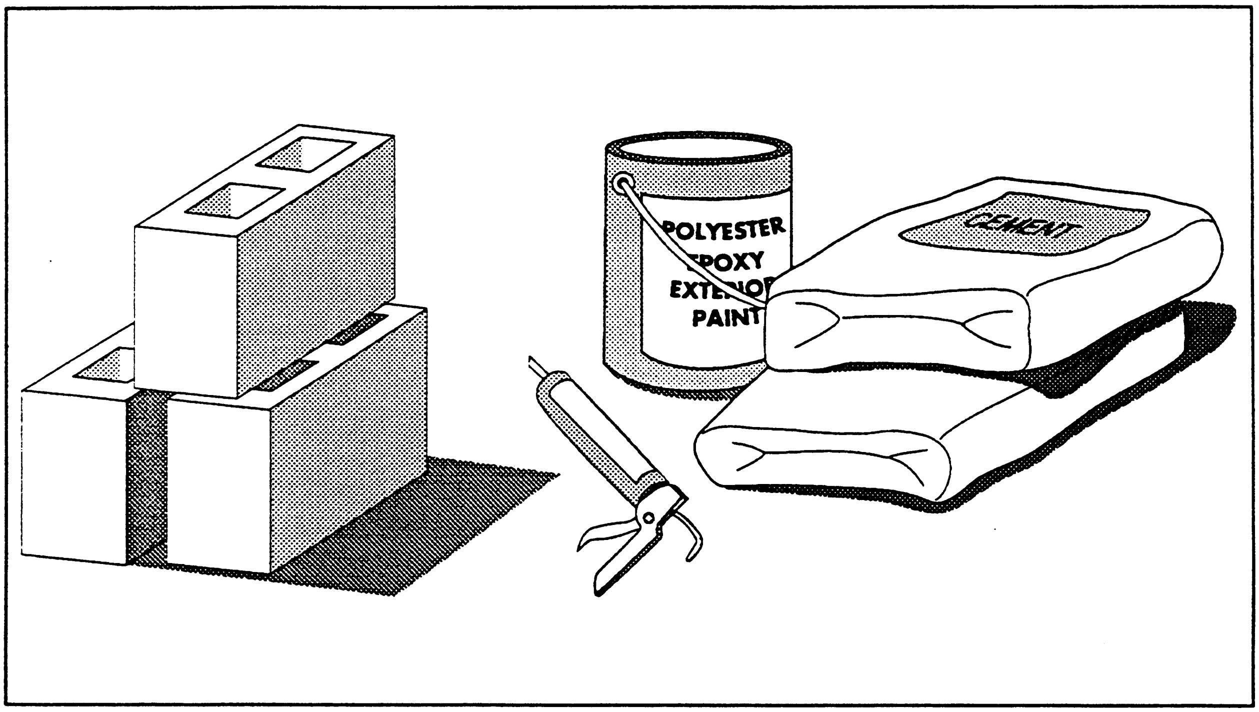
Technical Bulletin 2-93

Flood-Resistant Materials Requirements

for Buildings Located in Special Flood Hazard Areas

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
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FIA-TB-2
4/93

Key Word/Subject Index:

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FEMA/FIA
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Technical Standards Division
500 C St., SW, Room 417
Washington, D.C. 20472

Technical Bulletin 2-93 replaces Technical Bulletin 88-2 (draft) "Flood-Resistant Materials."

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 2-93

Flood-Resistant Materials Requirements for Buildings Located In Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

The requirement to use construction and finishing materials that are resistant to flood damage in all new and substantially improved buildings in identified Special Flood Hazard Areas (SFHAs) is an important part of the National Flood Insurance Program's (NFIP's) flood-damage-resistant design and construction standards. A residential building's lowest floor is required to be elevated to or above the base flood elevation (BFE). All construction below the lowest floor is susceptible to flooding and must consist of flood-resistant materials. Uses of enclosed areas below the lowest floor in a residential building are limited to parking, building access, and limited storage—areas that can withstand inundation by floodwater without sustaining significant structural damage.

The purpose of this Technical Bulletin is to provide data and guidance on what constitute "materials resistant to flood damage" and how and when these materials must be used to improve a building's ability to withstand flooding.

NFIP Regulations

Section 60.3(a)(3) of the NFIP regulations requires that the community:

> ***"Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a floodprone area, all new construction and substantial improvements shall...(ii) be constructed with materials resistant to flood damage..."***

> It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Required Use of Flood-Resistant Materials

Flood-Resistant Material

"Flood-resistant material" is defined as any building material capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. The term "prolonged contact" means at least 72 hours, and the term "significant damage" means any damage requiring more than low-cost cosmetic repair (such as painting).

As stated previously, **all structural and non-structural building materials at or below the BFE must be flood resistant.** This requirement applies regardless of the expected or historic flood duration. For example, buildings in coastal areas that experience relatively short-duration flooding (generally, flooding with a duration of less than 24 hours) must be constructed with flood-resistant materials below the BFE. As noted in the tables within this bulletin, **only Class 4 and Class 5 materials are acceptable for areas below the BFE in floodprone buildings.**

In some instances, Class 1, 2, and 3 materials may be permitted below the BFE, when specifically required to meet local building code provisions concerning life-safety issues. In below-BFE applications, materials that meet life-safety code requirements and have maximum resistance to damage from flood inundation should be used. This applies to the flood-resistant requirements only. In Zones V, VE, and V1-V30, the installation of such materials may create an obstruction. Because obstructions in V zones could result in structural failure of the building, they represent a life-safety issue and shall therefore take precedence over local building codes. Refer to Technical Bulletin 5, "Free of Obstruction Requirements," for further information.

Lowest Floor

Under the NFIP, the term "lowest floor" is used to define the lowest level of a building that must be located at or above the BFE as required under Sections 60.3(c)(2) and (3) of the NFIP regulations. The floodplain management regulations, under Section 60.3(c)(5), limit the use of all areas below the lowest floor to parking of vehicles, storage, and building access. These reasonable uses below the BFE are permitted because the amount of damage caused by flooding to these areas can easily be kept to a minimum if design and construction requirements contained in the NFIP regulations are met. Failure to meet the requirements can increase the building's damage potential and result in the application of higher flood insurance premiums. The requirement to use flood-resistant materials means that all interior wall, floor, and ceiling materials located below the BFE be unfinished and resistant to flood damage. This is meant to exclude the use of materials and finishes normally associated with living areas constructed above the BFE.

Flood Insurance Implication

An NFIP flood insurance requirement regarding the use of materials in areas below the BFE must also be considered. Flood insurance will not pay a claim for finishing materials (such as clay floor tiles) located in basements or in enclosed areas below the lowest floor of an elevated building, even if such materials are considered to be flood resistant. The NFIP defines finishing materials as anything beyond basic wall construction.

Flood-Resistant Classification of Materials

The information in this Technical Bulletin is based primarily on the U.S. Army Corps of Engineers (COE) 1992 "Flood Proofing Regulations." The following table (Table 1) classifies building materials according to their ability to resist flood damage.

Table 1 Flood-Resistant Classification of Materials		
NFIP	Class	Class Description
ACCEPTABLE	5	Highly resistant to floodwater damage. Materials within this class are permitted for partially enclosed or outside uses with essentially unmitigated flood exposure.
	4	Resistant to floodwater damage. Materials within this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection.
UNACCEPTABLE	3	Resistant to clean water damage. Materials within this class may be submerged in clean water during periods of intentional flooding.
	2	Not resistant to water damage. Materials within this class require essentially dry spaces that may be subject to water vapor and slight seepage.
	1	Not resistant to water damage. Materials within this class require conditions of dryness.

Source: COE 1992 "Floodproofing Regulations"

Flooring Materials

Table 2 lists flooring materials commonly used in construction that fall within the five classes described in Table 1. Not all available construction and finishing materials are listed. For products not listed herein, manufacturers' literature should be reviewed for recommended uses. Such recommendations must be complied with fully. All masonry and wood products used in floodprone buildings must comply with the applicable materials standards of the nationally recognized standards organizations, such as the American Society for Testing and Materials (ASTM), the American Concrete Institute (ACI), and the American Wood Products Association (AWPA).

Basis for Classification of Flooring Materials

The classification of flooring materials is based on their vulnerability to damage from inundation by floodwaters. Class 1, 2, and 3 flooring materials are not acceptable for below-BFE applications for one or more of the following reasons:

- Normal suspended-floor adhesives specified for above-grade use are water soluble or are not resistant to alkali or acid in water, including ground seepage and vapor.
- Flooring materials contain wood and wood products.
- Flooring materials are not resistant to alkali or acid in water.
- Sheet-type floor coverings (linoleum, rubber, and vinyl) restrict evaporation from below.
- Flooring materials are impervious but dimensionally unstable.

Table 2 Flooring Materials Classifications for Flood Resistance

Types of Flooring Materials	Classes of Flooring				
	Acceptable		Unacceptable		
	5	4	3	2	1
Asphalt Tile[1]					●
With asphaltic adhesives			●		
Carpeting (glued down type)					●
Cement/bituminous, formed-in-place		●			
Cement/latex, formed-in-place		●			
Ceramic tile[1]					●
With acid-and alkali-resistant grout			●		
Chipboard					●
Clay tile	●				
Concrete, precast or in-situ	●				
Concrete tile	●				
Cork					●
Enamel felt-base floor coverings					●
Epoxy, formed-in-place	●				
Linoleum					●
Magnesite (magnesium oxychloride)					●
Mastic felt-base floor covering					●
Mastic flooring, formed-in-place	●				
Polyurethane, formed-in-place	●				
PVA emulsion cement					●
Rubber sheets[1]					●
With chemical-set adhesives[2,3]	●				
Rubber tile[1]					●
With chemical-set adhesives[3]		●			
Silicone floor, formed-in-place	●				

Table 2 Flooring Materials Classifications for Flood Resistance					
Types of Flooring Materials	Classes of Flooring				
	Acceptable		Unacceptable		
	5	4	3	2	1
Terrazo		●			
Vinyl sheets (homogeneous)[1]					●
With chemical-set adhesives[2,3]	●				
Vinyl tile (homogeneous)[1]					●
With chemical-set adhesives[3]		●			
Vinyl tile or sheets (coated on cork or wood product backings)					●
Vinyl-asbestos tile (semi-flexible vinyl)[1]					●
With asphaltic adhesives		●			
Wood flooring or underlayments					●
Wood composition blocks, laid in cement mortar				●	
Wood composition blocks, dipped and laid in hot pitch or bitumen				●	
Pressure-treated lumber, .40 CCA[4]	●				
Naturally decay-resistant lumber[4,5]	●				

Notes:
1 Using normally specified suspended flooring (i.e., above-grade) adhesives, including sulfite liquor (lignin or "linoleum paste"), rubber/asphaltic dispersions, or "alcohol" type resinous adhesives (culmar, oleoresin)
2 Not permitted as Class 2 flooring
3 E.g., epoxy-polyamide adhesives or latex-hydraulic cement
4 Not in the COE list; added by FEMA
5 Refer to local building code for guidance

Wall and Ceiling Materials

Table 3 lists wall and ceiling materials commonly used in construction that fall within the five classes described in Table 1. Not all available construction and finishing materials are listed. For products not listed herein, manufacturers' literature should be reviewed for recommended uses. Such recommendations must be complied with fully. All masonry and wood products used in floodprone buildings must comply with the applicable materials standards of the nationally recognized standards organizations, such as the American Society for Testing and Materials (ASTM), the American Concrete Institute (ACI), and the American Wood Products Association (AWPA).

Basis for Classification of Wall and Ceiling Materials

The classification of wall and ceiling materials is based on their vulnerability to damage from inundation by floodwaters. Class 1, 2, and 3 wall and ceiling materials are not acceptable for below-BFE applications for one or more of the following reasons:

- Normal adhesives specified for above-grade use are water soluble or are not resistant to alkali or acid in water, including ground seepage and vapor.
- Wall and ceiling material contains wood, wood products, gypsum products, or other material that dissolves or deteriorates, loses structural integrity, or is adversely affected by water.
- Wall or ceiling material is not resistant to alkali or acid in water.
- Wall or ceiling material is impervious but is dimensionally unstable.
- Wall or ceiling materials absorb or retain water excessively after submergence.

Table 3 Walls and Ceiling Materials Classifications for Flood Resistance					
Types of Wall and Ceiling Materials	Classes of Walls and Ceilings				
	Acceptable		Unacceptable		
	5	4	3	2	1
Asbestos-cement board (and cement board[1])	●				
Brick, face or glazed	●				
Common				●	
Cabinets, built-in					
Wood				●	
Metal	●				
Cast stone (in waterproof mortar)	●				
Chalkboards					
Slate, porcelain glass, nucite glass	●				
Cement-asbestos				●	
Composition, painted				●	
Chipboard					●
Exterior sheathing grade				●	
Clay tile					
Structural glazed	●				
Ceramic veneer, ceramic wall tile-mortar set		●			
Ceramic veneer, organic adhesives				●	
Concrete	●				
Concrete block	●				
Corkboard				●	
Doors					
Wood hollow				●	
Wood, lightweight panel construction				●	
Wood, solid				●	
Metal, hollow	●				
Metal, Kalamein				●	

Table 3 Walls and Ceiling Materials Classifications for Flood Resistance					
Types of Wall and Ceiling Materials	Classes of Walls and Ceilings				
	Acceptable		Unacceptable		
	5	4	3	2	1
Fiberboard panels, vegetable types					
Sheathing grade (asphalt coated or impregnated)				●	
Otherwise					●
Gypsum products					
Gypsum board (including greenboard[1])				●	
Keene's cement of plaster				●	
Plaster, otherwise, including acoustical				●	
Sheathing panels, exterior grade				●	
Glass (sheets, colored tiles, panels)		●			
Glass blocks	●				
Hardboard					
Tempered, enamel or plastic coated				●	
All other types				●	
Insulation					
Foam or closed-cell types		●			
Batt or blanket types					●
All other types				●	
Metals, non-ferrous (aluminum, copper, or zinc tiles)			●		
Metals, Ferrous	●				
Mineral fiberboard					●
Plastic wall tile (polystyrene, urea formaldehyde, etc.)					
Set in waterproof adhesives, pointed with waterproof grout			●		
Set in water-soluble adhesives				●	

Table 3 Walls and Ceiling Materials Classifications for Flood Resistance					
Types of Wall and Ceiling Materials	Classes of Walls and Ceilings				
	Acceptable		Unacceptable		
	5	4	3	2	1
Paint					
Polyester-epoxy and other waterproof types		●			
All other types					●
Paperboard					●
Partitions, folding					
Wood, pressure treated, .40 CCA minimum[1] (if not treated, then material is Class 2)	●				
Metal		●			
Fabric-covered					●
Partitions, stationary					
Wood, pressure treated, .40 CCA minimum[1] (if not treated, then material is Class 2)	●				
Metal	●				
Glass, unreinforced		●			
Glass, reinforced		●			
Gypsum, solid or block					●
Rubber, moldings and trim with epoxypolyamide adhesive or latex-hydraulic cement		●			
All other applications					●
Steel, (panels, trim, tile) with waterproof applications	●				
With non-waterproof adhesive				●	
Stone, natural solid or veneer, waterproof grout	●				
Stone, artificial non-absorbent solid or veneer, waterproof grout	●				
All other applications				●	

Table 3 Walls and Ceiling Materials Classifications for Flood Resistance					
Types of Wall and Ceiling Materials	Classes of Walls and Ceilings				
	Acceptable		Unacceptable		
	5	4	3	2	1
Strawboard					
Exterior grade (asphalt-impregnated kraft paper)				●	
All other types				●	
Wall covering					
Paper, burlap, cloth types					●
Wood					
Solid, standard				●	
Solid, naturally decay-resistant[1,2]	●				
Solid pressure treated, .40 CCA minimum[1]	●				
Plywood					
Marine Grade[1]	●				
Pressure treated, .40 CCA minimum[1]	●				
Exterior grade				●	
Otherwise					●

Note: [1] Not on the COE list; added by FEMA
[2] Refer to local building code for guidance

Construction Examples

Flood-Resistant Materials in Buildings in Zones A, AE, A1-A30, AR, A0, and AH

Figure 1 illustrates a building elevated on solid foundation walls, over a crawlspace. The NFIP regulations require that the lowest floor be at or above the BFE. The construction method illustrated in Figure 1 meets this requirement. Note, however, that the flooring materials and supporting wood members are at or below the BFE. Therefore, in Figure 1, all materials supporting the lowest floor, including the flooring itself, must be made of flood-resistant materials.

To maximize the use of the area below the lowest floor, it is a common floodplain construction technique to elevate a building a full story (approximately 8 feet), even though the BFE may only be 4 or 5 feet above grade. In such cases, while the NFIP regulations require that Class 4 or 5 building materials be used below the BFE, FEMA strongly recommends that Class 4 or Class 5 materials also be used for the construction of the remainder of the building below the lowest floor. Flood damage from a greater-than-design flood event will thereby be reduced in the lower area.

Flood-Resistant Materials in Buildings in Zones V, VE, and V1-V30

All structural and non-structural materials installed below the BFE must be flood resistant . The NFIP regulations require that the bottom of the lowest horizontal structural member of the lowest floor (usually the floor beam or girder) of a building in Zone V, VE, or V1-V30 be at or above the BFE. Therefore, all materials below the floor beam(s) must be flood resistant. This includes but is not limited to breakaway wall materials and open latticework. Breakaway walls will remain in place during low-level floods and must be flood resistant, so that they will not deteriorate over time after being soaked by floodwaters. Figure 2, on the next page, illustrates this requirement.

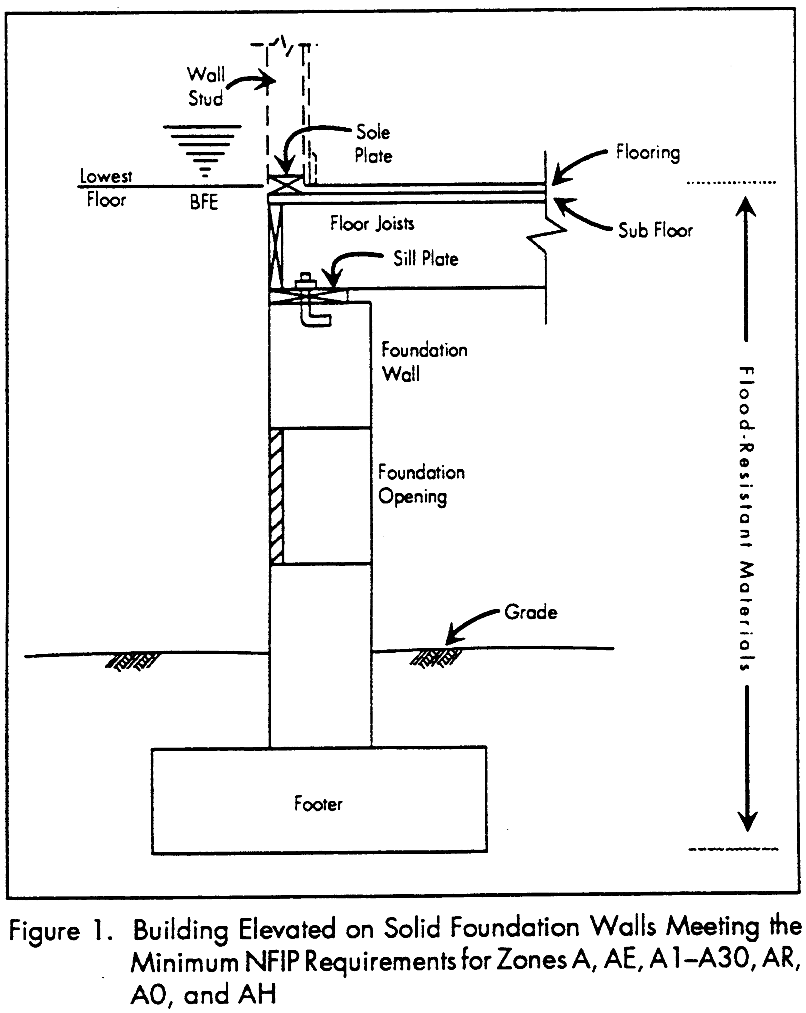

Figure 1. Building Elevated on Solid Foundation Walls Meeting the Minimum NFIP Requirements for Zones A, AE, A1–A30, AR, A0, and AH

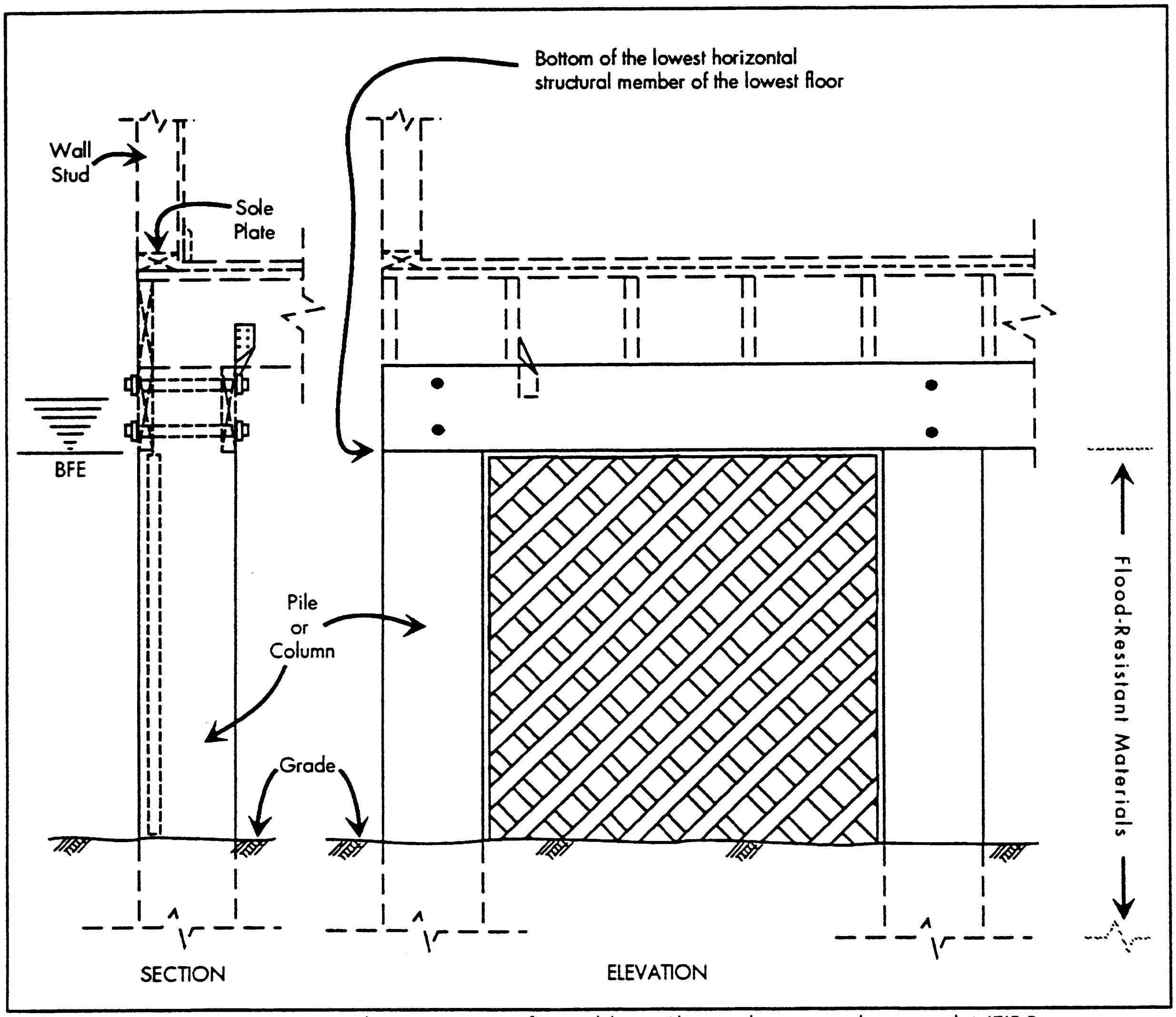

Figure 2. Flood-Resistant Material Requirements for Buildings Elevated in Accordance with NFIP Requirements for Zones V, VE, and V1–V30

Accessory Buildings

Some communities permit the construction of low-cost, small detached accessory buildings (e.g., garages, storage sheds) with a lowest floor elevation below the BFE (Technical Bulletin 5, "Free-of-Obstruction Requirements," provides definitions of "low-cost" and "small"). The below-BFE portions of such buildings must be constructed of flood-resistant materials so that flood damage will be minimized. Additional construction requirements for these buildings, such as the need to anchor the building to resist flotation, collapse, and lateral movement, also must be met before the building is permitted and built. For additional information about these requirements, contact the community that has permitting jurisdiction.

Wet Floodproofing

Wet floodproofing is designing a building to allow floodwaters to enter in order to equalize hydrostatic forces. The NFIP does not allow wet floodproofing in lieu of meeting the lowest floor elevation requirements. However, in situations where the NFIP regulations do not apply, such as voluntary floodproofing of an existing (Pre-FIRM) building not in association with substantial improvements, the use of flood-resistant materials is advisable. Using flood-resistant materials will make cleanup and repair following a flood much easier and less costly than if the floodprone areas are constructed of non-flood-resistant materials.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood insurance was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community provided that the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the U.S. Code of the Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's FIRMs.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Natural Hazards Branch of the appropriate FEMA regional office. The "User's Guide to Technical Bulletins" lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse — the form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning the use of flood-resistant materials:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2. "Floodproofing Non-Residential Structures," FEMA, May 1986, FEMA-102.

3. "Flood Proofing Regulations", Chapters 9 and 10, U.S. Army Corps of Engineers, March 1992, EP 1165-2-314.

4. "Flood Proofing Systems and Techniques," U.S. Army Corps of Engineers, December, 1984.

5. "Repairing Your Flooded Home," FEMA and the American Red Cross, August 1992, FEMA-234, ARC 4477.

6. "Technical Notes for Brick Construction,"Brick Institute of America, McLean, Virginia, n.d.

Glossary

Base flood — The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area — An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources.

Federal Emergency Management Agency (FEMA) — The independent federal agency that, in addition to carrying out other activities, oversees the administration of the National Flood Insurance Program.

Federal Insurance Administration (FIA) — The component of FEMA directly responsible for administering the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) — The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Floodprone area — Any land area susceptible to being inundated by floodwater from any source.

Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial damage — Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

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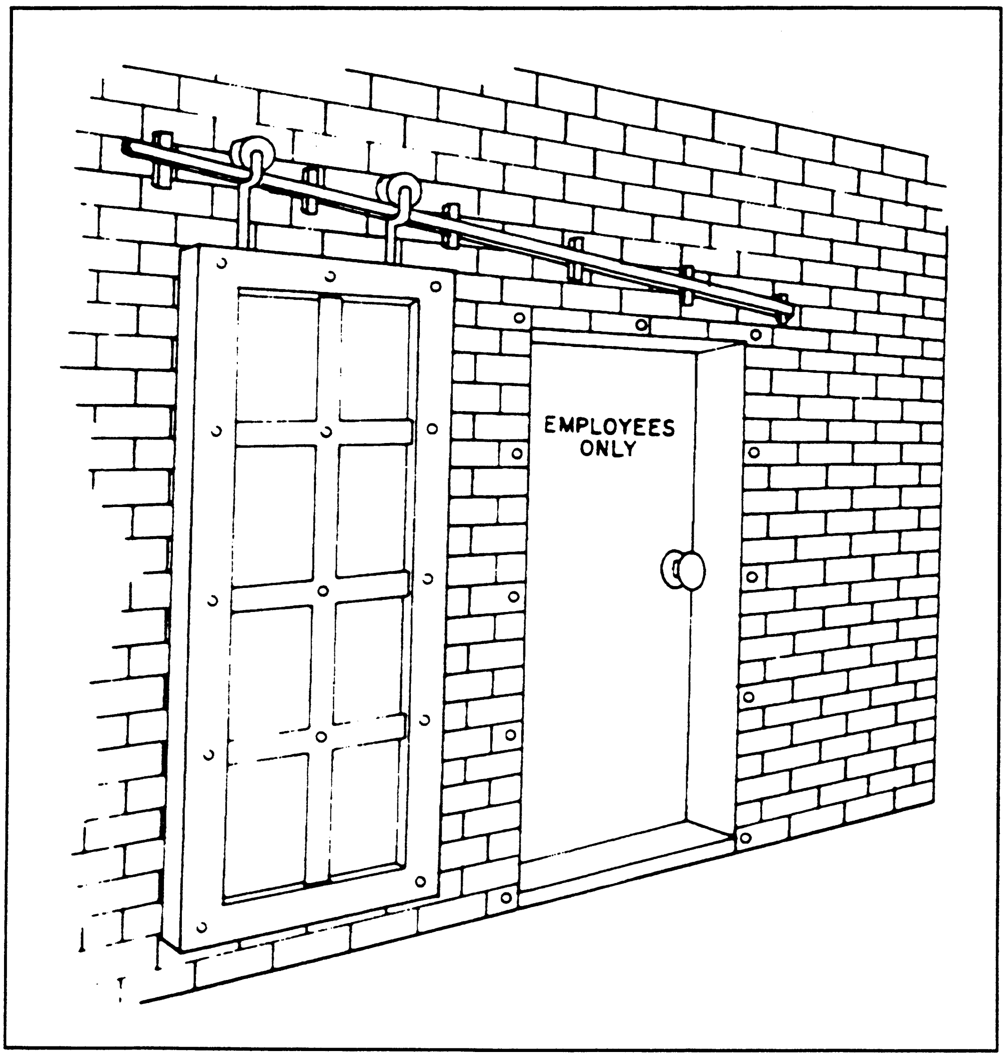
Technical Bulletin 3-93

Non-Residential Floodproofing — Requirements and Certification

for Buildings Located in Special Flood Hazard Areas

in accordance with the

National Flood Insurance Program



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Technical Bulletin 3-93 replaces Technical Bulletin 90-3 (draft) "Non-Residential Floodproofing Certification Requirements."

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 3-93

Non-Residential Floodproofing — Requirements and Certification for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

This bulletin describes design, construction, and planning requirements for the floodproofing of non-residential buildings under the National Flood Insurance Program (NFIP) regulations and how to correctly complete the NFIP's Floodproofing Certificate for Non-Residential Structures form. For the purposes of this bulletin, floodproofing means making a building watertight, substantially impermeable to floodwaters.

Before a floodproofed building is designed, numerous planning considerations, including flood warning time, uses of the building, mode of entry to and exit from the building and the site in general, floodwater velocities, flood depths, debris impact potential, and flood frequency, must be addressed to ensure that dry floodproofing will be a viable floodplain management tool. These critical considerations are discussed within this bulletin.

In the FEMA publication "Floodproofing of Non-Residential Structures," floodproofing is described as a combination of adjustments and/or additions of features to buildings that eliminate or reduce the potential for flood damage. Examples of such adjustments and additions include anchoring of the building to resist flotation, collapse, and lateral movement; installation of watertight closures for doors and windows; reinforcement of walls to withstand floodwater pressures and impact forces generated by floating debris; use of membranes and other sealants to reduce seepage of floodwater through walls and wall penetrations; installation of pumps to control interior water levels; installation of check valves to prevent the entrance of floodwater or sewage flows through utilities; and the location of electrical, mechanical, utility, and other valuable damageable equipment and contents above the expected flood level.

Floodproofing components for an individual building may also include floodwalls, small localized levees, or berms around buildings. However, such components, because they are not part of the building itself, are generally not credited for the flood insurance rating of a building under the NFIP and are therefore not detailed within this bulletin.

The NFIP allows a new or substantially improved non-residential building in an A zone (Zone A, AE, A1-A30, AR, A0, or AH) to have a lowest floor below the base flood elevation (BFE), provided that the building has been designed, constructed, and certified to be floodproofed and to meet established criteria. Floodproofing of areas below the BFE in residential buildings is not permitted under the NFIP. In a Coastal High Hazard Area (Zone V, VE, or V1-V30), construction or substantial improvement of a building with a lowest floor elevation below the BFE is not allowed, regardless of any floodproofing techniques employed.

A Floodproofing Certificate for Non-Residential Structures (FEMA Form 81-65) has been developed by FEMA for use in the certification of non-residential floodproofing designs. Because of the increased potential for significant building damage due to the failure of the floodproofing system, the NFIP requires a design certification for all floodproofed buildings. In accordance with Section 60.3(c)(4), communities shall require a correctly completed certificate (or its equivalent) for every floodproofed building within a Special Flood Hazard Area (SFHA) and shall maintain the completed certificates on file.

A Floodproofing Certificate for Non-Residential Structures is required for the following types of buildings (in A zones only):

- Floodproofed non-residential buildings (no residential uses).
- Floodproofed mixed-use buildings that are professionally designed with all residential uses located above the floodproofing design elevation.

NFIP Regulations

The NFIP regulations that specifically apply to the design of floodproofing for non-residential buildings are within Section 60.3(c)(3), which states that the community shall:

> ***"Require that all new construction and substantial improvements of non-residential structures within Zones A1-A30, AE, and AH on the community's FIRM (i) have the lowest floor (including basement) elevated to or above the base flood level, or (ii) together with attendant utility and sanitary facilities, be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy."***

Section 60.3(c)(8) further states that the community shall:

> ***"Require within any A0 zone on the community's FIRM that all new construction or substantial improvements of non-residential structures (i) have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified), or (ii) together with attendant utility and sanitary facilities, be completely floodproofed to that (base flood) level to meet the floodproofing standard specified in paragraph 60.3(c)(3)(ii)."***

Additionally, Section 60.3(c)(4) requires that any floodproofing design be certified in the following manner:

> ***"Provide that where a non-residential structure is intended to be made watertight below the base flood level, (i) a registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of construction are in accordance with the accepted standards of practice for meeting the applicable provisions of paragraphs (c)(3)(ii) or (c)(8)(ii) of this section, and (ii) a record of such certificates which includes the specific elevation (in relation to mean sea level) to which such structures are floodproofed shall be maintained with the official designated by the community..."***

It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Planning Considerations

A review of the following factors for the site in question will assist the design professional in determining whether floodproofing is appropriate. For example, if a site will be surrounded by rapidly rising, high-velocity floodwaters during a flood, and the available warning time is short, then the site is unsuitable for a floodproofed building.

Warning Time

The rate-of-rise of floodwaters for the site in question, the established flood warning system (if any), the flood warning time available, and the reliability of the flood warning must be reviewed to determine appropriate floodproof design elements. The rate-of-rise or the flood warning time available through an existing reliable (community-based or regionally based) flood warning system must be adequate to provide sufficient lead time to evacuate a floodprone building when flooding threatens. In addition, sufficient warning time must exist to successfully place floodproofing components, such as removable flood shields or gates, if such components are to be included in the floodproofing design. Other examples of floodproofing techniques that can require human intervention are operating sump pumps and closing valves. The amount of time necessary to put human intervention floodproofing components in place will depend upon the number of components, their complexity, and the availability of personnel to place them. Floodproofed buildings are not appropriate for any site in a flash flood area, because of the potentially short warning time.

Safety and Access

Safe access to a floodproofed building is a critical factor in the determination of whether floodproofing is an appropriate design alternative. In 1987, Colorado State University conducted a study of human stability in flood flow conditions based on the product number of depth of flow multiplied by the floodwater velocity. Results of this study indicated that any floodplain location with a product number of 4 or greater represents a significant hazard to individuals. Floodplain sites with a base flood product number number of 4 or greater (depth in feet multiplied by velocity in feet per second) will create a hazard for anyone attempting to escape from or gain access to the site. Such sites are not generally acceptable for floodproofed buildings, unless modifications are made to the site to reduce the flood hazard.

For any floodproofed building, all roads to be used as evacuation routes must remain passable as the floodwaters rise. In addition, all roads that provide access to buildings whose dry-floodproofing components require human intervention must remain passable long enough for the floodproofing components to be installed and for all personnel to safely evacuate the site. For sites with an acceptably low hazard (product number less than 4) that are contiguous to land above the BFE, evacuation and access during times of flooding are generally not critical considerations.

Flood Velocities, Flood Depths, and Debris

For sites with flood velocities in excess of 5 feet per second or base flood depths in excess of 3 feet, the cost of dry-floodproofed construction may be prohibitive. Part 3 of the section of this bulletin titled "Minimum Engineering Considerations" describes the flood forces that a floodproofed building must be able to resist. Flood-borne debris can generate impact forces that may make a dry-floodproofed design technically infeasible and therefore inappropriate. A level of safety above the BFE, referred to as freeboard, is recommended, as discussed under "Minimum Engineering Considerations."

> Note: While buildings need only be protected to the BFE for floodplain management purposes, freeboard is considered for flood insurance rating purposes. Because of the additional risk associated with any floodproofed building, 1 foot is subtracted from the elevation to which a building has been floodproofed, for insurance rating (if the building is floodproofed at least to the BFE). Therefore, to receive an insurance rating based on 100-year flood protection, the building must be floodproofed to an elevation at least 1 foot above the BFE. Insurance premiums will be lower if floodproofing exceeds this requirement.

Flood Frequency

A site that has been flooded frequently may not be appropriate for a dry-floodproofed building. The cumulative wear-and-tear on a building's external components as a result of recurring inundation may render a dry floodproofing strategy infeasible. The cost of repeated business interruption and of frequent cleanup activities, as well as the effects of having to repeatedly implement a flood emergency plan, must be assessed.

If the evaluation of each of the aforementioned factors indicates that dry floodproofing is a viable floodplain management alternative, then a floodproofing design is developed. For all floodproofed buildings, the design professional must then produce both a Flood Emergency Operation Plan and an Inspection and Maintenance Plan for the building.

Flood Emergency Operation Plan

A Flood Emergency Operation Plan is an integral part of any building's floodproofing design and is critical when the floodproofing requires human intervention such as the installation of flood gates or flood shields. A Flood Emergency Operation Plan is necessary for any floodproofed building to ensure that the floodproofing components will operate properly under all conditions, including power failures. A continuous source of electricity to operate any necessary floodproofing components, such as pumps, will be needed for any floodproofing design that includes such components. The design professional must produce the plan. An adequate plan must include the following:

1. An established chain of command and responsibility with leadership responsibilities clearly defined for all aspects of the plan.

2. A procedure for notification of necessary parties when flooding threatens and flood warnings are issued. Personnel required to be at the building should have a planned and safe means of ingress and should have no other emergency response duties during a flood event. Alternates should be assigned in the event that the primary persons responsible are unable to complete their assigned duties under the plan.

3. A list of specific duties assigned to ensure that all responsibilities are addressed expeditiously. The locations of materials necessary to properly install all floodproofing components must be included in the list.

4. An evacuation plan for all personnel—those without duties for the flood emergency as well as those with duties for implementing the plan. All possible ingress and egress routes must be identified.

5. A periodic training and exercise program to keep personnel aware of their duties and responsibilities. Training drills should be held at least once a year and should be coordinated with community officials. Flood safety precautions should be repeated during each training drill.

Inspection and Maintenance Plan

Every floodproofing design requires some degree of periodic maintenance and inspection to ensure that all components will operate properly under flood conditions. The necessary inspection and maintenance activities, including inspection intervals and repair requirements, must be described in the Inspection and Maintenance Plan. Components that should be inspected as part of an annual (as a minimum) maintenance and inspection program include the following:

1. Mechanical equipment such as sump pumps and generators.

2. Flood shields and closures, to ensure that they fit properly and that the gaskets and seals are in good working order, properly labeled, and stored as indicated in the Flood Emergency Operation Plan.

3. Walls and wall penetrations, for cracks and potential leaks.

4. Levees and berms, for excessive vegetative growth, cracks, or leaks.

Both the Flood Emergency Operation Plan and the Inspection and Maintenance Plan are necessary at the time that the Non-Residential Floodproofing Certificate is submitted to the community. Before issuing a building permit, the community should require that the property owner sign an agreement stating that the plan will be adhered to. The community should also be assured that the inspection and maintenance activities required by the plan will continue regardless of changes in the ownership of the floodproofed building. This assurance should be accomplished by appropriate deed restrictions. Any lease agreement should also contain clear language stating the leaseholder's responsibilities for the floodproofed building.

Minimum Engineering Considerations

The design professional, a registered professional engineer or architect, must certify that the following requirements have been met by the building's design, specifications, and plans:

1. The building must be watertight (i.e., floodwaters must not enter the building envelope):

   a. The building must be watertight to the floodproof design elevation, which is further defined as being at least the BFE. As previously noted, floodproofing to any elevation less than 1 foot above the BFE will have a serious negative impact on the flood insurance rating for the building. Generally a minimum of 1 foot of freeboard is recommended. Additional freeboard is warranted for sites where predicted flood depths may be inaccurate, such as sites within large drainage areas and rapidly urbanizing areas.

   b. The building's walls must be "substantially impermeable to the passage of water." FEMA has adopted the U.S. Army Corps of Engineers (COE) definition of substantially impermeable from the COE publication "Flood Proofing Regulations." This document states that a substantially impermeable wall "shall not permit the accumulation of more than 4 inches of water depth during a 24-hour period if there were no devices provided for its removal. However, sump pumps shall be required to control this seepage." Flood-resistant materials, described in Technical Bulletin 2, "Flood-Resistant Materials Requirements," must be used in all areas where such seepage is likely to occur.

2. The building's utilities and sanitary facilities, including heating, air conditioning, electrical, water supply, and sanitary sewage services, must be located above the BFE, completely enclosed within the building's watertight walls, or made watertight and capable of resisting damage during flood conditions.

3. All of the building's structural components must be capable of resisting specific flood-related forces. These are the forces that would be exerted upon the building as a result of floodwaters reaching the BFE (at a minimum) or floodproofing design level, and include the following:

   a. Hydrostatic Flood Force—This is the force that water at rest exerts on any submerged object. For a floodproofed building design, the calculations of hydrostatic flood forces must include saturated soil pressure on any portion of the building that is below grade (see Figure 1). Guidelines for determining hydrostatic pressure are provided on the following page.

HYDROSTATIC PRESSURES BY WATER DEPTH	
HEIGHT (H) (WATER DEPTH)	P_h (LBS/SQ.FT.)
1	62.4
2	124.8
3	187.2
4	249.6
5	312.0
6	374.4
7	436.8
8	499.2
9	561.6
10	624.0

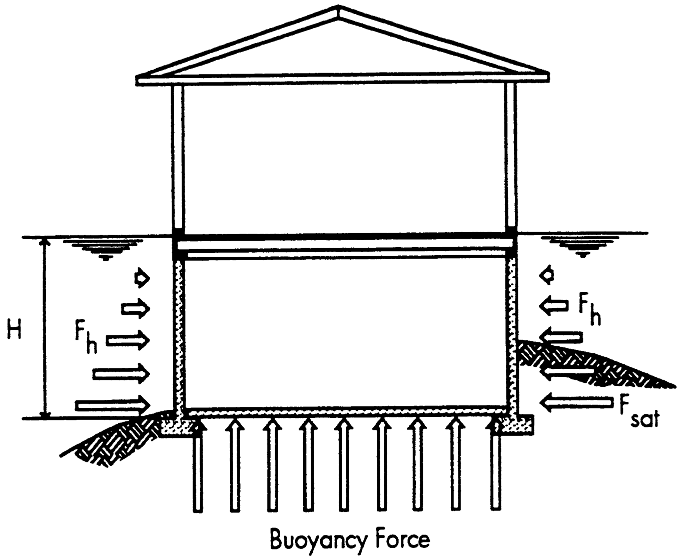


Figure 1. Hydrostatic Pressure Diagram

Resultant Lateral Force Due to Hydrostatic Pressure from Freestanding Water:

$F_h = \frac{1}{2} w H^2$

where: F_h is the lateral force from freestanding water (in pounds per linear foot of surface)

w is the specific weight of water (62.4 pounds per cubic foot)

H is the height of the standing water (to the floodproof design level)

If any portion of the building is below grade, then calculate the Resultant Cumulative Lateral Force Due to Hyrostatic Pressure from Saturated Soil:

$F_{sat} = \frac{1}{2} S D^2 + F_h$

where: F_{sat} is the lateral force from saturated soil

S is the equivalent fluid weight of saturated soil (in pounds per cubic foot)

D is the depth of saturated soil (in feet)

F_h is the lateral force from freestanding water

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

b. Buoyancy—This is the vertical force associated with the building's tendency to float when inundated or surrounded by floodwaters. This force can be calculated as shown below.

Buoyancy Force:

$F_b = wAH$

where: F_b is the force due to buoyancy

w is the specific weight of water (62.4 pounds per cubic foot)

A is the area of horizontal surface (floor or slab) being acted upon (in square feet)

H is the depth of building below the floodproofing design level (in feet)

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

c. Hydrodynamic Force—This is the force exerted on vertical surfaces exposed to moving floodwaters. The determination of hydrodynamic force is based on the expected velocity of the floodwaters with depths to the floodproofing design level (BFE or higher). The projected average base flood velocity within the floodway may be obtained using FEMA Flood Insurance Studies (FISs) where a floodway has been identified. It should be noted that velocities in the flood fringe will generally be less than the floodway velocities presented in the FIS. Where no FIS velocity data exist, velocities should be determined using Manning's equation, as found in most hydraulic reference and text books.

Hydrodynamic Force:

$F_d = C_d m {}^1\!/\!_2 (V)^2 A$

where: F_d is the lateral force due to hydrodynamic pressure

C_d is the drag coefficient

m is the mass density of water (1.94 slugs per cubic foot)

V is the velocity of the water (in feet per second)

A is the area of the wall affected (in square feet)

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

d. Debris Impact Force—This is the force associated with flood-borne debris striking the side of a building. This force presents the greatest unknown to the designer, but a value must be estimated to develop an effective floodproofing design. Unless more detailed information is available, such as historical debris flow data, the formula shown below should be used. This formula assumes a 1-second duration of impact. The weight of the object is generally estimated at 1,000 pounds but can be reduced to 500 pounds for areas subject to minor debris flow potential. Any areas subject to severe debris (such as mountainous regions or areas subject to ice floes) are not appropriate sites for floodproofed buildings unless the designer takes these forces into account in designing and armouring the building. Armouring often results in designs that are not cost-effective.

Debris Impact Force:

$$F_i = \frac{WV}{gt}$$

where: F_i is the Impact Force

W is the weight of the object (in pounds)

V is the velocity of the object (in feet per second)

g is the acceleration due to gravity (32.2 feet per second^2)

t is the duration of impact (in seconds)

Note: See Appendix C of the FEMA "Design Manual for Retrofitting Flood-Prone Residential Structures" for further information.

4. Like all construction that falls under the NFIP regulations, the building must meet the requirements of all applicable portions of local and State building codes, including the provisions of the Americans with Disabilities Act; life-safety codes for ingress, egress, and clearing; and venting and combustion air requirements.

Preparation of the Floodproofing Certificate for Non-Residential Buildings

The Floodproofing Certificate is required for all non-residential buildings to be floodproofed and is to be completed by the design professional. The first part of the Certificate contains information concerning the location and ownership of the building.

FEDERAL EMERGENCY MANAGEMENT AGENCY
NATIONAL FLOOD INSURANCE PROGRAM

O.M.B. No. 3067-007

FLOODPROOFING CERTIFICATE

FOR NON-RESIDENTIAL STRUCTURES

The floodproofing of non-residential buildings may be permitted as an alternative to elevating to or above the Base Flood Elevation; however, a floodproofing design certification is required. This form is to be used for that certification. Floodproofing of a residential building does not alter a community's floodplain management elevation requirements or affect the insurance rating unless the community has been issued an exception by FEMA to allow floodproofed residential basements. The permitting of a floodproofed residential basement requires a separate certification specifying that the design complies with the local floodplain management ordinance.

	FOR INSURANCE COMPANY USE
BUILDING OWNER'S NAME	POLICY NUMBER
STREET ADDRESS (including Apt., Unit, Suite and/or Bldg. Number) OR P.O. ROUTE AND BOX NUMBER	COMPANY NAIC NUMBER
OTHER DESCRIPTION (Lot and Block Numbers, etc.)	
CITY	STATE ZIP CODE

Building Location and Ownership information

Section I of the Certificate is the Flood Insurance Rate Map (FIRM) information, including the BFE used in designing the floodproofing system. Copies of the FIRM should be available through the community's floodplain administrator.

SECTION I FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

Provide the following from the proper FIRM:

COMMUNITY NUMBER	PANEL NUMBER	SUFFIX	DATE OF FIRM INDEX	FIRM ZONE	BASE FLOOD ELEVATION (in A0 Zones use depth)

Section I

Section II requests information regarding the floodproofing design. The first item is the elevation, referenced to the datum of the FIRM (generally the National Geodetic Vertical Datum of 1929), to which the building is floodproofed. This elevation must be equal to or greater than the BFE. It is important to note that for insurance rating purposes, the floodproofing design must provide protection to 1 foot above the BFE to receive rating credit. If the building is floodproofed only to the BFE, then the building's insurance rating will result in a higher premium. Before a decision is made to floodproof to less than 1 foot above the BFE, insurance implications should be carefully considered.

The second item is the height of the floodproofing above the lowest adjacent grade. This information is intended to be used by community building officials, FEMA, and NFIP insurance underwriters to analyze the level of safety that the floodproofing design will provide. Since floodwaters exert greater pressure on the floodproofed building as the height of the flooding increases (see Figure 1), floodproofing that exceeds 3 feet in height represents a greater risk and may result in insurance rates that reflect this increased risk.

SECTION II FLOODPROOFING INFORMATION (By a Registered Professional Engineer or Architect)

Floodproofing Design Elevation Information:

Building is floodproofed to an elevation of _______.___ feet NGVD. (Elevation datum used must be the same as that on the FIRM.)

Height of floodproofing on the building above the lowest adjacent grade is ___.__ feet.

(NOTE: for insurance rating purposes, the building's floodproofed design elevation must be at least one foot above the Base Flood Elevation to receive rating credit. If the building is floodproofed only to the Base Flood Elevation, then the building's insurance rating will result in a higher premium.)

Section II

Section III is the actual certification of the floodproofing design as required in Section 60.3(c)(4) of the NFIP regulations. It is important to note that design professionals signing this form are certifying that they have developed and/or reviewed the design plans and specifications and find them in compliance with accepted standards of practice for dry floodproofing. This certification is based on the floodproofing design, <u>not</u> the as-built condition of the building. The person signing this form must be a registered professional engineer or architect within the state or territory where the building will be constructed or substantially improved.

SECTION III CERTIFICATION (By a Registered Professional Engineer or Architect)

Non-Residential Floodproofed Construction Certification:

I certify that based upon development and/or review of structural design, specifications, and plans for construction that the design and methods of construction are in accordance with accepted standards of practice for meeting the following provisions:

The structure, together with attendant utilities and sanitary facilities, is watertight to the floodproofed design elevation indicated above, with walls that aresubstantially impermeable to the passage of water.

All structural components are capable of resisting hydrostatic and hydrodynamic flood forces, including the effects of buoyancy, and anticipated debris impact forces.

I certify that the information on this certificate represents my best effort to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.

CERTIFIER'S NAME	LICENSE NUMBER (or Affix Seal)		
TITLE	COMPANY NAME		
ADDRESS	CITY	STATE	ZIP
SIGNATURE	DATE	PHONE	

Copies should be made of this certificate for: 1) community official, 2) insurance agent/company, 3) building owner.

FEMA Form 81-65

Section III

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood insurance was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the federal government and participating communities that have been identified as being floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community provided that the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's FIRMs.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Natural Hazards Branch of the appropriate FEMA regional office. The "User's Guide to Technical Bulletins" lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse — the form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning non-residential floodproofing:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2. "Block and Brick Wall Integrity Against Water Heights and Systems and Materials to Prevent Flood Waters From Entering Buildings," Carl E.Pace, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi, 1984.

3. "Commercial-Industrial Flood Audit," New England District, U.S. Army Corps of Engineers, n.d.

4. "Cooperative Flood Loss Reduction, A Technical Manual for Communities and Industries," Flood Loss Reduction Associates, 1981.

5. "Design Manual for Retrofitting Flood-Prone Residential Structures," FEMA, September 1986, FEMA-114.

6. "Floodproofing Non-Residential Structures," FEMA, May 1986, FEMA-102.

7. "Flood Proofing Regulations," U.S. Army Corps of Engineers, March 1992, EP 1165-2-314.

8. "Human Stability in a High Flood Hazard Zone," S.R. Abt, R.J. Whittlen, A. Taylor, and D.J. Love, Water Resource Bulletin, August 1989.

9. "Sealants, Part 1," John P. Cook, Progressive Architecture, December 1974.

10. "Sealants, Part 2," John P. Cook, Progressive Architecture, February 1975.

11. "Systems and Materials to Prevent Flood Waters from Entering Buildings," U.S. Army Corps of Engineers, 1984.

12. "Tests of Brick-Veneer Walls and Enclosures for Resistance to Flood Waters," Carl E. Pace, U.S. Army Corps of Engineers, Lower Mississippi Division, Vicksburg, Mississippi, 1978.

Glossary

Base flood — The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area — An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources.

Federal Emergency Management Agency (FEMA) — The independent federal agency that, in addition to carrying out other activities, oversees the administration of the National Flood Insurance Program.

Federal Insurance Administration (FIA) — The component of FEMA directly responsible for administering the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) — The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Floodprone area — Any land area susceptible to being inundated by floodwater from any source.

Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is <u>not</u> considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

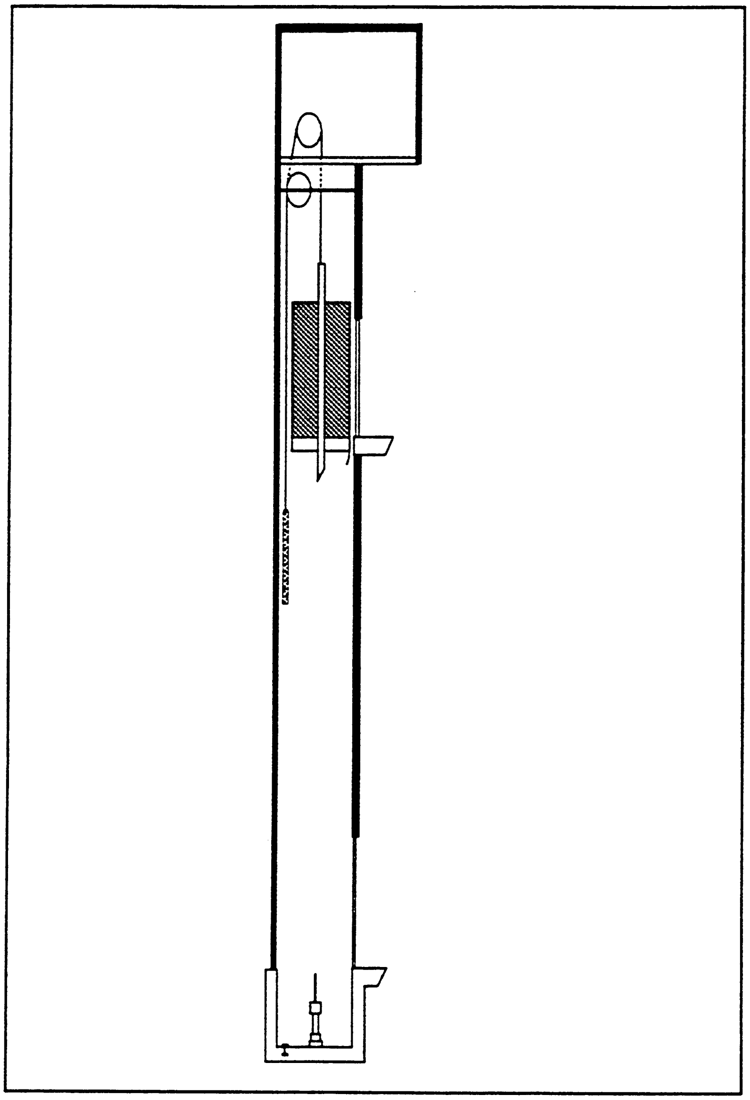
Substantial damage — Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

Technical
Bulletin
4-93

Elevator Installation

for Buildings Located in Special Flood Hazard Areas
in accordance with the
National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
FEDERAL INSURANCE ADMINISTRATION

FIA-TB-4
4/93

Key Word/Subject Index:

This index allows the user to quickly locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

FEMA/FIA
Office of Loss Reduction
Technical Standards Division
500 C St., SW, Room 417
Washington, D.C. 20472

Technical Bulletin 4-93 replaces Technical Bulletin 88-4 (draft) "Protection of Elevator Equipment."

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 4-93

Elevator Installation for Buildings Located In Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

Under the National Flood Insurance Program (NFIP), flood insurance coverage is limited for elevator equipment. New or replacement equipment relevant to an elevator, installed on or after October 1, 1987, and located below the lowest floor of an elevated building or in a basement is not covered for flood damage.

This Technical Bulletin provides information on proper installation of elevators in flood hazard areas to reduce flood damage. Elevator types and their associated equipment are described, and practical methods of protecting them from flood damage are provided.

The guidelines within this bulletin meet existing NFIP regulations that pertain to elevators, as well as serve to encourage the use of loss prevention measures that would reduce both the level of damage that can occur and the amount of time and work needed to make repairs. If these guidelines are followed, restoration of elevator service to the undamaged portion of the building can be accomplished as soon as possible after floodwaters recede and power is restored.

NFIP Regulations

The NFIP regulations require that elevators and their associated equipment be protected from flood damage. Section 60.3(a)(3) states that the community shall:

> ***"Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a floodprone area, all new construction and substantial improvements shall...(ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical...equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding."***

As these regulations indicate, all appropriate measures must be taken to mitigate flood damage to elevators and associated equipment to the maximum extent possible. While some components, to function properly, must be located below the lowest floor of a building, i.e., below the base flood elevation (BFE), most elevator components that can be damaged by floodwater can be located above the BFE or be designed to minimize flood damage. Components that can be damaged by floodwaters may be located below the BFE only if it is not technically feasible to elevate them above the BFE.

It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Types of Elevators

There are two types of elevators, hydraulic and traction. The hydraulic elevator consists of a cab attached to the top of a hydraulic jack similar to a jack used for a car lift in a service station. The hydraulic jack assembly normally extends below the lowest floor and is operated by a hydraulic pump and reservoir, both of which are usually located in a separate room adjacent to the elevator shaft, as shown in Figure 1. Hydraulic elevators are the type generally used in single-family residences.

The second type is the traction elevator. This is the system that is most commonly associated with elevators. The traction system consists of a cable that is connected to the top of the cab and is operated by an electric motor located in a penthouse above the elevator shaft, as shown in Figure 2.

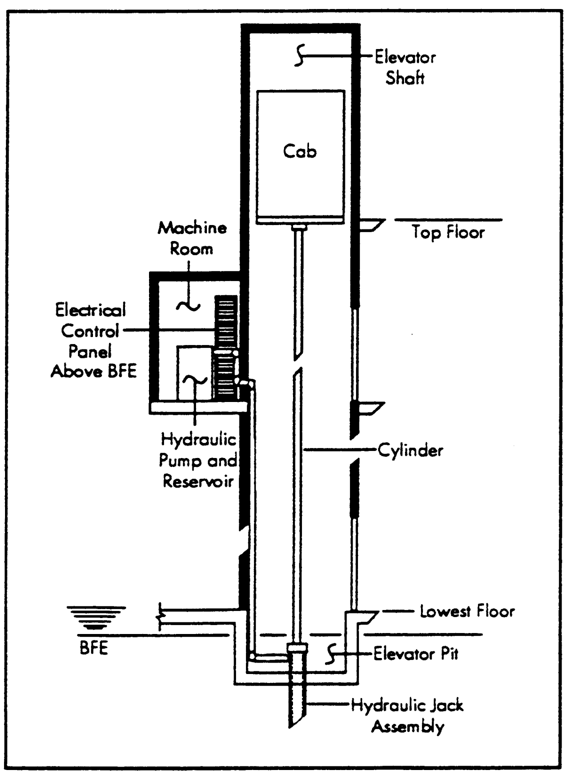


Figure 1. Hydraulic Elevator

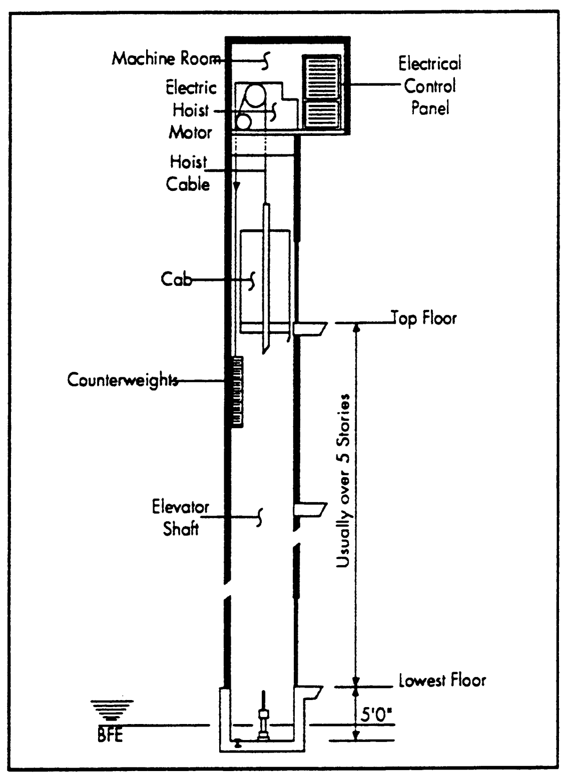


Figure 2. Traction Elevator

Flood Damage Protection

For compliance with NFIP regulations, the design and construction of an elevator installation must include all possible steps for protecting the elevator equipment from flood damage.

Hydraulic Elevators

The jack assembly for a hydraulic elevator (see Figure 1) will, by necessity, be located below the lowest floor and therefore generally below the BFE. The jack is located in a casing, and while it will resist damage from small amounts of water seepage, total inundation by floodwaters will usually result in contamination of the hydraulic oil and possible damage to the cylinders and seals of the jack. Salt water, because it is corrosive, can be particularly damaging. The hydraulic pump and reservoirs of the hydraulic elevator are also susceptible to water damage, but they can easily be located up to two floors above the jack and above the BFE as shown in Figure 1.

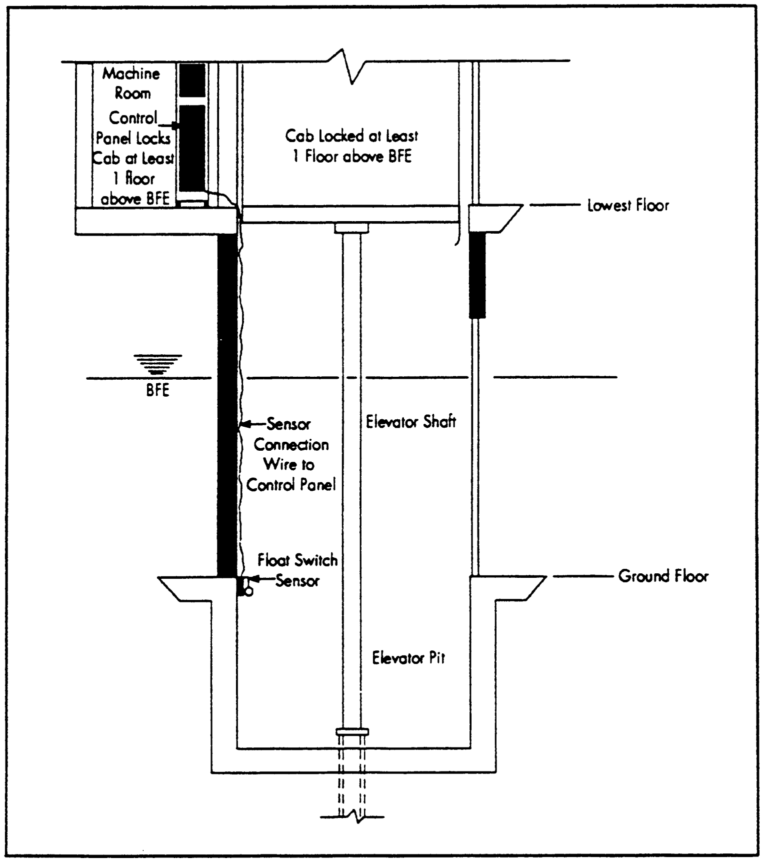


Figure 3. Float and Control Mechanism to Control Cab Descent

Traction Elevators

For traction elevators (see Figure 2), the electric motor and most other equipment are normally located above the elevator shaft and would not be susceptible to flood damage. Some equipment, however, such as the counterweight roller guides, compensation cable and pulleys, and oil buffers, usually must be located at the bottom of the shaft. When such equipment cannot be located above the BFE, it must be constructed using flood-resistant materials where possible.

Elevator Equipment

Some equipment common to all elevators will be damaged by floodwaters unless protected. The most obvious example is the elevator cab. Depending upon the size of the cab and the types of interior materials used, a cab may cost between $5,000 and $50,000. Flood damage, which can range from superficial to nearly a complete loss, can easily be avoided by keeping the cab above floodwaters. However, in most elevator control systems, the cab automatically descends to the lowest floor upon loss of electrical power. Installing a system of interlocking controls with one or more float switches in the elevator shaft to always keep the elevator cab from descending into floodwaters (see Figure 3) will result in a much safer system . **A float switch system or an-**

other system that provides the same level of safety is necessary for all elevators where there is a potential for the elevator cab to descend below the BFE during a flood.

Electrical equipment is often located below the BFE for both types of elevator systems. Some electrical equipment, such as electrical junction boxes and circuit and control panels, can be located above the BFE as shown in Figure 1. Other elevator components, such as doors and pit switches, must be located at or below the lowest floor. Where this becomes necessary, components may sometimes be replaced with more floodwater-resistant models. Some elevator equipment manufacturers offer water-resistant components; design professionals should contact suppliers to determine the availability of these components.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood insurance was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas, and ensuring that new development is adequately protected from flood damage. The NFIP is based on an agreement between the federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community provided that the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in Special Flood Hazard Areas. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's Flood Insurance Rate Maps.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Natural Hazards Branch of the appropriate FEMA regional office. The "User's Guide to Technical Bulletins" lists the bulletins issued to date and provides a key word/subject index for the entire series.

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Further Information

The following publications provide further information concerning elevator installation in buildings located in Special Flood Hazard Areas:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2. "Floodproofing Non-Residential Structures," FEMA , May 1986, FEMA-102.

3. "Flood Proofing Regulations," U.S. Army Corps of Engineers, March 1992, EP 1165–2–314.

4. "Floodproofing Test: Tests of Materials and Systems for Floodproofing Structures," U.S. Army Corps of Engineers, August 1988.

Glossary

Base flood — The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area — An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources.

Federal Emergency Management Agency (FEMA) — The independent federal agency that, in addition to carrying out other activities, oversees the administration of the National Flood Insurance Program.

Federal Insurance Administration (FIA) — The component of FEMA directly responsible for administering the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) — The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Floodprone area — Any land area susceptible to being inundated by floodwater from any source.

Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial damage — Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

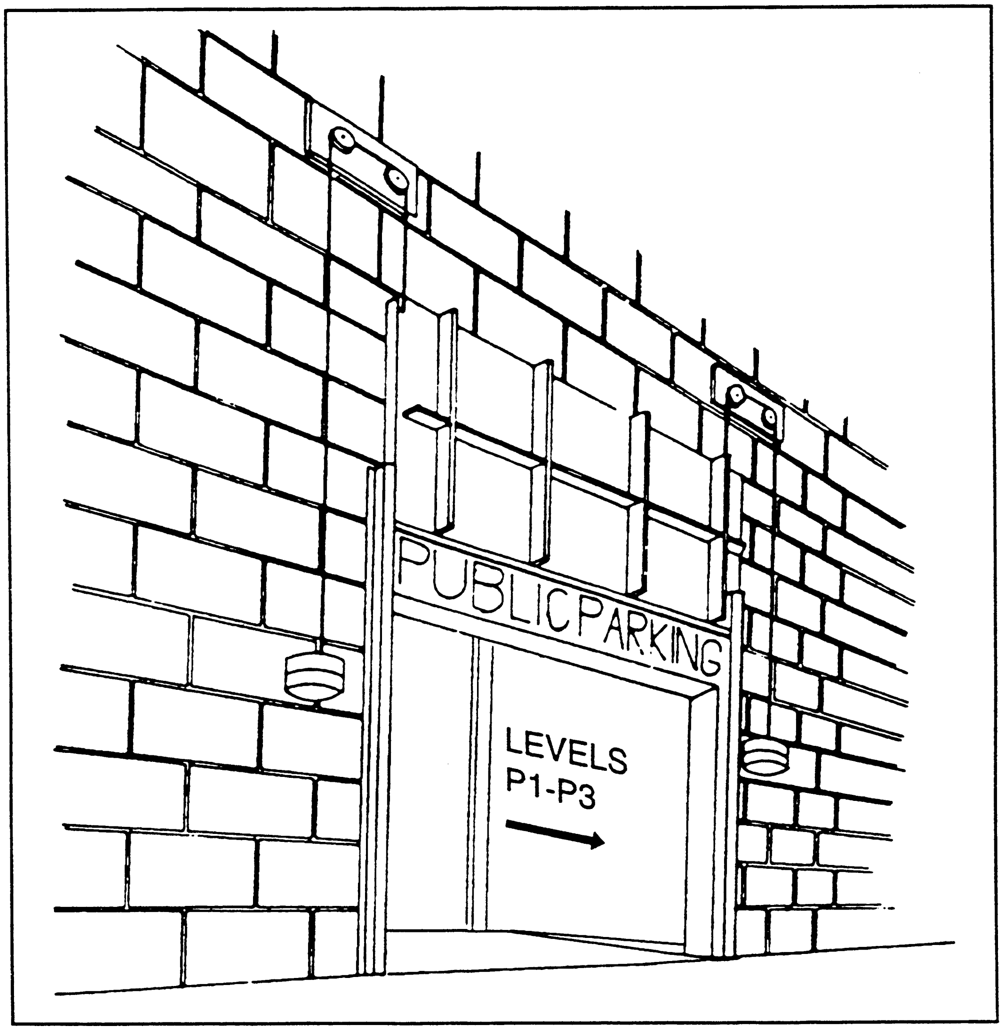
Technical Bulletin 6-93

Below-Grade Parking Requirements

for Buildings Located in Special Flood Hazard Areas

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
FEDERAL INSURANCE ADMINISTRATION

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4/93

Key Word/Subject Index:

This index allows the user to quickly locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

FEMA/FIA
Office of Loss Reduction
Technical Standards Division
500 C St., SW, Room 417
Washington, D.C. 20472

Technical Bulletin 6-93 replaces Technical Bulletin 90-2 (draft) "Below Grade Parking Garages."

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusai (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 6-93

Below-Grade Parking Requirements for Buildings Located In Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Introduction

The purpose of this bulletin is to provide technical guidance on the National Flood Insurance Program (NFIP) floodplain management requirements for below-grade parking garages for non-residential buildings in Special Flood Hazard Areas (SFHAs) shown on Flood Insurance Rate Maps (FIRMs).

Below-grade parking garages are commonly found in large engineered commercial buildings and are used for parking and access to the above-grade floors of the building. Flooding of these enclosed areas may result in significant damage to the building and any mechanical, electrical, or other utility equipment located there, such as ventilation equipment, lighting, elevator equipment, and drainage pumps. The garage walls, which often are major structural components of the building's foundation, are also susceptible to flood damage. The potential for injury to anyone in the garage, the potential for damage to parked cars, and the safety issue of removing parked cars when flooding threatens are important design considerations.

> Note: Users of this bulletin are advised that it provides guidance that must be used in conjunction with Technical Bulletin 3, "Non-Residential Floodproofing — Requirements and Certification." The conditions and requirements set forth in both bulletins must be met for any below-grade parking garage to be in compliance with the minimum requirements of the NFIP regulations. A Floodproofing Certificate for Non-Residential Structures must be completed for any building in an SFHA with below-grade parking.

NFIP Regulations

The NFIP regulations provide direction concerning whether or not below-grade parking is permitted in SFHAs, both coastal and riverine. For the purposes of the NFIP, below-grade parking is considered a basement. A basement is defined as any area of a building having its floor subgrade (below ground level) on all sides. The following subsections provide applicable excerpts from the NFIP regulations.

Below-Grade Parking Garages in Residential Buildings in A Zones

Section 60.3(c)(2) of the NFIP regulations states that a community shall:

> ***"Require that all new construction and substantial improvements of residential structures within Zones A1-A30, AE and AH on the community's FIRM have the lowest floor (including basement) elevated to or above the base flood level..."***

Under the NFIP, a below-grade parking garage is considered a basement if it is below grade on all sides. Therefore, the construction of below-grade parking garages is prohibited beneath residential buildings in Zones A1-A30, AE, and AH.

Section 60.3(c)(7) of the NFIP regulations deals with residential buildings in Zone A0 (sheet flow with depths of 1 to 3 feet) requirements. Section 60.3(c)(7) states that a community shall:

> ***"Require within any A0 zone on the community's FIRM that all new construction and substantial improvements of residential structures have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified)."***

Therefore, below-grade parking garages beneath residential buildings in Zone A0 are prohibited.

Below-Grade Parking Garages in Non-Residential Buildings in A Zones

Section 60.3(c)(3) of the NFIP regulations states that a community shall:

> ***"Require that all new construction and substantial improvements of non-residential structures within Zones A1-A30, AE, and AH on the community's FIRM (i) have the lowest floor (including basement) elevated to or above the base flood level, or (ii) together with attendant utility and sanitary facilities, be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy."***

Below-grade parking garages are permitted beneath non-residential buildings in Zones A1-A30, AE, and AH provided the building (including the parking garage) is floodproofed to the base flood level in accordance with the design performance standards provided above in Section 60.3(c)(3)(ii). Only below-grade parking garages (in non-residential buildings) that are dry floodproofed are permitted under the NFIP. Guidance on floodproofing is provided in the FEMA manual "Floodproofing Non-Residential Structures" and in Technical Bulletin 3, "Non-Residential Floodproofing — Requirements and Certification."

Section 60.3(c)(8) of the NFIP regulations deals with non-residential buildings in Zone A0 (sheet flow with depths of 1 to 3 feet) requirements. Section 60.3(c)(8) states that a community shall:

> ***"Require within any A0 zone on the community's FIRM that all new construction and substantial improvements of nonresidential structures (i) have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified), or (ii) together with attendant utility and sanitary facilities be completely floodproofed to that (base flood) level to meet the floodproofing standard specified in Section 60.3(c)(3)(ii)."***

Therefore, below-grade parking garages are permitted beneath non-residential buildings in Zone A0 provided the building (including the parking garage) is floodproofed to the base flood level in accordance with the design performance standards of Section 60.3(c)(3)(ii). Because of the severe damage that can be caused by velocity waters and debris, below-grade parking garages are not recommended in A0 zones where velocities have been identified.

Section 60.3(c)(4) further states:

> ***"...that where a non-residential structure is intended to be made watertight below the base flood level, i) a registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of construction are in accordance with accepted standards of practice for meeting the applicable provisions of paragraph (c)(3)(ii) or (c)(8)(ii) of this section."***

The floodproofing of a below-grade parking garage and any other portion of a building below the base flood elevation (BFE) must be certified to meet the standards of Section 60.3(c)(3). Additional guidance on this certification requirement can be found in Technical Bulletin 3, "Non-Residential Floodproofing — Requirements and Certification."

Below-Grade Parking Garages in V Zones

Section 60.3(e)(4) of the NFIP regulations states that a community shall:

> ***"Provide that all new construction and substantial improvements in Zones V1-V30 and VE, and also in Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that (i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level."***

The floor of a below-grade parking garage would be considered the "lowest floor" of a V-zone building under the NFIP (since the lowest horizontal structural member would be the footing of the garage) and could not meet the above requirement. Therefore, below-grade parking garages are prohibited beneath all residential and non-residential buildings in V zones.

> It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Design professionals should contact the community to determine whether more restrictive local or State regulations apply to the building or site in question. All applicable standards of the State or local building code must also be met for any building in a flood hazard area.

Designing a Floodproofed Below-Grade Parking Garage

All below-grade parking garages must be dry-floodproofed; therefore, hydrostatic and hydrodynamic forces must be considered in the design. In most designs, the loadings on the above-grade portion of the building are transferred to the structural elements of the below-grade parking garage. Therefore, any structural failure in the parking garage may well result in a failure of the entire building. FEMA's Technical Bulletin 3, "Non-Residential Floodproofing — Requirements and Certification," must be consulted for necessary guidance on floodproofing designs for below-grade parking garages.

> Note: While the NFIP regulations require that non-residential buildings be floodproofed only to the BFE, flood insurance rating procedures include a freeboard, or level of safety criterion. When a floodproofed building is rated for flood insurance, the level of flood protection is assumed at 1 foot below the top elevation of the floodproofing. For rating purposes, the NFIP requires that non-residential buildings be floodproofed to 1 foot above the BFE in order to receive rating credit for the floodproofing design.

A critical element in any floodproofing design for a below-grade parking garage is the point where the garage entrance ramp meets the street grade. The best method of protecting a dry-floodproofed garage from floodwaters is to design the garage entry to be above BFE. The entry can also be brought up and over a ramp of fill dirt placed above the BFE. In some cases, however, the garage entry must meet street grade at an elevation below the BFE. Such a design requires that a high-strength flood shield that can withstand the high hydrostatic pressure be installed so that floodwaters will not enter the dry-floodproofed garage.

Any portions of a floodproofing design that entail human intervention (such as placing a flood shield) greatly increase the potential for loss of life and property damage during a flood. A sufficient number of emergency exits must be available so that anyone in the garage will not be trapped by rising floodwaters, and a warning and evacuation plan must be developed and tested so that it can be readily implemented when a flood threatens. Such a plan is necessary for all below-grade garages as stated in Technical Bulletin 3, which provides guidance on warning and evacuation plans.

Below-Grade Parking for Mixed-Use Buildings

While the NFIP regulations state that dry floodproofing of below-grade parking garages is allowed only for non-residential buildings in A zones, professionally designed buildings that have both commercial (non-residential) and residential uses may be designed with floodproofed below-grade parking garages. All residential-use areas of the building must be above the BFE. An insurance agent experienced in the NFIP should be consulted during the design phase concerning the cost of insurance for a mixed-use building.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood insurance was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community provided that the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria. Included in the NFIP requirements, found under Title 44 of the Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management ordinances, communities adopt the NFIP design performance standards for new and substantially improved buildings located in floodprone areas identified on FIA's FIRMs.

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Further Information

The following publications provide further information concerning below-grade parking garages:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2. "Floodproofing Non-Residential Structures," FEMA, May 1986, FEMA-102

Glossary

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Base Flood Elevation (BFE) — The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement — Any area of a building having its floor subgrade (below ground level) on all sides.

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Lowest floor — The lowest floor of the lowest enclosed area of a building, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for parking of vehicles, building access, or storage (in an area other than a basement) is not considered a building's lowest floor.

Special Flood Hazard Area (SFHA) — Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial damage — Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

Technical Bulletin 7-93

Wet Floodproofing Requirements
for Structures Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE
FEDERAL INSURANCE ADMINISTRATION

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FEMA/Mitigation Directorate
Program Development Branch
500 C St., S.W.
Washington, D.C. 20472

Technical Bulletin 7-93 replaces Technical Bulletin 85-1 (draft) "Wet Floodproofing"

Graphic design based on the Japanese print *The Great Wave Off Kanagawa*, by Katsushika Hokusi (1760-1849), Asiatic collection, Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 7-93

Wet Floodproofing Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program

INTRODUCTION

This bulletin describes planning, design, and construction requirements for wet floodproofing certain types of structures and their uses under the National Flood Insurance Program (NFIP). The basic characteristic that distinguishes wet floodproofing from dry floodproofing is the internal flooding of a structure as opposed to providing essentially watertight protection. Specifically, wet floodproofing can be defined as:

> Permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding by allowing flood waters to enter the structure.

Flooding of a structure's interior is intended to counteract hydrostatic pressure on the walls, surfaces, and supports of the structure by equalizing interior and exterior water levels during a flood. Inundation also reduces the danger of buoyancy from hydrostatic uplift forces. Such measures may require alteration of a structure's design and construction, use of flood-resistant materials, adjustment of building operation and maintenance procedures, relocation and treatment of equipment and contents, and emergency preparedness for actions that require human intervention.

In accordance with the NFIP, Wet Floodproofing is allowed in only limited situations

Application of wet floodproofing as a flood protection technique under the NFIP is limited to specific situations in A Zones (including A, AE, A1-30, AH, AO, AR zones). For certain uses and types of structures described in this bulletin, communities may allow wet floodproofing only through the issuance of a variance from certain floodplain management requirements. The situations and conditions in which a community may allow wet floodproofing are described in detail in the section entitled **Applicability**.

For structures in V zones (includes V, VE, V1-30 zones), more stringent design and construction requirements have been established for the portion of a structure below the Base Flood Elevation (BFE). For information on V-zone design and construction requirements, refer to the NFIP regulations under 44 CFR Section 60.3, the Technical Bulletin series, and FEMA's "Coastal Construction Manual" (FEMA 55).

APPLICABILITY

New Construction and Substantial Improvements of Residential and Non-Residential Structures

An important objective of the NFIP is to protect structures constructed in floodplains from flood-induced damage. In support of this objective, the NFIP regulations include building design and construction criteria that apply to new construction and substantial improvements (including structures which have incurred substantial damage) of existing structures in Special Flood Hazard Areas (SFHA). According to these criteria, residential structures in A zones must be constructed with their lowest floors elevated to or above the BFE. Non-residential structures constructed in A zones must either have their lowest floors elevated to or above the BFE or be dry floodproofed (made watertight) to or above the BFE. Measures to accomplish dry floodproofing of non-residential structures must not only provide watertight protection but also must be designed to withstand hydrostatic, hydrodynamic, and impact forces produced by flooding. The intent is to provide complete protection at least up to the floodproofing design level which must, at a minimum, be at the BFE.

Note: To receive a flood insurance rate based on 100 year flood protection, the structure must be dry floodproofed to an elevation at least 1 foot above the BFE. (i.e. 1 foot of freeboard)

In accordance with the NFIP, there are limited enclosed areas within newly constructed and substantially improved residential and non-residential structures where the community may allow wet floodproofing without a variance as a flood protection technique. These are limited to:

Enclosed areas below the BFE that are used solely for parking, building access, or limited storage. New construction and the substantial improvement of residential and non-residential structures whose lowest floors have been constructed at or above the BFE may be constructed with enclosed areas below the BFE. These areas must; (1) be used solely for parking, building access, or limited storage, (2) be designed to allow for the automatic entry and exit of flood waters through the use of openings, and (3) be constructed of flood resistant materials.

Attached garages. A garage attached to a residential structure, constructed with the garage floor slab below the BFE, must be designed to allow for the automatic entry of flood waters. Openings are required in the exterior walls of the garage or in the garage doors. In addition to allowing the automatic entry of flood waters, the areas of the garage below the BFE must be constructed with flood resistant materials. Garages attached to non-residential structures must meet the aforementioned requirements or be dry floodproofed. For guidance on below-grade parking areas refer to Technical Bulletin 6, "Below-Grade Parking Requirements".

Certain categories of structures where FEMA has advised communities that variances to allow wet floodproofing may be issued.

Communities must determine whether a variance from local floodplain management regulations may be issued to allow wet floodproofing for the categories of structures described in this section. To make such a determination, the community must, at a minimum, apply the NFIP variance criteria set forth in the 44 CFR Section 60.6. Included in these criteria is the requirement that the variance be the minimum necessary to afford relief, considering the flooding conditions at the site. This means that when a community issues a variance from elevation or dry floodproofing requirements, the structure must still be protected to the maximum extent possible using an appropriate alternative flood protection technique, such as wet floodproofing. To properly administer the granting of a variance for wet floodproofing, communities should have variance review procedures in place. These variance procedures must be within the bounds of State enabling law and meet the minimum requirements of the NFIP.

Variances to allow wet floodproofing may be issued for the following categories of structures. **These structures must comply with floodway encroachment provisions of the NFIP Regulations in accordance with section 60.6(a)(1).**

Structures Functionally Dependent On Close Proximity to Water: Certain structures that must be located near water are functionally dependent uses, as defined in section 59.1, and are permitted to be wet floodproofed after the issuance of a variance from NFIP elevation and dry floodproofing requirements. These structures may include certain types of docking, seafood processing, and port facilities associated with marine activities. Specific criteria for issuing a variance for functionally dependent uses are established in section 60.6(a)(7). These include the requirement that the structure or other development be protected by methods that minimize flood damage and create no additional threat to public safety.

Historic Buildings: Under section 60.6, variances may be issued for the repair and rehabilitation of historic structures, as defined in Section 59.1, upon the determination that the proposed repair or rehabilitation will not preclude the structure's continued designation of a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure.

Accessory structures, used solely for parking (two-car detached garages or smaller) or limited storage (small, low-cost sheds): If a community wishes to allow a non-elevated/non-dry floodproofed accessory structures, the community must establish the meaning of low-cost and small accessory structures. Communities may allow wet floodproofing of these structures provided that they represent a minimal investment and are designed to have a low damage potential with respect to the structure and contents.

The following requirements, at a minimum, must be attached to the variance for an accessory structure:

1) it must be anchored to resist flotation, collapse, and lateral movement;

2) the portions of these structures located below the BFE must be constructed of flood-resistant materials;

3) it must be designed to allow for the automatic entry of flood waters;

4) mechanical and utility equipment must be elevated or floodproofed to or above the BFE;

5) it must comply with the floodway encroachment provisions of the NFIP Regulations; and

6) its use must be limited to parking and/or limited storage.

Some communities have included provisions in their floodplain management ordinance for permitting the construction of these low-cost, small detached accessory structures. Communities wishing to regulate the placement of such structures in this manner should contact their FEMA Regional Office for guidance and assistance.

Certain Agricultural Structures: FEMA recognizes that wet floodproofing may be appropriate for certain types of agricultural structures located in wide, expansive floodplains. A variance may be issued only if the structure is used solely for agricultural purposes in which the use is exclusively in connection with the production, harvesting, storage, drying, or raising of agricultural commodities, including the raising of livestock. Only in circumstances when it can be demonstrated that agricultural structures can be designed in such a manner that results in minimal damage to the structure and its contents and will create no additional threats to public safety, may a variance be issued. Because the wet floodproofing of a new agricultural structure with the lowest floor below the BFE is not in conformance with NFIP requirements, any variance issued must address both the nonconforming flood protection technique and the restriction of use to the above-described agricultural purposes. Types of agricultural structures that may be wet floodproofed following the issuance of a variance are:

- **Farm Storage Structures** used exclusively for the storage of farm machinery and equipment (e.g., pole and pre-fabricated metal frame structures with open or closed sides).

- **Grain bins.**

- **Corn cribs.**

▸ **General purpose barns** for the temporary feeding of livestock, provided they remain open on at least one side.

In addition to the variance requirements 1-5 under the Accessory Structure category presented above, a variance for an agricultural structure must also be limited to agricultural purposes.

Existing (Pre-FIRM) Structures That Are Not Substantially Improved or Substantially Damaged

For existing structures that are not being substantially improved or that have not been substantially damaged, the NFIP elevation and dry floodproofing regulations do not apply. Owners may voluntarily choose to wet floodproof such a particular structure to reduce potential flood damage. Many existing structures are constructed of materials that are generally permeable to flood waters, difficult to make watertight, or unsuitable for flood protection techniques other than elevation or relocation. Although it may be technically feasible to retrofit some older structures by sealing the perimeter walls and creating a watertight structure, it is often unadvisable to do so because of high probability that the dry floodproofing will fail due to some unforeseen factor in these usually non-engineered, older structures. In these cases, wet floodproofing and flood protection through either relocation or elevation of structures may offer the only technically viable flood-damage reduction alternatives. In some situations, wet floodproofing may be the only realistic economic alternative for existing structures that are not substantially improved or damaged.

INSURANCE IMPLICATION

It must be emphasized that variances are granted with respect to floodplain management requirements and do not affect flood insurance rates. The Federal Insurance Administration, by statute, must charge insurance rates commensurate with the risk to which a building is exposed. Insurance rates for buildings constructed under variances are generally higher than rates for a comparable structure that is fully compliant. In some instances the additional costs of insuring these buildings, if they are not elevated or floodproofed in accordance with the NFIP requirements, would approach or even exceed the costs of meeting NFIP elevation or dry floodproofing requirements, and the structure would still be exposed to flood damages.

In accordance with the NFIP regulations, communities must notify the applicant in writing that the issuance of a variance will result in increased premium rates for flood insurance and that such construction below the BFE increases risks to life and property [44 CFR 60.6(a)(5)].

NFIP Regulations

44 CFR Section 60.3 (a)(3) of the NFIP regulations requires that the community must:

> *"Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding."*

NFIP regulations require that all enclosures below the BFE in A Zones must either be designed to allow for the equalization of hydrostatic forces during a flood event or be floodproofed. When water is allowed to enter, section 60.3(c)(5) of the NFIP regulations states that a community shall:

> *"Require for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access, or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of flood waters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding is provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of flood waters."*

Section 60.3(d)(3) places further restrictions on construction in floodways by stating that a community shall:

> *"Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge."*

Concerning the issuance of variances, section 60.6(a)(3) states:

> *"Variances shall only be issued by a community upon (i) a showing of good and sufficient cause, (ii) a determination that failure to grant a variance would result in exceptional hardship to the applicant, and (iii) a determination that granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, create nuisances, cause fraud on or victimization of the public, or conflict with existing local laws or ordinances;"*

And section 60.6(a)(4) states that

> *"Variances shall only be issued upon a determination that the variance is the minimum necessary, considering the flood hazard, to afford relief;"*

Concerning functionally dependent uses under the NFIP variance criteria, "Functionally dependent use" is defined in section 59.1 as:

> *"Functionally dependent use means a use which cannot perform its intended purpose unless it is located or carried out in close proximity to water. The term includes only docking facilities, port facilities that are necessary for the loading and unloading of cargo and passengers, and ship building and ship repair facilities, but does not include long-term storage or related manufacturing facilities."*

Section 60.6(a)(7) states that:

> *"Variances may be issued by a community for new construction and substantial improvements and for other development necessary for the conduct of a functionally dependent use provided that (i) the criteria of paragraphs (a)(1) through (a)(4) of this section are met, and (ii) the structure or other development is protected by methods that minimize flood damage during the base flood and create no additional threats to public safety."*

Concerning granting variances for historic structures under the NFIP variance criteria, section §60.6(a) states that:

> *"...Variances may be issued for the repair and rehabilitation of historic structures upon the determination that the proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure."*

Lastly, concerning granting variances in designated floodways, section 60.6(a)(1) states that:

> *"Variances shall not be issued by a community within any designated regulatory floodway if any increase in flood levels during the base flood discharge would result;"*

Note: Readers are strongly advised to become familiar with all provisions of section 60.6.

It should be noted that Technical Bulletins provide guidance on the minimum requirements of the NFIP regulations. Community or State requirements that exceed those of the NFIP take precedence. Those contemplating wet floodproofing a structure should contact the community to determine whether more restrictive local or State regulations apply to the structure or site in question. All applicable standards of the State or local building code must also be met for any structure in a special flood hazard area.

Planning Considerations

A review of the following factors for the site in question will assist in determining whether wet floodproofing is appropriate. For example, if a site will be subject to rapidly rising, high-velocity flood waters during a flood, and the available warning time is short, then the site is unsuitable for a wet floodproofed structure. In this situation, elevation or relocation of the building outside the floodplain would be the preferred alternatives.

Warning Time

The rate-of-rise of flood waters for the site in question, the established flood warning system (if any), the flood warning time available, and the reliability of the flood warning must be reviewed to determine appropriate wet floodproof design elements. The rate-of-rise or the flood warning time available through an existing reliable (community-based or regionally-based) flood warning system must be adequate to provide sufficient lead time to evacuate a flood prone structure when flooding threatens. In addition, sufficient warning time must exist to successfully implement a plan that requires human intervention which would include such items as the removal of equipment or contents, or the elevation of contents within the structure. Wet or dry floodproofed structures are not appropriate for any site in a flash flood area, because of the potentially short warning time.

Safety and Access

Safe access to a wet floodproofed structure may be a critical factor in the determination of whether wet floodproofing is an appropriate design alternative. It is anticipated that most wet floodproofed structures will not need to be accessed during flooding. In situations where there is a need to access the structure during conditions of flooding, safe access shall be considered. In 1987, Colorado State University conducted a study of human stability in flood flow conditions based on the product number of depth of flow multiplied by the floodwater velocity. Results of this study indicated that any floodplain location with a product number of 4 or greater (depth in feet multiplied by velocity in feet per second) will create a hazard for anyone attempting to escape from or gain access to the site. Such sites are only acceptable for wet floodproofed structures if modifications are made to the site to reduce the flood hazard and sufficient warning time is available to safely evacuate the site.

Other flood characteristics that must be considered include:

Floodway Encroachment: Encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway are prohibited under the NFIP unless it has been demonstrated, through hydrologic and hydraulic analysis performed in accordance with standard engineering practice, that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge. Floodways are usually the most dangerous portion of the floodplain, containing the highest velocity and debris-laden flood flows. Extreme caution must be used in the placement of any structure in a floodway.

Duration: The amount of time a structure's interior is flooded presents two major concerns. First, damage due to the deterioration of structural components, interior finishes, equipment/machinery, and contents generally increases with prolonged inundation. The other concern is the financial loss due to business interruption, determined by both the length of time inundated and time to clean-up. Financial losses due to disruption can be extreme.

Flood-Borne Contaminants: Flood waters may contain numerous contaminants and are often caustic and toxic. In urbanized and industrialized areas, floodwater can contain higher amounts of salts, alkalis, oils, wastes, chemicals, and debris. In agricultural areas flood water often contains, herbicides, pesticides, and fertilizers. Based on flooding characteristics, some flooding sources will contain higher concentrates of suspended solids than others. Due to the action of "dirty" floodwater, inundated materials can absorb and surfaces can become coated with mud, debris, and grime, exposing contents and building components to corrosive salts and chemicals. This often leads to residual deposits and odors after flood waters recede. These deposits and odors can render a structure unsafe and non-occupiable for an extended period of time after the flood waters recede.

Frequency: Frequent flooding may render a wet floodproofing strategy infeasible. Detriments that must be assessed include cumulative "wear and tear" effects of recurring inundation and the costs associated with repeated business interruption, frequent remove of contents, and frequent clean-up activities.

Depth: It is difficult to establish a safe range of flood depths for the use of wet floodproofing, and perhaps inappropriate to attempt to do so. It is somewhat more applicable to evaluate limiting factors. Many wet floodproofing actions involve some degree of either permanent or contingent elevation of contents, equipment, and machinery. A maximum depth may be established as the depth that would preclude the use of wet floodproofing procedures that can effectively protect the structure and its contents.

Water Temperature: In very cold weather, ice may pose significant problems in implementing wet floodproofing. The impact of large, water-borne, chunks of ice can damage or destroy a structure, and water that freezes inside of a structure can result in strong expansive forces that can damage both structural and non-structural building components.

Operational Procedures

The operational procedures aspect of applying wet floodproofing techniques involves both the structure's functional requirements for daily use and the allocation of space, with consideration of each function's potential for flood damage. Daily operations and space use can be organized and modified to greatly reduce the structure and contents vulnerability to damage. The goals are to minimize damage caused by floodwater and to minimize economic losses due to business interruption. The following describes the various operations concerns involved in an effective wet floodproofing concept:

Flood Warning System. Because wet floodproofing will, in most cases, require some human intervention when a flood is imminent, it is extremely important that there be adequate time to execute such actions. Specific time required is a function of the type and degree of actions necessary in addition to the resources available for their implementation. In some areas, it may be possible to benefit from the use of an existing flood warning system. In other cases, however, it will be necessary to independently develop a system. Such a system may be as simple as a weather band radio that operates on a tone alarm from the National Weather Service for smaller watersheds and monitoring river forecast levels for larger watersheds.

Inspection and Maintenance Plan Every wet floodproofing design requires some degree of periodic maintenance and inspection to ensure that all components will operate properly under flood conditions. The necessary inspection and maintenance activities, including inspection intervals and repair requirements, must be described in the Inspection and Maintenance Plan. Components that should be inspected as part of an annual (as a minimum) maintenance and inspection program include opening covers and valves intended to equalize hydrostatic pressure.

Flood Emergency Operation Plan. A Flood Emergency Operation Plan is an integral part of any structure's floodproofing design and is critical when the floodproofing requires human intervention such as adjustments to, or relocation of contents and utilities. While such a plan is recommended for existing structures, it is a requirement for all new structures where human intervention is critical to the proper operation of the floodproofing. An adequate plan for the type of structures discussed in this bulletin shall include a list of specific duties to ensure that all wet floodproofing measures requiring human intervention are addressed. The locations of materials necessary to properly install all floodproofing components must be included in the list.

A pre-determination of the flood stages at which floodwater enters each wet floodproofed structure must be made, along with a pre-determination of the amount of warning time available. Based upon these elements, contingency actions should be prioritized, particularly any evacuation that will be involved. The plan should be completely tested to ascertain its practicality, and also should be reviewed and updated following a flood event.

Other Considerations

Having considered all of the above, a community may choose to:

limit the size and number of structures that may be wet floodproofed,

restrict the location of wet floodproofed structures to areas where the depth of flooding and/or floodwater velocity will not result in damage to structure or its contents, and/or

consider the possibility of combining elevation and dry floodproofing with wet floodproofing where the level of risk warrants such action.

Engineering Considerations

There are three main components to wet floodproofing a structure; design elements, flood resistant materials, and protection of contents. As with the application of dry floodproofing techniques, developing a wet floodproofing strategy requires site-specific evaluations that may necessitate the services of a design professional.

Protection of the Structure

Hydrostatic forces must be counteracted to prevent wall collapse and flood-induced uplift. This is achieved through the use of wall openings that allow water to enter the structure, thereby equalizing the hydrostatic pressure. The NFIP requirements concerning openings are discussed in Technical Bulletin 1, "Openings in Foundation Walls." In addition, provisions must be made to prevent air trapped within the structure during periods of inundation from becoming pressurized and damaging on the exterior walls and roof. Because structures may become buoyant in the presence of flood water, superstructures need to be designed to prevent separation from the foundation. All structural and non-structural components must be constructed of materials that are durable, resistant to flood forces, and resistant to deterioration caused by repeated inundation by floodwater. Components not inundated with flood water must be able to resistant damage as a result of excessive humidity associated with flooding and post-flood conditions. Technical Bulletin 2 "Flood Resistant Materials" provides specific guidance on which materials are acceptable under the NFIP.

Foundations: The failure of foundations in structures subjected to inundation is a major cause of structural damage. Foundation design is a site-specific process that must take into account local soils and building load conditions. Included in the site analysis should be the influence of hydrologic and hydraulic conditions (velocity of flow, rate-of-rise, depth, flood-borne constituents, and duration) on the foundation design. The ability of floodwater to adversely affect the integrity of structure foundations by eroding supporting soil, scouring foundation material, and undermining footings necessitates careful examination of foundation designs.

An extremely important consideration is that the structure be adequately anchored to the foundation. Uplift forces during a flood event are often great enough to separate an improperly anchored structure from its foundation.

Cavity Wall Construction: Wet floodproofing equalizes hydrostatic pressure throughout the structure by allowing floodwater to fill in all spaces and equalize internal and external hydrostatic pressure. Thus, any attempt to seal internal air spaces within the wall system is not only technically difficult, but also contrary to the wet floodproofing approach. Provisions must be made so that the cavity space fills with water and drains at a rate approximately equal to the floodwater rate-of-rise and fall.

If the cavity wall air space is filled with insulation, it should be a type that is not subject to damage from inundation. Batt and blanket types such as spun mineral fiber or fiberglass bat insulation are not acceptable as they retain water and contaminants within their voids. Foam and closed cell type insulation have characteristics that can withstand a certain level of inundation. These include polystyrene, expanded foam, and thermal glass.

The air space within the cavity wall will also be inundated by floodwater and the contaminants it carries. Silt, chemicals, and organic materials, will remain in the cavity space after the floodwater has receded. Such contaminants can be hazardous to the structure and the occupants; caustic chemicals can deteriorate building materials and debris that harbors organic growth can be have associated bacterial problems and odors. If a cavity wall is used, the cavity wall should have "clean-out" access panels that allow the internal air space to be flushed with water or other cleaning agents and fresh air to circulate within the cavity. Refer to FEMA 234, "Repairing Your Flooded Home" for further guidance on cleaning wall cavities.

Solid Wall Construction: Wall systems without internal air spaces are considered solid wall construction, which includes cast-in-place concrete, fully grouted cell masonry, pressure treated wood- or metal-frame shell. Solid walls are designed without internal spaces that could retain floodwater. Because these walls can be somewhat porous, they can absorb moisture, and to a limited degree, associated contaminants. Such porous wall systems that permit the intrusion of moisture into the wall could cause internal damage especially in a cold (freeze-thaw) climate. Solid walls made of non-porous materials are preferred over cavity walls. But in those cases where solid wall construction made of porous material is being considered, the use of both exterior and interior cladding with properties as described above for cavity wall systems is more desirable.

Wall Finishes: The exterior cladding of a structure subject to flooding should be nonporous, resistant to chemical corrosion or debris deposits, and conducive to easy cleaning. Relatively impervious cladding such as hard brick, pressure-treated wood, metal, and concrete are some of the acceptable materials.

As with exterior surfaces, interior cladding should be easy to clean and not susceptible to damage from inundation. Materials that are solid and relatively impervious such as concrete, hard brick, plastic, and pressure-treated wood, are most suitable.

Metal-clad structures such as those found in many agricultural operations should be constructed of corrosion-resistant materials. Framing and cladding must meet the same flood-resistant requirements as all other materials. Metal fasteners used with metal panel cladding systems are susceptible to corrosion and should be a corrosion-resistant type, such as hot dipped galvanized or stainless steel.

Where interior wall finishes are present, they shall meet the same flood resistant standards as all other materials located below the BFE.

Floors: Subfloor systems in wet floodproofed structures are normally concrete or gravel. Materials that are attached to the concrete subfloor, such as tile, paint, or wood, and the attachment mechanism (adhesives, nails, screws, etc.) that secures the finish material to the subfloor structure, should be able to withstand inundation associated with a base flood event without damage or alteration.

Ceilings and Roofs. When it is anticipated that flood levels will come in contact with the ceiling, flood resistant material requirements apply for ceiling materials and attachment mechanisms (hangers, adhesives, screws). To protect the ceilings and roofs from the pressure of entrapped air or water, pressure relief vents should be used. Even in those cases where flood waters are expected to be below ceiling levels, ceilings materials including attachment mechanisms should be able to withstand prolonged exposure to moisture and humidity associated with flood and post-flood conditions.

Building Envelope Openings. Openings in a structure's floors, walls, ceilings, and roofs are often enclosed by architectural components such doors, windows, louvers, vents, skylights, etc. These components include fasteners, gaskets, seals, glazing, locks, and finishes. Again, even those items not expected to be inundated must be resistant to humidity and moisture damage. NFIP flood resistant material requirements apply to all architectural components that are to be exposed to flooding or resulting excessive moisture. All materials shall be capable of resisting damage associated with a base flood event. Door systems include frame, hinges, threshold, and panels. Since solid wood, wood laminate, or hollow core wood door panels may warp, swell and/or rot, sealed metals are preferable.

Windows are susceptible to damage from debris carried by floodwater. The use of glass blocks, sealed unbreakable panes, and wire-reinforced glass will resist flood damage. Protective screens may also be successful in preventing debris impact. The use of tempered glass or impact-resistant plastic (acrylic or polycarbonate) is recommended for large window areas of 20 square feet or more.

Protection of Mechanical and Electrical Systems; While the NFIP regulations do not prohibit the placement of mechanical and electrical components below the BFE, they are required to be designed and/or located so as to prevent flood water from entering or accumulating within them. The preferred method of meeting this requirement is to locate flood-threatened components above the expected flood level. Other options that may meet the NFIP requirements for electrical systems that can not be elevated involve emergency operation and maintenance procedures, including disconnecting and elevating or relocating electrically controlled equipment, installing elevated control panels for cutoff of electricity, or enclosing service equipment in waterproof utility enclosure areas. Mechanical systems that must be located below the design flood level should be provided with waterproofed enclosures to protect bearings, seals, gears clutches, valves, or controls that will not withstand immersion, silt damage, or water pressure.

Electrical System. Electricity is a primary source of energy for many vital building operations. Wet floodproofing an electrical system primarily involves preventing vulnerable components from coming in contact with water. Elevation of all electrical components except the minimum necessary to operate the structure (minimal number of light switches and receptacles) is required. Where switches and receptacles must be located below the BFE, sealed or capped moisture-resistant components are required. Ground Fault Circuit Interrupters shall be utilized for all electrical circuits that serve areas below the BFE. Key system components for which elevation above floodwater is desirable include transformers, switchboards, and branch panels. A possible alternative may be to enclose these elements with a waterproof protective barrier. In circumstances which dictate that it is not practicable to safely maintain power during inundation, complete cutoff must be utilized. This of course presents the need for inspections and actions to ensure complete drying of electrical components prior to power restoration.

Electrical service provided to a structure from poles or other overhead sources should enter the structure at a point above the expected flood level. Underground service cables may be feasible provided that they are waterproofed and not exposed to direct contact with flood water.

Heating and Ventilating In general, heating and ventilating equipment is not designed to withstand inundation and is prone to severe floodwater damage. Thus, elevating is recommended to preclude inundation of system components. In situations where elevation is not practical, quick release/disconnect mechanisms should be incorporated into the design. One example is fan motor components for grain bin aeration systems which are configured to be easily removed and relocated prior to flooding.

Liquid Storage Containers Liquid and gas containers are subject to extreme hydrostatic pressure during inundation. Where possible, such containers should be elevated to or above the BFE or located outside the floodplain. If a newly constructed container will be subject to inundation, it is required under the NFIP to be anchored to withstand a buoyant force acting upon it in its empty state. Containers should have watertight fill caps and vents that extend above the expected flood level, and should be labelled according to contents. Labeling will allow emergency personnel to identify the contents in the event the tanks breaks loose and floats away. It is important to note that underground tanks are also subject to uplift forces. Empty tanks, both above and below ground, should be filled with potable water prior to the arrival of floodwater. The post-flood disposal of this possibly contaminated water must be in accordance with all applicable federal, state and local regulations.

Flood Resistant Materials

In accordance with the NFIP, all materials exposed to floodwater must be durable, resistant to flood forces, and retardant to deterioration caused by repeated exposure to flood water. Generally, these performance requirements result in masonry construction being the most suited to wet floodproofing in terms of damage resistance. In some cases wood or steel structures may be candidates, provided that the wood is pressure treated or naturally decay resistant and steel is galvanized or protected with rust-retardant paint. Detailed guidance is provided in Technical Bulletin #2 "Flood-Resistant Material Requirements."

Protection of Contents and Equipment

Isolation from Floodwater. Consideration should be given to preventing, to the maximum extent possible, the contact of floodwater with damage-susceptible items. This can be accomplished through relocation prior to flooding, elevation, or in-place protection of flood-damageable items.

Relocation: The most effective method of protection for equipment and contents is to relocate threatened items out of harm's way. The interior of the structure must be organized in a way that ensures easy access and facilitates relocation. Aisles, doors, and corridors shall be wide enough and equipment size should be evaluated to allow any planned relocation or removal. Where structures are used to store bulk materials, such as grain, provisions must be made for the orderly removal and relocation of the contents to an area outside the floodplain.

Elevation: Within the flood-prone structure, elevation of key items could be achieved through the use of existing or specially constructed platforms or pedestals. Contingent elevation can be accomplished by the use of hoists or some type of overhead suspension system. Elevation techniques can be applied to a wide range of objects--machinery, utility system components (particularly electrical equipment), fuel and storage containers, and contents.

In-Place Protection: Some items can be protected, in-place, through a variety of options. Protective waterproof enclosures may be feasible for items that are difficult to move or relocate. Anchors and tie-downs, shall be used where appropriate to prevent flotation and movement, especially in the case of storage containers. Depending on flood characteristics, such enclosures may not have to be inconveniently high or completely permanent. Low barriers or flood shields may supply the necessary protection. Also, steps or ramps can be incorporated into the design to further maintain easy access.

Protective coatings can be applied to equipment to reduce inundation damage. Petroleum based greases, hot dip plastics, spray or cold plastics can all be applied to oily surfaces. If they are applied to painted surfaces they must be non-migratory and not applied to threaded surfaces. Coatings can provide protection and enhance cleanup ease.

The use of "quick-disconnect" type plug and receptacle sets on standard electrical motors and other electrical connections provides several advantages. This allows for rapid shutdown, eliminates the need for an electrician, simplifies removal operations, and enables rapid reinstallation and restart. Similarly, motor-pump type units can be equipped with quick disconnect fittings on both suction and discharge lines in addition to electrical power lines. These actions also provide the added benefit of facilitating routine maintenance and relocation of equipment.

Mounting equipment and inventory on skids or pallets contributes greatly to contingent relocation, elevation, and removal actions using a fork lift. Large items that can be lifted from overhead should be permanently fitted with lifting bars or lugs. This eliminates time for rigging and benefits routine procedures. Any accessory items required, such as motor mount shims or necessary tools, should be stored nearby.

Technical Bulletins

This is one of a series of Technical Bulletins FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in Title 44 of the U.S. Code of Federal Regulations at Section 60.3. The bulletins are intended for use primarily by State and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for complying with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office. The User's Guide to Technical Bulletins lists the bulletins issued to date and provides a key word/subject index for the entire series.

Ordering Information

Copies of the Technical Bulletins can be obtained from the appropriate FEMA regional office. Technical Bulletins can also be ordered from the FEMA publications warehouse. Use of FEMA Form 60-8 will result in a more timely delivery from the warehouse. The form can be obtained from FEMA regional offices and your state's Office of Emergency Management. Send publication requests to FEMA Publications, P.O. Box 70274, Washington, D.C. 20024.

Further Information

The following publications provide further information concerning non-residential floodproofing:

1. "Answers to Questions About Substantially Damaged Buildings," FEMA, May 1991, FEMA-213.

2 "Commercial-Industrial Flood Audit," New England District, U.S. Army Corps of Engineers, n.d.

3. "Cooperative Flood Loss Reduction," A Technical Manual for Communities and Industries, Flood Loss Reduction Associates, 1981.

4. "Design Manual for Retrofitting Flood-Prone Residential Structures," FEMA, September 1986, FEMA-114.

5. "Floodproofing Non-Residential Structures," FEMA, May 1986, FEMA-102.

6. "Flood Proofing Regulations, U.S. Army Corps of Engineers," March 1992, EP 1165-2-314.

7. "Human Stability in a High Flood Hazard Zone," S.R. Abt, R.J. Whittlen, A. Taylor, and D.J. Love, Water Resource Bulletin, August 1989.

8. "Repairing Your Flooded Home," FEMA, August 1992, FEMA-234.

9. "Sealants, Part 1," John P. Cook, Progressive Architecture, December 1974.

10. "Sealants, Part 2," John P. Cook, Progressive Architecture, February 1975.

11. "Tests of Brick-Veneer Walls and Enclosures for Resistance to Flood Waters," Carl E. Pace, U.S. Army Corps of Engineers, Lower Mississippi Division, Vicksburg, Mississippi, 1978.

Glossary

Base flood The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Base Flood Elevation (BFE) The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929 or other datum as specified.

Basement Any area of a structure having its floor subgrade (below ground level) on all sides.

Coastal High Hazard Area An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources. These areas are identified as V zones.

Existing Construction/Structure For floodplain management purposes, existing construction means structures for which the start of construction commences before the effective date of a floodplain management regulation adopted by a community. These structures are often referred to as "Pre-FIRM" structures.

Federal Emergency Management Agency (FEMA) The independent federal agency that, in addition to carrying out other activities, oversees the administration of the NFIP.

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

Flood Insurance Rate Map (FIRM) The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analyses, areas of 100-year flood hazard in a community.

Flood Prone Area Any land area susceptible to being inundated by floodwater from any source.

Lowest Floor The lowest floor of the lowest enclosed area of a structure, including a basement. Any NFIP-compliant unfinished or flood-resistant enclosure useable solely for ɔarking of vehicles, building access, or storage (in an area other than a basement) is not onsidered a structure's lowest floor.

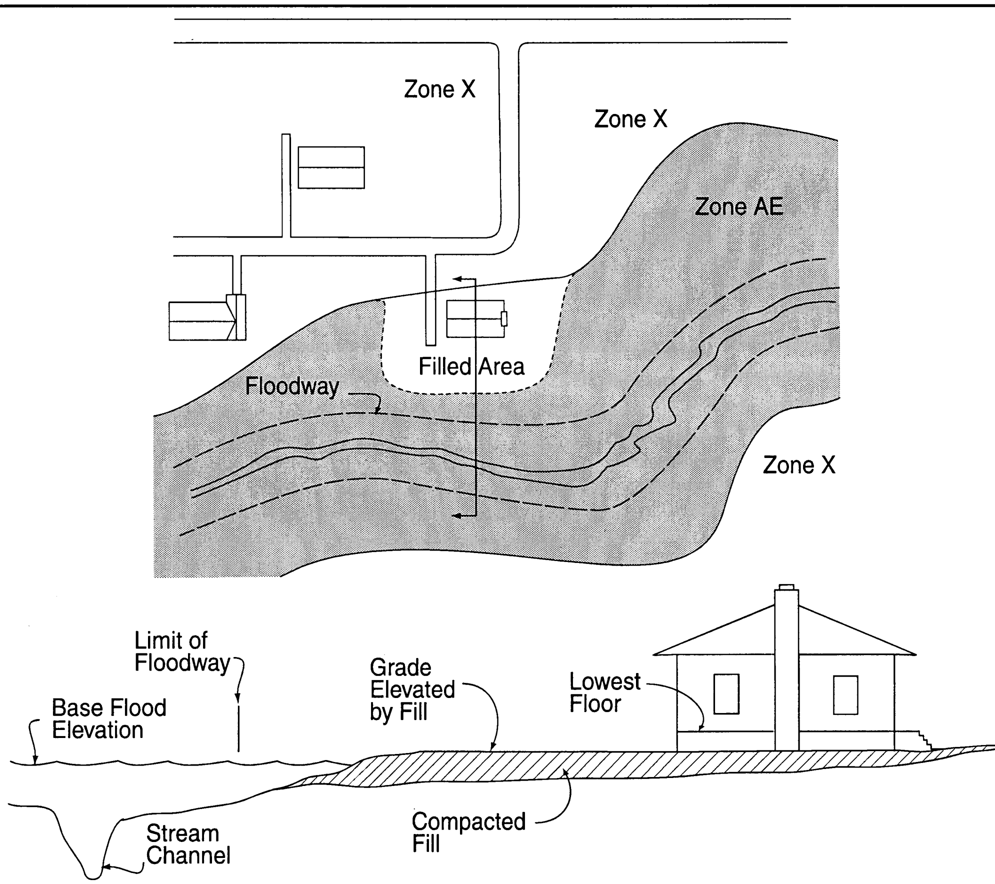
litigation Directorate The component of FEMA directly responsible for administering the ɔodplain management aspects of the National Flood Insurance Program.

Technical Bulletin 10-01

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

FIA-TB-10
(5/01)

Key Word/Subject Index

This index allows the user to locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

Federal Emergency Management Agency
Mitigation Directorate
Program Policy and Assessment Branch
500 C Street, SW.
Washington, DC 20472

Wave design on cover based on the Japanese print *The Great Wave Off Kanagawa*, by Katsuchika Hokussai (1760–1849), Asiatic Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 10-01

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding in accordance with the National Flood Insurance Program

Introduction

For the purpose of administering the National Flood Insurance Program (NFIP), FEMA identifies and maps flood hazard areas nationwide by conducting flood hazard studies and publishing Flood Insurance Rate Maps (FIRMs). These flood hazard areas, referred to as Special Flood Hazard Areas (SFHAs), are based on a flood having a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood or Base Flood).

Structures within the SFHA in a community participating in the NFIP are subject to floodplain management regulations that impact building standards and are designed to minimize flood risk. For example, Title 44, Part 60, Section 3(c)(2) of the Code of Federal Regulations—abbreviated as 44 CFR 60.3(c)(2)—requires that the lowest floor of a residential structure, including basement, built within the SFHA be at or above the Base Flood Elevation (BFE). In addition, flood insurance must be purchased for these structures if they are used as collateral to secure a loan provided by a federally regulated lender. Flood insurance coverage may be purchased for all eligible structures within a participating community. Insurance rates for structures located within the SFHA differ from the rates for structures located outside the SFHA.

When permitted under applicable Federal, state, and local laws, ordinances, and regulations, earthen fill is sometimes placed in an SFHA to reduce flood risk to the filled area. Under certain conditions, when engineered earthen fill is placed within an SFHA to raise the surface of the ground to or above the BFE, a request may be submitted to FEMA to revise the FIRM to indicate that the filled land is outside of the SFHA. When such revisions are warranted, FEMA usually revises the FIRM by issuing a Letter of Map Revision based on fill (LOMR-F). After FEMA has revised the FIRM to show that the filled land is outside the SFHA, the community is no longer required to apply the minimum NFIP floodplain management standards to any structures built on the land and the mandatory flood insurance purchase requirements no longer apply. It is worth noting that states and local communities may have floodplain regulations that are more restrictive than the minimum requirements of the NFIP and may continue to enforce some or all of their floodplain management requirements in areas outside the SFHA.

Although a structure built on a site that has been elevated by the placement of fill may be removed by FEMA from the SFHA, the structure may still be subject to damage during the Base Flood and higher-magnitude floods. Constructing the entire structure at or above the level of the BFE will minimize the flood risk from the Base Flood and is therefore the most prudent approach to constructing on fill. Conversely, a structure with a basement (subgrade area) adjacent to or near the floodplain may well be impacted by subsurface flooding brought on by surface flooding.

This bulletin provides guidance on the construction of buildings on land elevated above the BFE through the placement of fill. Several methods of construction are discussed, and the most prudent—those that result in the entire building being above the BFE—are recommended.

In some areas of the country, basements are a standard construction feature. Individuals may wish to construct basements on land after it has been removed from the floodplain by a FEMA revision. Buildings with basements built in filled areas are at an added risk of flooding when compared to buildings on other types of foundations. However, there are two major ways to minimize this additional risk from subsurface flooding. First, the building should be located farther back from the edge of the fill closest to the flooding source. Second, the higher the basement floor is elevated, the less the risk. This technical bulletin provides guidance on how to determine that these buildings will be reasonably safe from flooding during the occurrence of the Base Flood and larger floods. To be reasonably safe from flooding during the Base Flood condition, the basement must (1) be dry, not have any water in it, and (2) be structurally sound, not have loads that either exceed the structural capacity of walls or floors or cause unacceptable deflections. In practice, this means that soils around the basement must have low permeability to minimize or stop water infiltration to the basement wall and floors. Any water that does permeate to the basement must be removed by a drainage layer on the outside (soil side) of the basement. In addition, the foundation walls and floor slab must be designed and constructed for any increased loads that may occur during the Base Flood condition.

NFIP Regulations

Part of a community's application to participate in the NFIP must include "a commitment to recognize and duly evaluate flood hazards in all official actions in the areas having special flood hazards and to take other such official actions reasonably necessary to carry out the objectives of the program" [44 CFR 59.22 (a)(8)].

NFIP regulations at 44 CFR 60 include Subpart A: Requirements for Flood Plain Management Regulations. Each community participating in the NFIP adopts a floodplain management ordinance that meets or exceeds the minimum requirements listed in 44 CFR 60. Subpart A establishes specific criteria for determining the adequacy of a community's floodplain management regulations. The overriding purpose of the floodplain management regulations is to ensure that participating communities take into account flood hazards, to the extent that they are known, in all official actions relating to land management and use.

One of the minimum requirements established by the regulations is set forth at 44 CFR 60.3 (a)(3), which states that, for all proposed construction or other development within a participating community, the community must "Review all permit applications to determine whether the proposed building sites will be reasonably safe from flooding." 44 CFR 59.1 defines "development" as

> *"...any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operation or storage of equipment or materials,"*

Warning

Construction of a residential building in an identified SFHA with a lowest floor below the BFE is a violation of the floodplain management requirements set forth at 44 CFR 60.3(c)(2), unless the community has obtained an exception to NFIP requirements from FEMA and has approved procedures in place.

By issuance of this Technical Bulletin, FEMA is noting that residual flood hazards may exist in areas elevated above the BFE by the placement of engineered earthen fill. Residual risks in these areas include subsurface flood conditions and flooding from events that exceed the base flood. This bulletin is intended to guide local floodplain management officials in determining whether structures placed in filled areas are reasonably safe from flooding. FEMA will require that the jurisdiction having authority for floodplain management determine that an area is reasonably safe from flooding before removing it from the SFHA.

Floodways, V Zones, and Alluvial Fan Flood Hazard Areas

This bulletin does **not** apply to the following:

- Construction in the floodway. The NFIP prohibits encroachments into the floodway that would cause increases in flood stage.
- Construction in SFHAs designated Zone V, VE, or V1-V30 on FIRMs. The NFIP prohibits the use of structural fill for support of buildings in V zones. Buildings constructed in a V zone must be constructed on an open foundation consisting of piles, piers, or posts and must be elevated so that the bottom of the lowest horizontal structural member is at or above the BFE. In addition, this bulletin strongly recommends that structural fill **not** be used to elevate buildings constructed in A zones in coastal areas. Detailed guidance concerning proper construction methods for buildings in coastal areas is presented in FEMA's *Coastal Construction Manual* (FEMA 55) and in NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements*.
- Construction in SFHAs subject to alluvial fan flooding (designated Zone A0 with depths and velocities shown on FIRMs). The NFIP will not remove land from the floodplain based on the placement of fill in alluvial fan flood hazard areas.

More Restrictive State and Local Requirements

NFIP Technical Bulletins provide guidance on the **minimum** requirements of the NFIP regulations. State or local requirements that exceed those of the NFIP take precedence. Design professionals should contact community officials to determine whether more restrictive state or local regulations apply to the building or site in question. All applicable standards of the state or local building code must be met for any building in a flood hazard area.

Notes for Local Officials

Professional Certification

As required by state and local floodplain management ordinances, a proposed development must be determined to be reasonably safe from flooding. The official having the authority to make this determination should require all appropriate information for making the determination. This may include a certification by a qualified design professional that indicates the land or structures to be removed from the SFHA are reasonably safe from flooding, according to the criteria described in this technical bulletin. Such a professional certification may come from a professional engineer, professional geologist, professional soil scientist, or other design professional qualified to make such evaluations. A sample of such a certification is shown in Figure 1.

Project Name and Address

I, ______________________ certify that the design for the aforementioned development is reasonably safe from flooding in accordance with the guidance provided within FEMA's Technical Bulletin 10-01 related to ensuring that structures are reasonably safe from flooding and in accordance with accepted professional practices.

Signature ______________________ Date ____________

Title ______________________

Type of License ______________________ License Number ______________________

Address and Phone

Professional Seal

License Expiration Date

Figure 1 Sample of professional certification form.

Administrative Options for Community Permitting

Communities may choose a variety of administrative procedures to assist them in gathering information that can be used to determine whether a proposed development is reasonably safe from flooding. Communities are encouraged to establish procedures that alert them to potential future development of a filled area. These procedures should allow for the evaluation of future development and a means to determine whether it will be reasonably safe from flooding. The following are examples of such procedures:

- Require building sites to be identified on final subdivision plats and evaluate those building sites against the standards described in this Technical Bulletin.
- Require grading plans as a condition of issuing fill permits and require that those grading plans include building sites, and evaluate those building sites based on this Technical Bulletin.
- Require buffer zones or setback zones around the perimeter of fill pads or at the edge of the floodplain and establish construction requirements within these buffer zones to ensure that buildings are safe from residual risk.
- Require as a condition of final subdivision plat approval that the developer agree that no basements will be built in any flood areas.
- Adopt or have regulations that control development of areas immediately adjacent to floodplains that would ensure that any construction is reasonably safe from flooding. For example, under the Minnesota State Building Code, communities designate areas outside of the floodplain as "Secondary Flood Hazard Areas" where building officials evaluate plans for basements and can require modifications to the basement if an official believes there is a residual risk.
- When issuing a permit for the placement of fill only in the SFHA, stipulate that no buildings will be built on the site without a subsequent building permit.

Placement of Fill

Properly placing fill requires an understanding of soil mechanics, local site conditions, the specific characteristics of the soils being placed, the methods used to place and compact the fill, and soil testing procedures. Standard engineering and soil mechanics texts cover these subjects in detail. The performance of these filled areas should consider, but is not limited to, the following:

- the consolidation of the fill layers and any underlying layers
- the effect of this consolidation on either excessive settlement or differential settlement
- how the permeability of the soils affects water infiltration on any structures built on the site

Loss of Storage and Conveyance

The placement of fill in the SFHA can result in an increase in the BFE by reducing the ability to convey and store flood waters. This can result in increased flood damage to both upstream and downstream properties. To prevent these possible results, some communities prohibit fill, require compensatory storage for filled areas, and/or identify a more restrictive floodway.

Risk of Flood Damage in Areas Adjacent to the SFHA

Areas adjacent to the SFHA may have residual risks of flood damage similar to those in areas removed from the SFHA through the placement of fill. Both areas are subject to residual risk from subsurface water related to flooding and from floods greater than the Base Flood. Methods of construction discussed in this bulletin should also be used in these areas.

Building on Land Removed From the SFHA by the Placement of Fill

The safest methods of constructing a building on filled land removed from the SFHA are those that result in the entire structure being above the BFE. Methods that place the lowest floor of the building at, rather than above, the BFE are at greater flood risk, and methods that result in the lowest floor (including a basement floor) below the BFE have the highest flood risk of all. Placement of the lowest floor of these structures below the BFE, even through they are outside the SFHA, will result in an increased threat from subsurface flooding and magnified damages from flooding that exceeds the BFE.

Freeboard

Freeboard is an additional height used as a factor of safety in determining the elevation of a structure, or floodproofing, to compensate for factors that may increase the flood height (ASCE 24-98, *Flood Resistant Design and Construction*). When fill is used to protect buildings from the Base Flood, the community should consider whether freeboard should be required. This consideration should include whether better information exists or conditions have changed (from when the BFE was originally established) that indicate that the BFE may be higher than originally expected. One example of when the BFE may be higher is when a culvert or bridge is blocked by debris. Flood modeling assumes an open channel or culvert. Even when the BFE is not expected to be higher, freeboard may be appropriate to provide increased protection from flood events less frequent than the Base Flood or to account for future changes that may increase the BFE.

The foundation types for buildings outside the SFHA described in the following sections are listed in order of their increasing risk of flood damage.

Non-Basement Foundations

Non-basement foundations consist primarily of stem wall, crawlspace, and slab-on-grade foundations.

Stem Wall Foundation

A stem wall foundation can be used to raise the lowest floor above the surrounding grade. After the stem walls have been constructed and extended to the desired elevation, the area enclosed by the stem walls is filled with engineered compacted fill and a slab is poured on top (see Figure 2). Through the placement of additional fill, the site may be elevated above the BFE. This approach provides freeboard—an additional amount of elevation that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a stem wall foundation and placing this additional fill on the site provide the highest level of flood protection.

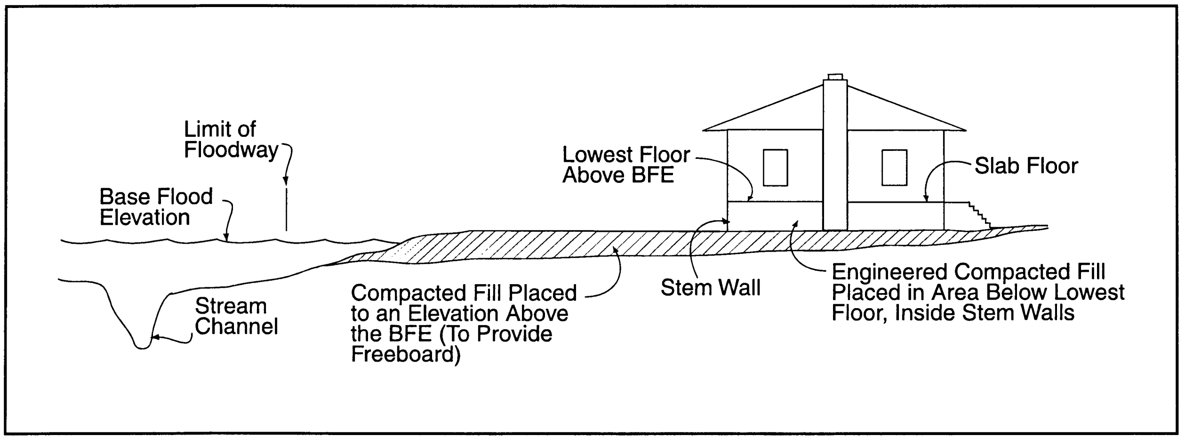


Figure 2 Structure on a stem wall foundation. The lowest floor is raised above the BFE. The space enclosed by the stem walls is filled with engineered compacted fill.

Crawlspace Foundation

Constructing a crawlspace beneath the first floor will raise the lowest floor of the structure above the surrounding grade (see Figure 3). Openings in the foundation walls are recommended. If flooding reaches the building, the openings allow flood waters to enter the area below the lowest floor and equalize the hydrostatic pressure on the foundation walls (see NFIP Technical Bulletin 1, *Openings In Foundation Walls*).

The crawlspace alternative is less preferable than stem wall construction, which does not result in an enclosed area under the first floor and therefore requires no flood openings. Placing additional fill to a level above the BFE provides freeboard that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a crawlspace foundation and placing additional fill on the site provide increased flood protection.

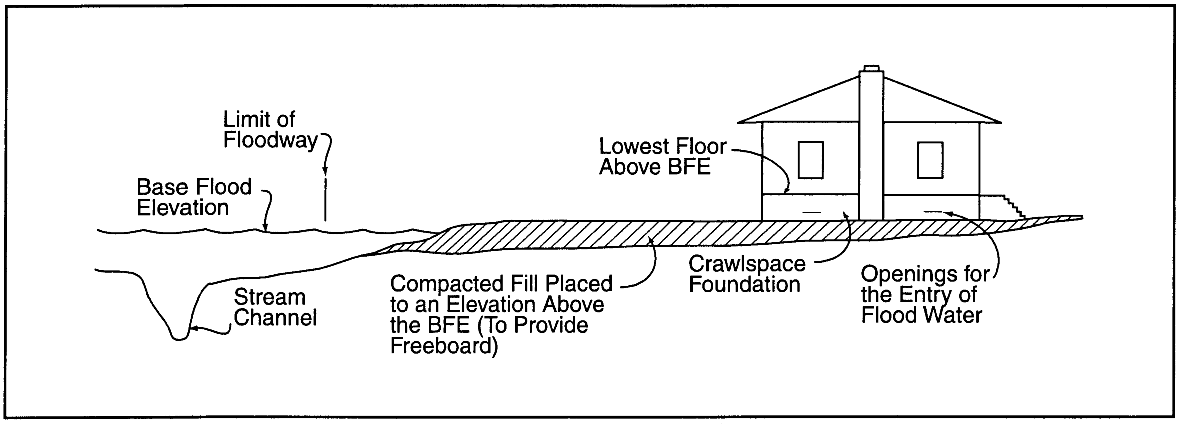


Figure 3 Structure on a crawlspace foundation. The lowest floor is raised above the BFE. Openings in the foundation walls allow water from floods higher than the fill elevation to enter the crawlspace and equalize the pressure on foundation walls.

Slab-On-Grade Foundation

This method normally provides less flood protection than crawlspace construction because it does not elevate the house above the adjacent grade (see Figure 4). As a result, the lowest floor of the house can be as low as the BFE and would be inundated by any flood greater than the BFE. Placing additional engineered fill beneath the building to a level above the BFE would provide freeboard and therefore increased flood protection.

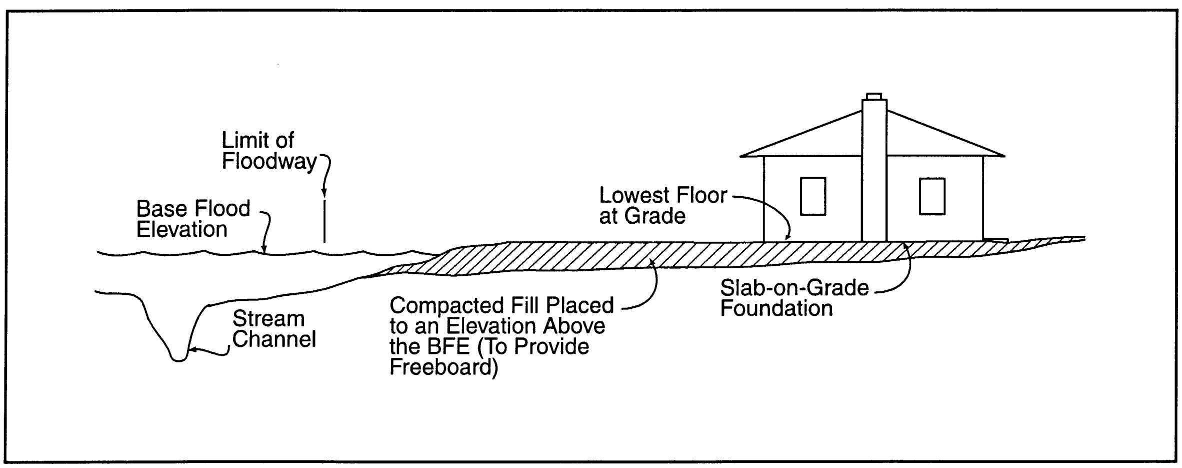


Figure 4 Structure on a slab-on-grade foundation. The lowest floor is typically slightly higher than the surrounding grade.

Basement Foundations

Although basements are a desired feature in some areas of the United States, NFIP minimum requirements generally do not allow their construction in the SFHA, because of the increased risk of flood damages. The only instances where this is not the case are buildings for which FEMA has granted a special exemption to allow floodproofed basements. However, once land is removed from the SFHA through a map revision, these NFIP minimum requirements no longer apply. As a result, builders and property owners who build on land removed from the SFHA sometimes elect to install basements, which are at a higher risk of flood damage than the foundation types described previously.

Constructing a basement on such land is **not** recommended, because the basement (i.e., lowest) floor and portions of the basement walls may well be subjected to subsurface flooding. The basement may therefore be subject to seepage and lateral hydrostatic and uplift pressure caused by high groundwater levels associated with flooding in surrounding areas. Additionally, when flooding exceeds the BFE, the basement area may be totally inundated with floodwater. When builders and homeowners decide to accept the additional risk associated with basement construction on filled land, they need to ensure that the basement and the rest of the house are reasonably safe from flooding.

Warning

In filled areas adjacent to floodplains, floods can still greatly influence the groundwater at the filled site. High groundwater at a site with a basement can result in water infiltrating the basement or greatly increased hydrostatic pressures on the walls and basement slab that can cause failure or permanent deformation. Even when floods have not reached houses with basements, FEMA has seen numerous examples of flooded basements, bowed basement floors, and collapsed basement walls that have resulted from the effects of high groundwater caused by flooding. In addition, the collapse of flooded basements has also occurred when water is rapidly pumped from basements surrounded by saturated soils whose pressure exceeds the capacity of the basement walls.

Flood Insurance Coverage for Basements

It is extremely important to note that the NFIP offers only limited coverage for basement flooding. First, in order for a claim to be paid, there must be a general condition of overland flooding where floodwaters come in contact with the structure. Secondly, the NFIP does not provide coverage for finished nonstructural elements such as paneling and linoleum in basement areas. Contents coverage is restricted to a limited number of items listed in the flood insurance policy. Contact a local insurance agent for more information.

Four basement construction methods are described below in increasing order of flood risk.

Basement Foundation With Lowest Floor At or Above BFE

Placing the lowest floor of the basement at or above the BFE has the effect of eliminating flood-induced damage up to the BFE (see Figure 5). In general, the higher the basement floor is above the BFE the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, the basement should be built with its floor at or above the BFE. An added benefit is that floods that exceed the BFE will cause significantly less damage to a structure with this type of basement than to structures with basements whose floors are at greater depths.

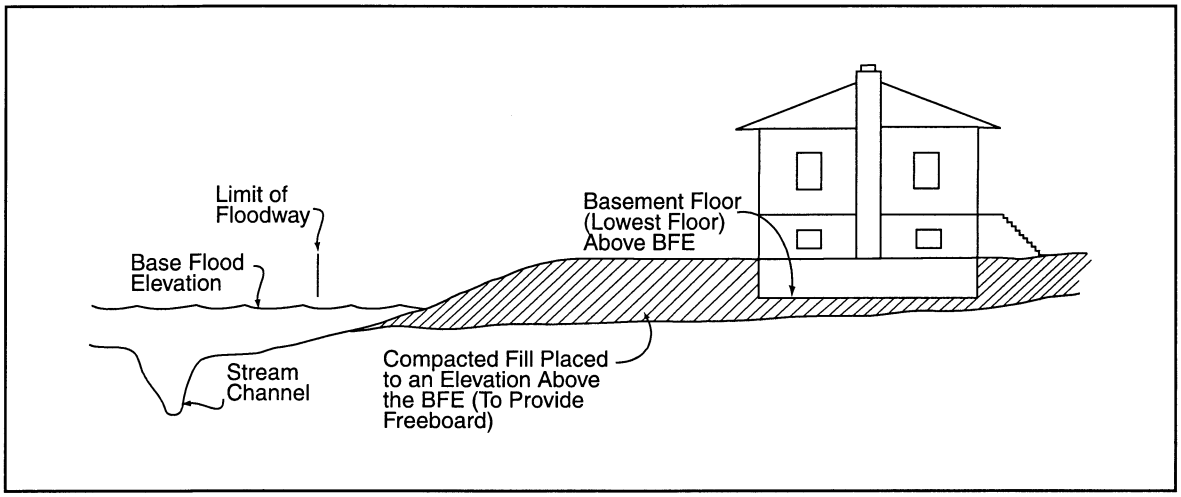


Figure 5 Basement foundation with lowest floor above the BFE. Damage from floods below the BFE is eliminated.

Basement Foundation in Fill Placed Above BFE

Placing fill to a level higher than the BFE has the effect of reducing the depth of the basement floor below the BFE (see Figure 6). It is recommended that fill be placed to a level at least 1 foot above the BFE. In general, the higher the basement floor the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, enough fill should be properly placed so that the lowest grade adjacent to the structure is raised to an elevation greater than the BFE. An added benefit of fill placed above the BFE is that it helps protect the building from floods greater than the Base Flood. These floods are less likely to reach the structure.

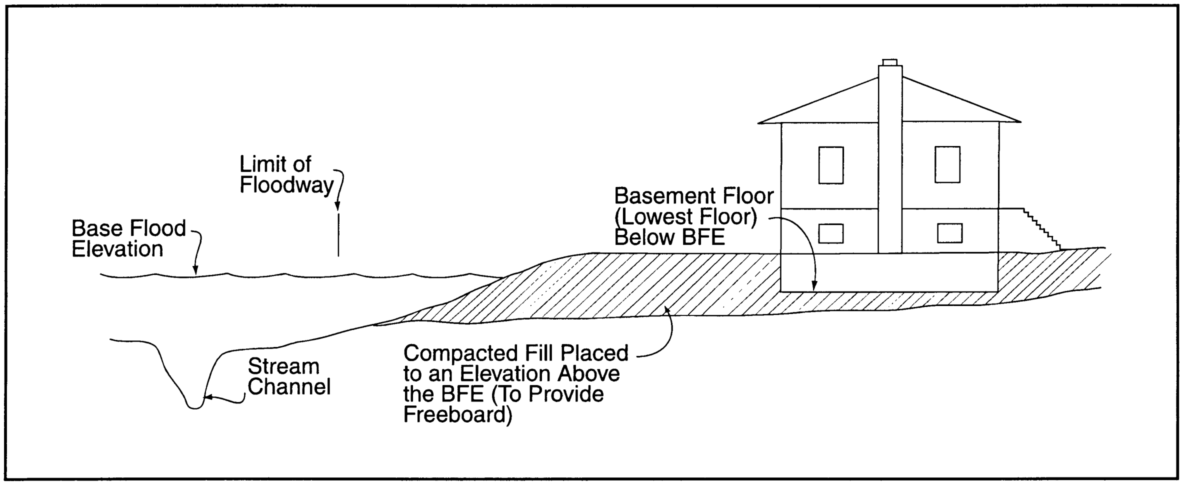


Figure 6 Basement foundation in fill placed above the BFE. The depth of the basement floor below the BFE is less than when no fill is placed.

Basement Foundation With Lowest Opening Above BFE

In the event that the lowest floor is not elevated to or above the BFE and fill is not placed to a level above the BFE, the next best method of reducing flood risk is to place the lowest opening into the basement (e.g., window well) at a level higher than the BFE (see Figure 7). This will reduce the chances that surface flooding will enter and inundate the basement. However, the basement walls and floor slab will still be subjected to hydrostatic pressure with the potential for damage and seepage into the basement. In addition, the above-grade basement walls will be exposed to water from floods greater than the Base Flood. For this reason, the lowest opening in the basement walls should be above the BFE, as shown in Figure 7.

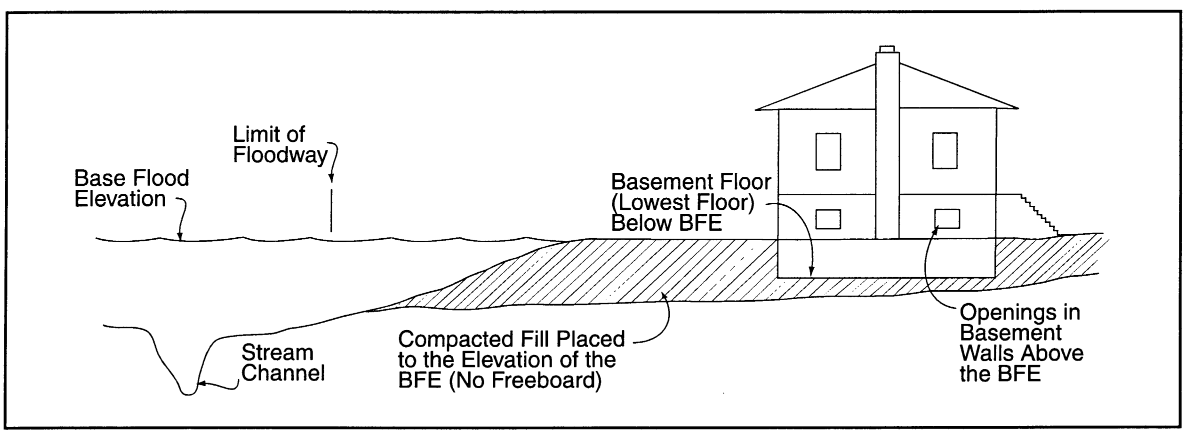


Figure 7 Basement foundation with lowest opening above the BFE. Surface flooding is less likely to enter and inundate the basement.

Basement Foundation With Lowest Opening at BFE

This is the least preferable condition of all because it results in the highest flood risk and is not recommended (see Figure 8). The lack of fill above the BFE, coupled with the lowest floor being below BFE and lowest opening at the BFE, exposes the basement to flooding from both subsurface flooding and any flood greater than the Base Flood.

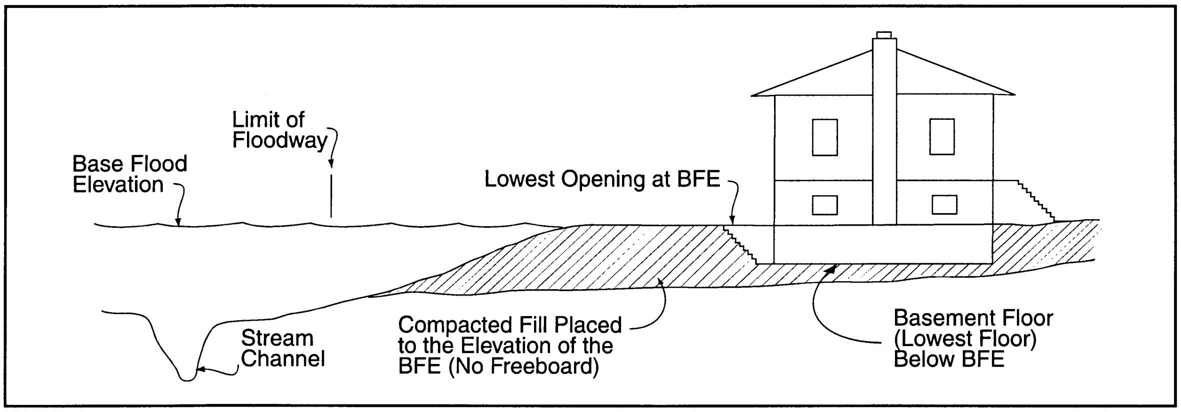


Figure 8 Basement foundation with lowest opening at the BFE. The basement is exposed to flooding from any flood greater than the Base Flood.

Flood Risk by Foundation Type

Table 1 summarizes the foundation construction methods described in this bulletin and ranks them in order of increasing flood risk—the safest foundation types appear near the top; the less safe foundation types appear near the bottom. The foundation construction methods that result in a building that is reasonably safe from flooding are shown in the dark gray area of the table. If the basement construction methods shown in the light gray area are used, the requirements described in the following sections of this bulletin must be met in order for the building to be considered reasonably safe from flooding.

Table 1 Flood Risk by Foundation Construction Method

Foundation Flood Risk

Flood Risk During the Base Flood	Fill		Foundation Construction Method										
			Stem Walls		Crawlspace		Slab-On-Grade		Basement				
									Floor Level			Openings	
	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Below BFE	Above BFE	At BFE
Increasing Level of Flood Risk ↓ (Reasonably Safe From Flooding)	■		■										
(Reasonably Safe From Flooding)	■				■								
(Reasonably Safe From Flooding)	■						■						
(Reasonably Safe From Flooding)		■		■									
(Reasonably Safe From Flooding)		■				■							
(Reasonably Safe From Flooding)		■						■					
(Reasonably Safe From Flooding)	■								■			■	
(Reasonably Safe From Flooding)	■									■		■	
(Follow Guidance)		■								■		■	
(Follow Guidance)		■								■			■
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(Follow Guidance)		■									■		■

[gray box] Reasonably Safe From Flooding

[white box] Follow Guidance in This Bulletin To Ensure That Building Is Reasonably Safe From Flooding

Basement Construction Guidance

For those who have chosen to accept the additional risk associated with basement construction below the Base Flood on filled land that has been removed from the SFHA, this bulletin provides technical guidance about measures that can be taken to protect basements and meet the requirement that buildings be made reasonably safe from flooding. A simplified approach, including the requirements that must be met for its use, is presented first. For buildings that do not meet the criteria for the simplified approach, this bulletin provides technical guidance for the development of an engineering design tailored to the site conditions.

Structural Design

Design of foundation elements is addressed in model building codes. This technical bulletin does not address the structural design of basement walls or foundations. Floors and slabs should be designed for the hydrostatic pressures that can occur from the Base Flood. For the structural design, it is recommended that the full hydrostatic pressures be assumed unrelieved by the drainage system. Foundation walls that have not been designed for hydrostatic pressures, such as unreinforced masonry or pressure-treated wood wall systems, should not be used (see Figure 9).

Figure 9 Failure of this unreinforced masonry basement during flooding in East Grand Forks, MN, in 1997 caused approximately $32,000 in damage.

Simplified Approach

Design Requirements

If, for a building and building site, **all** the requirements listed below are met (see Figure 10), the building is reasonably safe from flooding. If all of these requirements are not met, the more detailed analysis described under Engineered Basement Option, on page 19 of this bulletin, should be performed to determine whether the building is reasonably safe from flooding.

- ☐ The ground surface around the building and within a defined setback distance from the edge of the SFHA (see next item) must be at or above the BFE.
- ☐ The setback is the distance from the edge of the SFHA to the nearest wall of the basement. The minimum allowable setback distance is 20 feet.
- ☐ The ground around the building must be compacted fill; the fill material—or soil of similar classification and degree of permeability—must extend to at least 5 feet below the bottom of the basement floor slab.
- ☐ The fill material must be compacted to at least 95 percent of Standard Laboratory Maximum Dry Density (Standard Proctor), according to ASTM Standard D-698. Fill soils must be fine-grained soils of low permeability, such as those classified as CH, CL, SC, or ML according to ASTM Standard D-2487, *Classification of Soils for Engineering Purposes*. See Table 1804.2 in the 2000 *International Building Code* (IBC) for descriptions of these soil types.
- ☐ The fill material must be homogeneous and isotropic; that is, the soil must be all of one material, and the engineering properties must be the same in all directions.
- ☐ The elevation of the basement floor should be no more than 5 feet below the BFE.
- ☐ There must be a granular drainage layer beneath the floor slab, and a ¼-horsepower sump pump with a backup power supply must be provided to remove the seepage flow. The pump must be rated at four times the estimated seepage rate and must discharge above the BFE and away from the building. This arrangement is essential to prevent flooding of the basement or uplift of the floor under the effect of the seepage pressure.
- ☐ The drainage system must be equipped with a positive means of preventing backflow.
- ☐ Model building codes (such as the 2000 International Residential Code) also address foundation drainage (IRC Section R405) and foundation walls (IRC Section R404). Model building codes generally allow foundation drains to discharge through either mechanical means or gravity drains. In addition, there is often an exception to the requirement for drainage systems in well-drained soils. However, in or near floodplains, well-drained soils can, in fact, help convey groundwater towards the building foundation. Therefore, this exception should not apply in or near floodplains.

New Construction/Structure For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes all subsequent improvements to the structure. These structures are often referred to as "Post-FIRM" structures.

Special Flood Hazard Area (SFHA) Area delineated on a Flood Insurance Rate Map as being subject to inundation by the base flood and designated as Zone A, AE, A1-A30, AR, A0, AH, V, VE, or V1-V30.

Substantial Damage Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial Improvement Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.

Wet Floodproofing Permanent or contingent measures applied to a structure and/or it contents that prevent or provide resistance to damage from flooding by allowing water to enter the structure.

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☐ In some cases in or near floodplains, even with standard drainage systems, hydrostatic pressures from groundwater against the basement can result. When a standard drainage system is unable to eliminate hydrostatic pressure on the foundation, model building codes, including the 2000 International Residential Code (IRC Section R404.1.3), require that the foundation be designed in accordance with accepted engineering practice. **The simplified approach contained in this Technical Bulletin assumes no hydrostatic pressure on the foundation and should be used only when a standard drainage system, discharged by a sump pump that is equipped with backup power and that discharges above BFE, is employed.** For other drainage systems, the designer should use the engineered basement option presented on page 19 of this bulletin and other appropriate building code requirements.

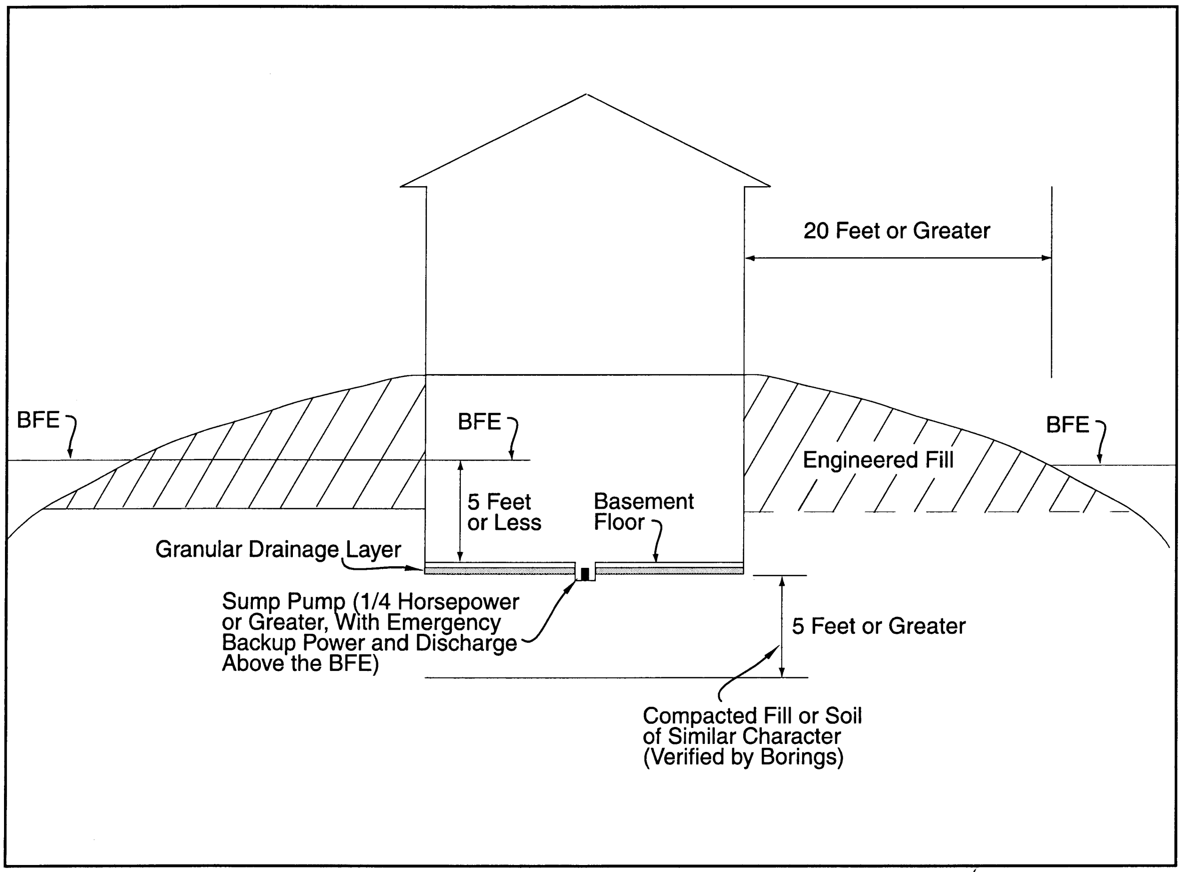


Figure 10 Requirements for use of the simplified approach to basement construction.

Technical Background for the Simplified Approach

The simplified approach is based on the following conditions:

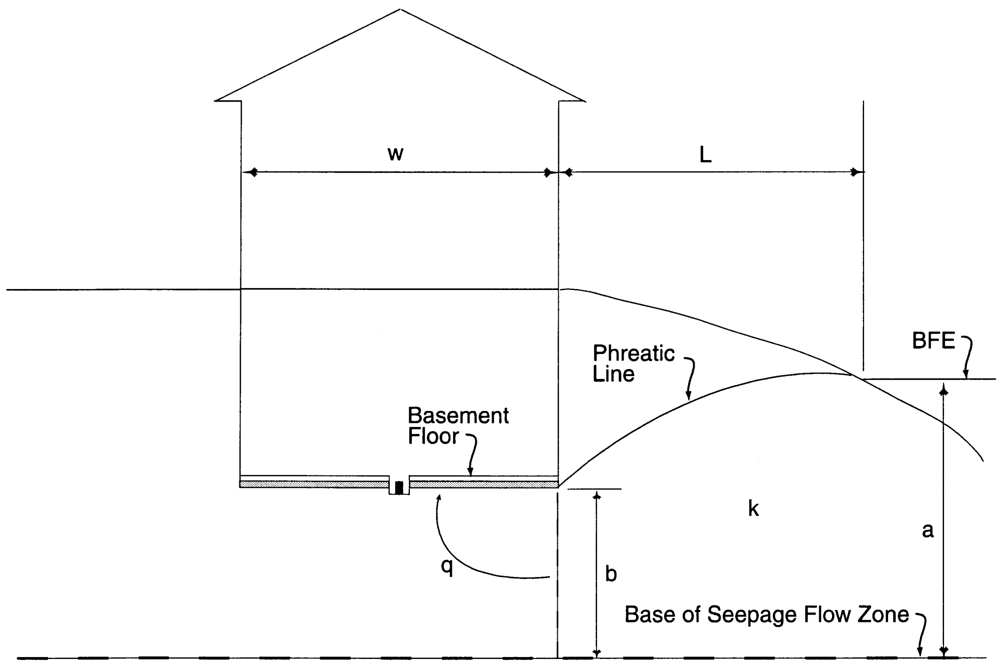
1. The area of the footprint of the basement is less than or equal to 1,200 square feet.

2. The soil is saturated; therefore, there is no time lag in the development of the seepage pattern with a change in flood water level. The groundwater table in floodplains is typically very shallow, and fine-grained soils have a substantial potential for maintaining saturation above the water table by capillary rise.

3. The tailwater level is at the elevation of the BFE. For this bulletin, "tailwater" is defined as the groundwater level beyond the structure, on the side away from the flood water surface. This is a reasonably conservative assumption because the flood would raise the groundwater level in the general area. In some cases, the tailwater level can be higher than the flood level because there is higher ground, as a valley wall, that feeds the groundwater into the floodplain soils.

4. The effective elevation of the base of the seepage flow zone can be defined (see Figure 11). This elevation is needed to permit calculation of the quantity of seepage flow. If the base elevation is not known, its depth below the base of the floor slab can be conservatively approximated as one-half of the building width most nearly perpendicular to the shoreline of the flood water. This would approximate the boundary effects of the three-dimensional seepage flow, in that it would represent the flow coming in from all sides and meeting in the center beneath the floor slab. This approach assumes a constant soil type and density over the flow zone. If the site has stratified soil layers, the engineered basement option should be used (see page 19 of this bulletin).

5. The quantity of seepage flow can be calculated by a simplified method based on Dupuit's assumption that equipotential lines are vertical. (The Dupuit method uses Darcy's law with specific physical characteristics. A more detailed description can be found in the first two references listed under "Further Information," on page 23 of this bulletin.) The elements of the method are presented in Figure 11. The entry surface, with hydraulic head "a," is a vertical line extending downward from the edge of the flood surface. The exit surface, with hydraulic head "b," is a vertical line extending downward from the side of the structure closest to the flood water's edge. The length of the flow path, "L," is the setback distance. Flow is assumed to be horizontal, and the horizontal coefficient of permeability is the effective permeability. For simplicity, the small inclined entry zone at the river bank and the exit zone below the basement floor are ignored. This is a reasonably conservative measure. The phreatic line, or the line below which the seepage flow occurs under positive pressure, extends from the edge of the flood water to the elevation of the bottom of the basement floor slab. If the exit zone below the basement floor were included, the hydraulic head at "b" would be higher. As shown in Figure 11, the phreatic line is not a straight line, but within the limits of the assumed boundary values, it is close to a straight line.



(1) $q = k(a^2 - b^2)/2L$

where: q = flow in cfs for a 1-foot width of seepage zone
k = soil permeability in feet per second
a = head at entry surface in feet
b = head at drain surface in feet
L = length of seepage zone (setback distance) in feet

(2) $Q = Pq$

where: Q = total seepage flow into drain in cfs
P = 2(basement length + width)
(for a square basement, P = 4w)

(3) Required sump pump capacity = 4Q for a safety factor of 4

Figure 11 Method for calculation of seepage flow.

The Dupuit equation for the quantity of seepage flow is:

$$q = k(a^2 - b^2)/2L$$

where: q is the flow in cubic feet per second for a 1-foot width of seepage zone

k is the soil permeability in feet per second (fps) (maximum value of k is 1×10^{-3} fps)

a and b are hydraulic heads in feet ($a < b + 5$)

L is the length of the flow zone in feet ($L > 20$ feet)

To obtain Q, the total seepage flow, in cubic feet per second, q must be multiplied by the length around the periphery of the four sides of the structure. This is a simplifying approach that obviates the need for a three-dimensional flow net calculation and is reasonably conservative.

It should be noted that the soil permeability does not affect the geometry of the seepage zone or the geometry of the phreatic line. The permeability does have a significant effect on the quantity of seepage that must be collected and discharged by the drainage layer and the sump pump. The calculation of the quantity Q provides a basis for the selection of a sump pump of adequate capacity. To allow for possible errors in the estimation of the soil permeability, the pump should have a capacity of at least four times the calculated value of Q. As noted in the requirements section, a standard sump pump of ¼ horsepower or greater will generally satisfy the requirements of seepage removal for the conditions described above.

Engineered Basement Option

If the requirements specified for the simplified approach are not met, a licensed soils engineer or geologist should perform a detailed engineering analysis to determine whether the structure will be reasonably safe from flooding. The analysis should consider, but is not limited to, the issues described in the following sections.

Depth, Soil Type, and Stratification of Subsurface Soils

The depth, soil type, and stratification of the subsurface soils may be complex. Four potential generalized scenarios are shown in Figures 12 and 13. Figure 12 shows two cases of homogeneous soil. The depth of penetration of the basement and the depth of the flow zone are not limited to the assumptions on which the simplified approach is based. Case I represents a foundation consisting of clayey soils, either fill or natural deposits or a combination, which are more or less homogeneous because they have similar engineering properties. If an adequate setback distance is provided, the seepage quantity would be relatively low, and uplift pressure beneath the slab could be controlled by an appropriately sized sump pump because of low permeability.

Case II represents a foundation consisting of sandy soils, either fill or natural soil deposits or a combination, which are more or less homogeneous because they have similar engineering properties. The seepage quantity would be fairly large, and more attention would have to be given to the setback distance and to the provision of an adequately sized sump pump to prevent excessive uplift pressure beneath the floor slab because of high permeability.

Figure 13 shows two simple cases of stratified soils, with impervious clays overlying pervious sands. This is a common occurrence in natural floodplain deposits. In Case III, the contact between the two soil strata is at some distance **below** the basement floor. This case would involve a moderate quantity of seepage, depending on the thickness, d, of the impervious stratum below the basement floor. There is also a potential for excessive uplift pressure beneath the floor, at the level of the bottom of the clay stratum. If d is equal to h, the net hydraulic head between the flood level and the floor level, the safety factor against uplift would be approximately 1.0. If d is less than h, there would be excessive uplift, with a safety factor equal to less than 1.0.

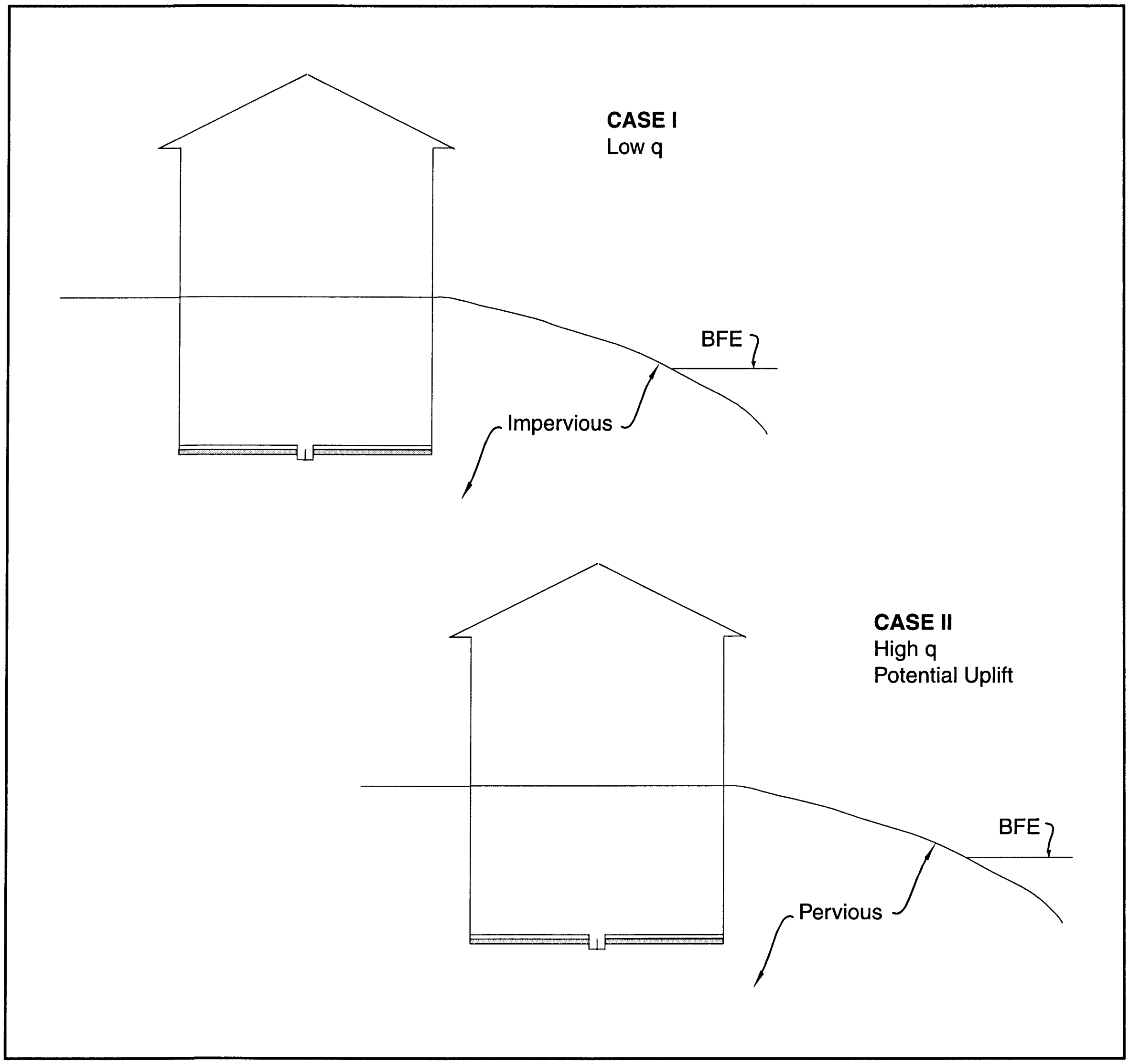


Figure 12 Case I and Case II – homogeneous soil.

Case IV shows impervious soils overlying pervious soils, with the contact between the soil strata at some distance **above** the basement floor. This case would involve a large quantity of seepage and potential for excessive uplift beneath the basement floor.

Geotechnical Investigations

Geotechnical investigations must be made for cases that do not conform with the assumptions on which the simplified approach is based. Information that is needed to permit an adequate engineering analysis includes the following:

- The BFE, which is to be used as the design flood water surface for calculating expected seepage.

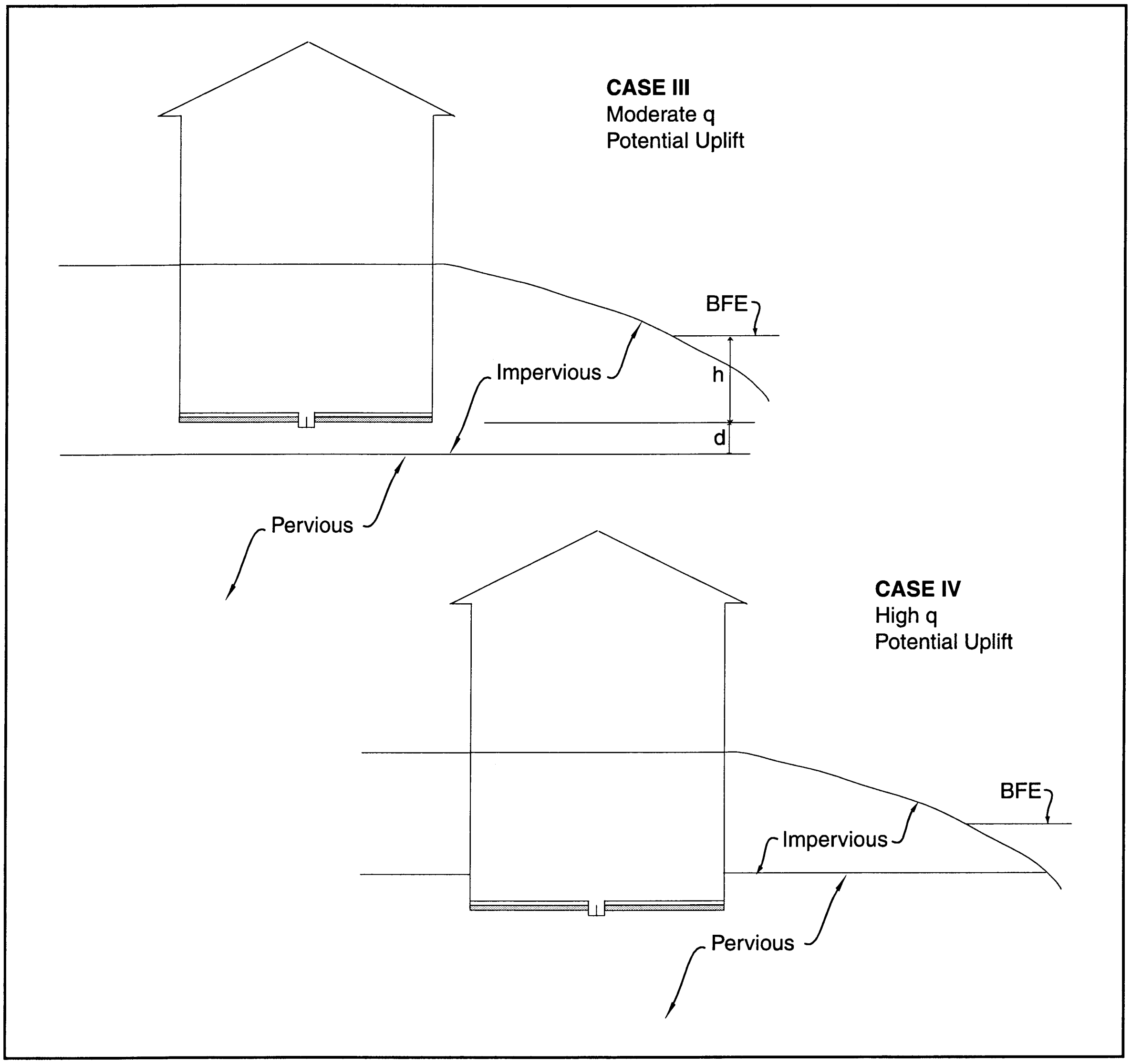


Figure 13 Case III and Case IV – stratified soils.

- The elevation of the **bottom** of the basement floor. This can be adjusted as needed to achieve more suitable conditions.
- The setback distance of the basement wall from the edge of the flood water. This can be adjusted to achieve more suitable seepage control or to accommodate available space restraints.
- The elevation of the groundwater table and its seasonal variations. A high water table would cause problems with groundwater control during construction of a basement, even without a flood event.
- The stratification of the subsurface materials, for both natural and fill soils. In general, borings should be drilled to a depth below the bottom of the floor slab that is at least two times as great as the depth of the bottom of the floor slab below the BFE.

- The engineering classification of the soils, for both natural and fill soils. This must be done in accordance with ASTM D2487, *Classification of Soils for Engineering Purposes*. This is the Unified Soil Classification System that is universally used throughout the United States. Local or county agricultural soil survey maps should not be used, because they do not give specific information about location and depth of soils, and their designations are not pertinent to civil engineering use.
- Subsurface conditions landward from the structure. This includes information about the location of the water table, whether it is higher or lower than the flood level, and information about any penetrations of the soil, such as ponds. Attention should be given to the possibility that higher ground, such as valley walls, could contribute to the groundwater level in the floodplain, either perennially or during periods of heavy rain.
- Information about any penetrations through the basement walls below the BFE, such as utility lines and other openings.
- Analysis of seepage quantity. The analysis can be made by the conservative simplified method described in Item 5 in the section titled Technical Background for the Simplified Approach (illustrated in Figure 11), or by the construction of a flow net that takes into account all of the boundary conditions more rigorously. A flow net may be required to permit analysis of uplift pressures. Uplift pressures may be more significant in laminated or stratified soil deposits.

Buildings in Existing Filled Areas

In evaluating buildings in existing filled areas, the two approaches already described—the simplified approach or the engineered basement option—can be used. If the simplified approach is used, all the requirements for the use of this approach must be met. Some possible means for evaluating whether these requirements are met include soil tests and investigations, including soil borings and hand augers; field records from the time the fill was placed; and soil surveys. If the requirements for the simplified approach are not met, a licensed soils engineer or geologist should perform a more detailed engineering analysis as described under Engineered Basement Option on page 19. More extensive soil investigations and testing may be required to complete the analysis.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood coverage was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the Federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community, provided the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria set forth in Part 60 of the NFIP Floodplain Management Regulations (44 CFR 60). Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management

ordinances or laws, communities adopt the NFIP performance standards for new, substantially improved, and substantially damaged buildings in floodprone areas identified on FEMA's FIRMs.

Technical Bulletins

This publication is one of a series of Technical Bulletins that FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in 44 CFR 60.3. The bulletins are intended for use primarily by state and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for conforming with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office or the local floodplain administrator. NFIP Technical Bulletin 0, the *User's Guide to Technical Bulletins,* lists the bulletins issued to date, provides a key word/subject index for the entire series, and lists addresses and telephone numbers for FEMA's 10 Regional Offices.

Ordering Information

Copies of FEMA Technical Bulletins can be obtained from the FEMA Regional Office that serves your area. In addition, Technical Bulletins and other FEMA publications can be ordered from the FEMA Publications Distribution Facility at 1-800-480-2520. The Technical Bulletins are also available at the FEMA web site at www.fema.gov.

Further Information

The following publications contain information related to the guidance presented in this bulletin:

American Society of Civil Engineers. 1998. SEI/ASCE 24-98, *Flood Resistant Design and Construction.*

Cedergren, H. R. 1977. *Seepage, Drainage and Flow Nets*. Wiley. New York.

Harr, M. E. 1977. *Mechanics of Particulate Media*. McGraw Hill. New York.

International Code Council. 2000. *International Building Code*. Birmingham, AL.

International Code Council. 2000. *International Residential Code*. Birmingham, AL.

U.S. Department of the Army, Corps of Engineers. 1986. EM 1110-2-1901, *Seepage Analysis and Control for Dams*. Washington, DC.

U.S. Department of the Army, Corps of Engineers. 1978. EM 1110-2-1913, *Design and Construction of Levees*. Washington, DC.

Glossary

Base Flood – The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Basement – Any area of a building having its floor subgrade (below ground level) on all sides.

Community – Any state or area or political subdivision thereof, or any Indian tribe or authorized tribal organization, or Alaska Native village or authorized native organization, which has the authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction.

Federal Emergency Management Agency (FEMA) – The independent Federal agency that, in addition to carrying out other activities, administers the NFIP.

Federal Insurance Administration (FIA) – The component of FEMA directly responsible for administering the flood insurance aspects of the NFIP.

Flood Insurance Rate Map (FIRM) – The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analysis, areas of 100-year flood hazard in a community.

Floodprone area – Any land area susceptible to being inundated by flood water from any source.

Mitigation Directorate – The component of FEMA directly responsible for administering the flood hazard identification and floodplain management aspects of the NFIP.

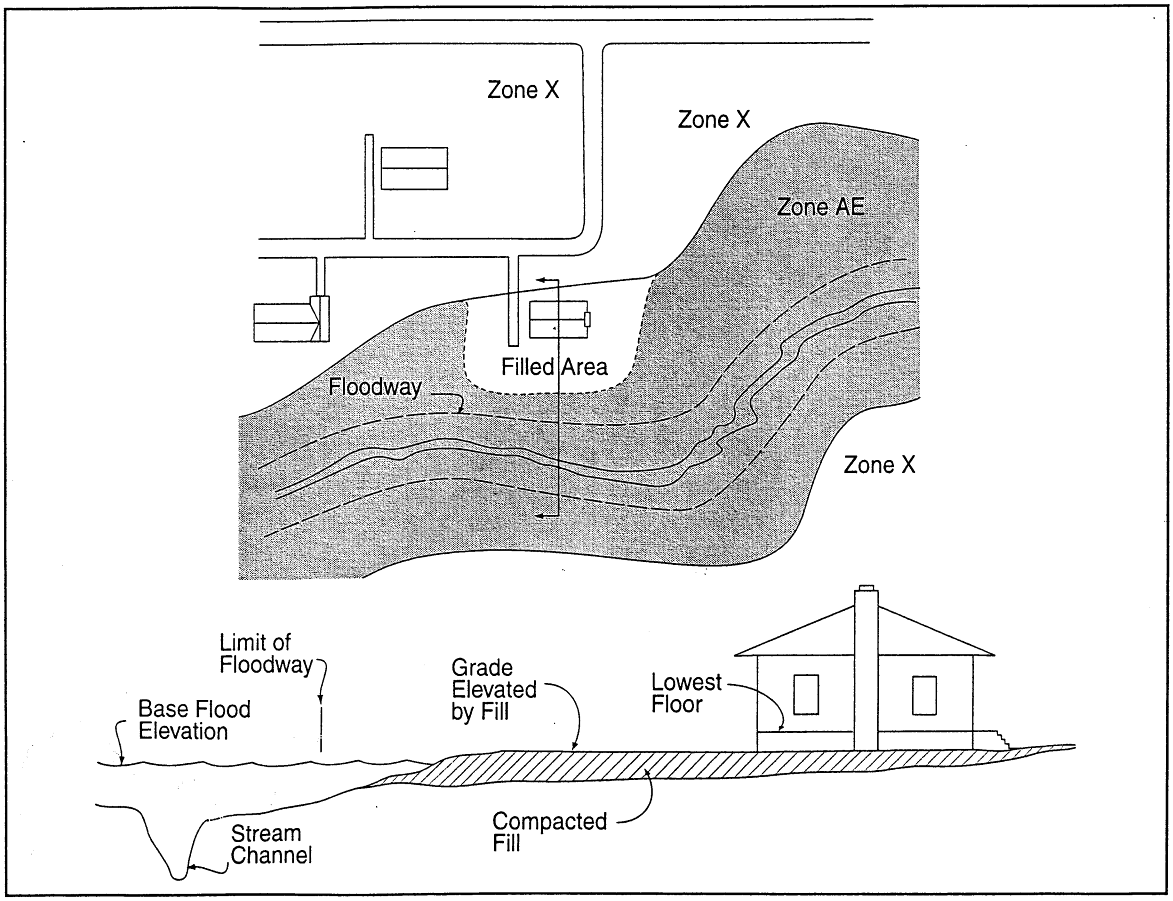
New construction/structure – For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes subsequent improvements to the structure. For flood insurance purposes, these structures are often referred to as "post-FIRM" structures.

Special Flood Hazard Area (SFHA) – Area subject to inundation by the base flood, designated Zone A, A1-30, AE, AH, AO, V, V1-V30, or VE.

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

FIA-TB-10
(5/01)

Key Word/Subject Index

This index allows the user to locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

Federal Emergency Management Agency
Mitigation Directorate
Program Policy and Assessment Branch
500 C Street, SW.
Washington, DC 20472

Wave design on cover based on the Japanese print *The Great Wave Off Kanagawa*, by Katsuchika Hokussai (1760–1849), Asiatic Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 10-01

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding in accordance with the National Flood Insurance Program

Introduction

For the purpose of administering the National Flood Insurance Program (NFIP), FEMA identifies and maps flood hazard areas nationwide by conducting flood hazard studies and publishing Flood Insurance Rate Maps (FIRMs). These flood hazard areas, referred to as Special Flood Hazard Areas (SFHAs), are based on a flood having a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood or Base Flood).

Structures within the SFHA in a community participating in the NFIP are subject to floodplain management regulations that impact building standards and are designed to minimize flood risk. For example, Title 44, Part 60, Section 3(c)(2) of the Code of Federal Regulations—abbreviated as 44 CFR 60.3(c)(2)—requires that the lowest floor of a residential structure, including basement, built within the SFHA be at or above the Base Flood Elevation (BFE). In addition, flood insurance must be purchased for these structures if they are used as collateral to secure a loan provided by a federally regulated lender. Flood insurance coverage may be purchased for all eligible structures within a participating community. Insurance rates for structures located within the SFHA differ from the rates for structures located outside the SFHA.

When permitted under applicable Federal, state, and local laws, ordinances, and regulations, earthen fill is sometimes placed in an SFHA to reduce flood risk to the filled area. Under certain conditions, when engineered earthen fill is placed within an SFHA to raise the surface of the ground to or above the BFE, a request may be submitted to FEMA to revise the FIRM to indicate that the filled land is outside of the SFHA. When such revisions are warranted, FEMA usually revises the FIRM by issuing a Letter of Map Revision based on fill (LOMR-F). After FEMA has revised the FIRM to show that the filled land is outside the SFHA, the community is no longer required to apply the minimum NFIP floodplain management standards to any structures built on the land and the mandatory flood insurance purchase requirements no longer apply. It is worth noting that states and local communities may have floodplain regulations that are more restrictive than the minimum requirements of the NFIP and may continue to enforce some or all of their floodplain management requirements in areas outside the SFHA.

Although a structure built on a site that has been elevated by the placement of fill may be removed by FEMA from the SFHA, the structure may still be subject to damage during the Base Flood and higher-magnitude floods. Constructing the entire structure at or above the level of the BFE will minimize the flood risk from the Base Flood and is therefore the most prudent approach to constructing on fill. Conversely, a structure with a basement (subgrade area) adjacent to or near the floodplain may well be impacted by subsurface flooding brought on by surface flooding.

This bulletin provides guidance on the construction of buildings on land elevated above the BFE through the placement of fill. Several methods of construction are discussed, and the most prudent—those that result in the entire building being above the BFE—are recommended.

In some areas of the country, basements are a standard construction feature. Individuals may wish to construct basements on land after it has been removed from the floodplain by a FEMA revision. Buildings with basements built in filled areas are at an added risk of flooding when compared to buildings on other types of foundations. However, there are two major ways to minimize this additional risk from subsurface flooding. First, the building should be located farther back from the edge of the fill closest to the flooding source. Second, the higher the basement floor is elevated, the less the risk. This technical bulletin provides guidance on how to determine that these buildings will be reasonably safe from flooding during the occurrence of the Base Flood and larger floods. To be reasonably safe from flooding during the Base Flood condition, the basement must (1) be dry, not have any water in it, and (2) be structurally sound, not have loads that either exceed the structural capacity of walls or floors or cause unacceptable deflections. In practice, this means that soils around the basement must have low permeability to minimize or stop water infiltration to the basement wall and floors. Any water that does permeate to the basement must be removed by a drainage layer on the outside (soil side) of the basement. In addition, the foundation walls and floor slab must be designed and constructed for any increased loads that may occur during the Base Flood condition.

NFIP Regulations

Part of a community's application to participate in the NFIP must include "a commitment to recognize and duly evaluate flood hazards in all official actions in the areas having special flood hazards and to take other such official actions reasonably necessary to carry out the objectives of the program" [44 CFR 59.22 (a)(8)].

NFIP regulations at 44 CFR 60 include Subpart A: Requirements for Flood Plain Management Regulations. Each community participating in the NFIP adopts a floodplain management ordinance that meets or exceeds the minimum requirements listed in 44 CFR 60. Subpart A establishes specific criteria for determining the adequacy of a community's floodplain management regulations. The overriding purpose of the floodplain management regulations is to ensure that participating communities take into account flood hazards, to the extent that they are known, in all official actions relating to land management and use.

One of the minimum requirements established by the regulations is set forth at 44 CFR 60.3 (a)(3), which states that, for all proposed construction or other development within a participating community, the community must "Review all permit applications to determine whether the proposed building sites will be reasonably safe from flooding." 44 CFR 59.1 defines "development" as

> *"...any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operation or storage of equipment or materials,"*

Warning

Construction of a residential building in an identified SFHA with a lowest floor below the BFE is a violation of the floodplain management requirements set forth at 44 CFR 60.3(c)(2), unless the community has obtained an exception to NFIP requirements from FEMA and has approved procedures in place.

By issuance of this Technical Bulletin, FEMA is noting that residual flood hazards may exist in areas elevated above the BFE by the placement of engineered earthen fill. Residual risks in these areas include subsurface flood conditions and flooding from events that exceed the base flood. This bulletin is intended to guide local floodplain management officials in determining whether structures placed in filled areas are reasonably safe from flooding. FEMA will require that the jurisdiction having authority for floodplain management determine that an area is reasonably safe from flooding before removing it from the SFHA.

Floodways, V Zones, and Alluvial Fan Flood Hazard Areas

This bulletin does **not** apply to the following:

- Construction in the floodway. The NFIP prohibits encroachments into the floodway that would cause increases in flood stage.
- Construction in SFHAs designated Zone V, VE, or V1-V30 on FIRMs. The NFIP prohibits the use of structural fill for support of buildings in V zones. Buildings constructed in a V zone must be constructed on an open foundation consisting of piles, piers, or posts and must be elevated so that the bottom of the lowest horizontal structural member is at or above the BFE. In addition, this bulletin strongly recommends that structural fill **not** be used to elevate buildings constructed in A zones in coastal areas. Detailed guidance concerning proper construction methods for buildings in coastal areas is presented in FEMA's *Coastal Construction Manual* (FEMA 55) and in NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements.*
- Construction in SFHAs subject to alluvial fan flooding (designated Zone A0 with depths and velocities shown on FIRMs). The NFIP will not remove land from the floodplain based on the placement of fill in alluvial fan flood hazard areas.

More Restrictive State and Local Requirements

NFIP Technical Bulletins provide guidance on the **minimum** requirements of the NFIP regulations. State or local requirements that exceed those of the NFIP take precedence. Design professionals should contact community officials to determine whether more restrictive state or local regulations apply to the building or site in question. All applicable standards of the state or local building code must be met for any building in a flood hazard area.

Notes for Local Officials

Professional Certification

As required by state and local floodplain management ordinances, a proposed development must be determined to be reasonably safe from flooding. The official having the authority to make this determination should require all appropriate information for making the determination. This may include a certification by a qualified design professional that indicates the land or structures to be removed from the SFHA are reasonably safe from flooding, according to the criteria described in this technical bulletin. Such a professional certification may come from a professional engineer, professional geologist, professional soil scientist, or other design professional qualified to make such evaluations. A sample of such a certification is shown in Figure 1.

Project Name and Address

I, ______________________________ certify that the design for the aforementioned development is reasonably safe from flooding in accordance with the guidance provided within FEMA's Technical Bulletin 10-01 related to ensuring that structures are reasonably safe from flooding and in accordance with accepted professional practices.

______________________________ ______________
Signature Date

____
Title

______________________________ ______________________________
Type of License License Number

Address and Phone

Professional Seal

____
License Expiration Date

Figure 1 Sample of professional certification form.

Administrative Options for Community Permitting

Communities may choose a variety of administrative procedures to assist them in gathering information that can be used to determine whether a proposed development is reasonably safe from flooding. Communities are encouraged to establish procedures that alert them to potential future development of a filled area. These procedures should allow for the evaluation of future development and a means to determine whether it will be reasonably safe from flooding. The following are examples of such procedures:

- Require building sites to be identified on final subdivision plats and evaluate those building sites against the standards described in this Technical Bulletin.
- Require grading plans as a condition of issuing fill permits and require that those grading plans include building sites, and evaluate those building sites based on this Technical Bulletin.
- Require buffer zones or setback zones around the perimeter of fill pads or at the edge of the flood-plain and establish construction requirements within these buffer zones to ensure that buildings are safe from residual risk.
- Require as a condition of final subdivision plat approval that the developer agree that no basements will be built in any flood areas.
- Adopt or have regulations that control development of areas immediately adjacent to floodplains that would ensure that any construction is reasonably safe from flooding. For example, under the Minnesota State Building Code, communities designate areas outside of the floodplain as "Secondary Flood Hazard Areas" where building officials evaluate plans for basements and can require modifications to the basement if an official believes there is a residual risk.
- When issuing a permit for the placement of fill only in the SFHA, stipulate that no buildings will be built on the site without a subsequent building permit.

Placement of Fill

Properly placing fill requires an understanding of soil mechanics, local site conditions, the specific characteristics of the soils being placed, the methods used to place and compact the fill, and soil testing procedures. Standard engineering and soil mechanics texts cover these subjects in detail. The performance of these filled areas should consider, but is not limited to, the following:

- the consolidation of the fill layers and any underlying layers
- the effect of this consolidation on either excessive settlement or differential settlement
- how the permeability of the soils affects water infiltration on any structures built on the site

Loss of Storage and Conveyance

The placement of fill in the SFHA can result in an increase in the BFE by reducing the ability to convey and store flood waters. This can result in increased flood damage to both upstream and downstream properties. To prevent these possible results, some communities prohibit fill, require compensatory storage for filled areas, and/or identify a more restrictive floodway.

Risk of Flood Damage in Areas Adjacent to the SFHA

Areas adjacent to the SFHA may have residual risks of flood damage similar to those in areas removed from the SFHA through the placement of fill. Both areas are subject to residual risk from subsurface water related to flooding and from floods greater than the Base Flood. Methods of construction discussed in this bulletin should also be used in these areas.

Building on Land Removed From the SFHA by the Placement of Fill

The safest methods of constructing a building on filled land removed from the SFHA are those that result in the entire structure being above the BFE. Methods that place the lowest floor of the building at, rather than above, the BFE are at greater flood risk, and methods that result in the lowest floor (including a basement floor) below the BFE have the highest flood risk of all. Placement of the lowest floor of these structures below the BFE, even through they are outside the SFHA, will result in an increased threat from subsurface flooding and magnified damages from flooding that exceeds the BFE.

Freeboard

Freeboard is an additional height used as a factor of safety in determining the elevation of a structure, or floodproofing, to compensate for factors that may increase the flood height (ASCE 24-98, *Flood Resistant Design and Construction*). When fill is used to protect buildings from the Base Flood, the community should consider whether freeboard should be required. This consideration should include whether better information exists or conditions have changed (from when the BFE was originally established) that indicate that the BFE may be higher than originally expected. One example of when the BFE may be higher is when a culvert or bridge is blocked by debris. Flood modeling assumes an open channel or culvert. Even when the BFE is not expected to be higher, freeboard may be appropriate to provide increased protection from flood events less frequent than the Base Flood or to account for future changes that may increase the BFE.

The foundation types for buildings outside the SFHA described in the following sections are listed in order of their increasing risk of flood damage.

Non-Basement Foundations

Non-basement foundations consist primarily of stem wall, crawlspace, and slab-on-grade foundations.

Stem Wall Foundation

A stem wall foundation can be used to raise the lowest floor above the surrounding grade. After the stem walls have been constructed and extended to the desired elevation, the area enclosed by the stem walls is filled with engineered compacted fill and a slab is poured on top (see Figure 2). Through the placement of additional fill, the site may be elevated above the BFE. This approach provides freeboard—an additional amount of elevation that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a stem wall foundation and placing this additional fill on the site provide the highest level of flood protection.

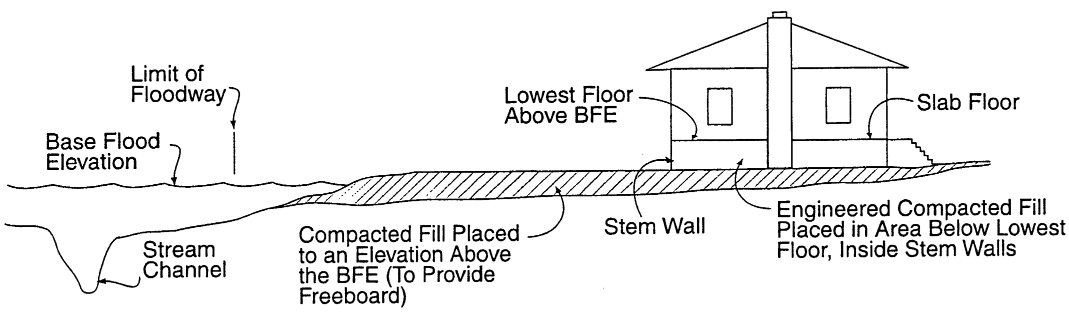


Figure 2 Structure on a stem wall foundation. The lowest floor is raised above the BFE. The space enclosed by the stem walls is filled with engineered compacted fill.

Crawlspace Foundation

Constructing a crawlspace beneath the first floor will raise the lowest floor of the structure above the surrounding grade (see Figure 3). Openings in the foundation walls are recommended. If flooding reaches the building, the openings allow flood waters to enter the area below the lowest floor and equalize the hydrostatic pressure on the foundation walls (see NFIP Technical Bulletin 1, *Openings In Foundation Walls*).

The crawlspace alternative is less preferable than stem wall construction, which does not result in an enclosed area under the first floor and therefore requires no flood openings. Placing additional fill to a level above the BFE provides freeboard that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a crawlspace foundation and placing additional fill on the site provide increased flood protection.

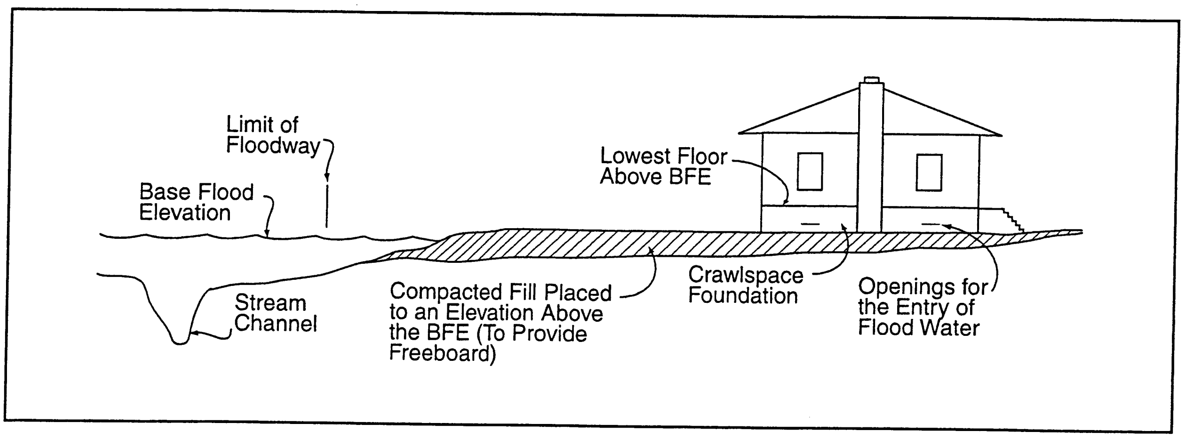


Figure 3 Structure on a crawlspace foundation. The lowest floor is raised above the BFE. Openings in the foundation walls allow water from floods higher than the fill elevation to enter the crawlspace and equalize the pressure on foundation walls.

Slab-On-Grade Foundation

This method normally provides less flood protection than crawlspace construction because it does not elevate the house above the adjacent grade (see Figure 4). As a result, the lowest floor of the house can be as low as the BFE and would be inundated by any flood greater than the BFE. Placing additional engineered fill beneath the building to a level above the BFE would provide freeboard and therefore increased flood protection.

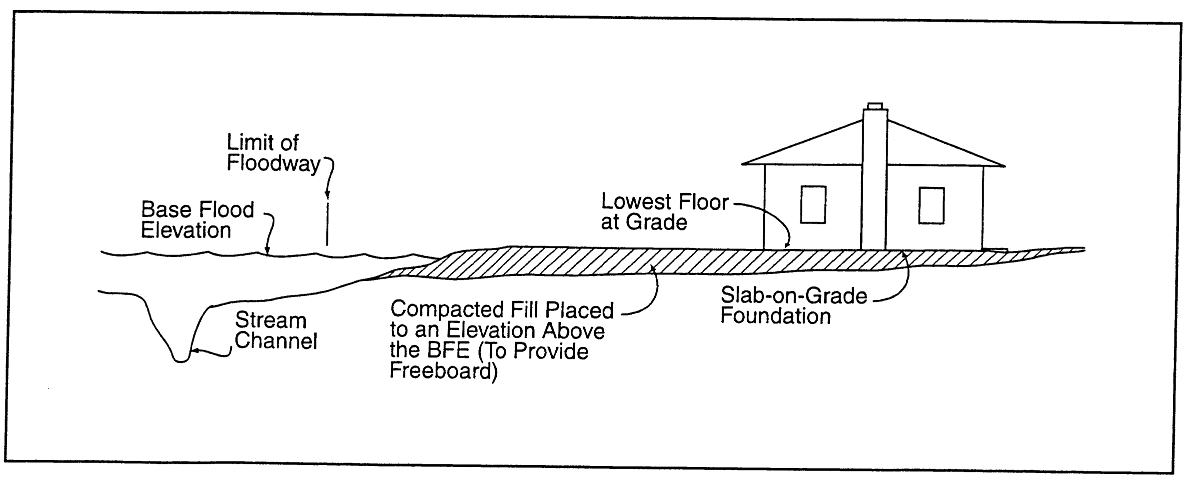


Figure 4 Structure on a slab-on-grade foundation. The lowest floor is typically slightly higher than the surrounding grade.

Basement Foundations

Although basements are a desired feature in some areas of the United States, NFIP minimum requirements generally do not allow their construction in the SFHA, because of the increased risk of flood damages. The only instances where this is not the case are buildings for which FEMA has granted a special exemption to allow floodproofed basements. However, once land is removed from the SFHA through a map revision, these NFIP minimum requirements no longer apply. As a result, builders and property owners who build on land removed from the SFHA sometimes elect to install basements, which are at a higher risk of flood damage than the foundation types described previously.

Constructing a basement on such land is **not** recommended, because the basement (i.e., lowest) floor and portions of the basement walls may well be subjected to subsurface flooding. The basement may therefore be subject to seepage and lateral hydrostatic and uplift pressure caused by high groundwater levels associated with flooding in surrounding areas. Additionally, when flooding exceeds the BFE, the basement area may be totally inundated with floodwater. When builders and homeowners decide to accept the additional risk associated with basement construction on filled land, they need to ensure that the basement and the rest of the house are reasonably safe from flooding.

Warning

In filled areas adjacent to floodplains, floods can still greatly influence the groundwater at the filled site. High groundwater at a site with a basement can result in water infiltrating the basement or greatly increased hydrostatic pressures on the walls and basement slab that can cause failure or permanent deformation. Even when floods have not reached houses with basements, FEMA has seen numerous examples of flooded basements, bowed basement floors, and collapsed basement walls that have resulted from the effects of high groundwater caused by flooding. In addition, the collapse of flooded basements has also occurred when water is rapidly pumped from basements surrounded by saturated soils whose pressure exceeds the capacity of the basement walls.

Flood Insurance Coverage for Basements

It is extremely important to note that the NFIP offers only limited coverage for basement flooding. First, in order for a claim to be paid, there must be a general condition of overland flooding where floodwaters come in contact with the structure. Secondly, the NFIP does not provide coverage for finished nonstructural elements such as paneling and linoleum in basement areas. Contents coverage is restricted to a limited number of items listed in the flood insurance policy. Contact a local insurance agent for more information.

Four basement construction methods are described below in increasing order of flood risk.

Basement Foundation With Lowest Floor At or Above BFE

Placing the lowest floor of the basement at or above the BFE has the effect of eliminating flood-induced damage up to the BFE (see Figure 5). In general, the higher the basement floor is above the BFE the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, the basement should be built with its floor at or above the BFE. An added benefit is that floods that exceed the BFE will cause significantly less damage to a structure with this type of basement than to structures with basements whose floors are at greater depths.

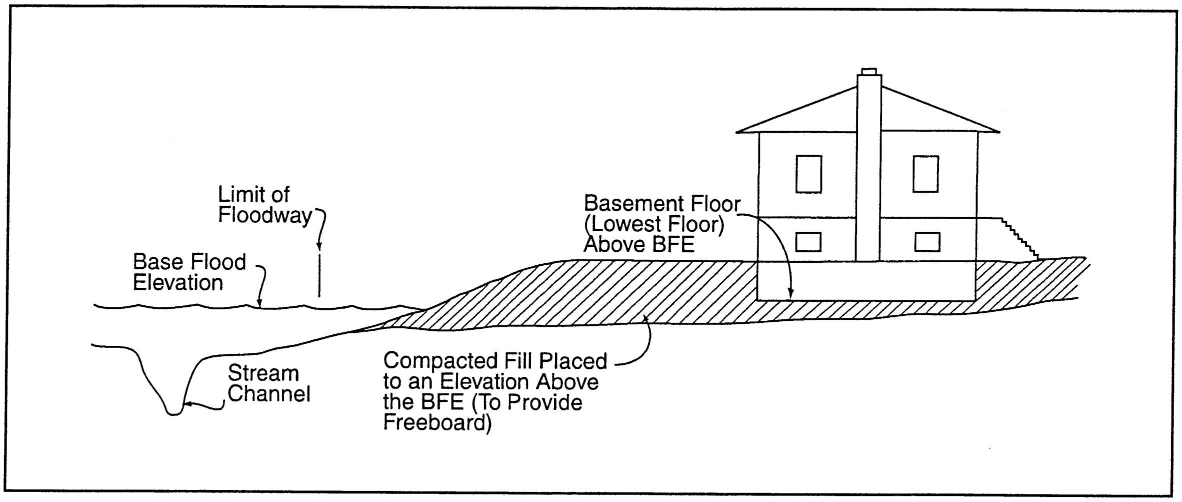


Figure 5 Basement foundation with lowest floor above the BFE. Damage from floods below the BFE is eliminated.

Basement Foundation in Fill Placed Above BFE

Placing fill to a level higher than the BFE has the effect of reducing the depth of the basement floor below the BFE (see Figure 6). It is recommended that fill be placed to a level at least 1 foot above the BFE. In general, the higher the basement floor the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, enough fill should be properly placed so that the lowest grade adjacent to the structure is raised to an elevation greater than the BFE. An added benefit of fill placed above the BFE is that it helps protect the building from floods greater than the Base Flood. These floods are less likely to reach the structure.

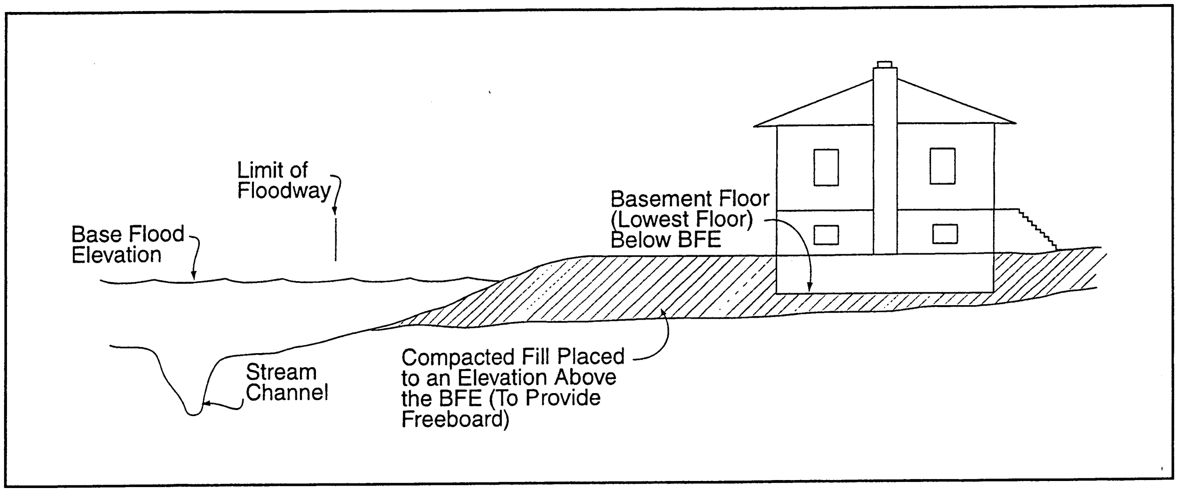


Figure 6 Basement foundation in fill placed above the BFE. The depth of the basement floor below the BFE is less than when no fill is placed.

Basement Foundation With Lowest Opening Above BFE

In the event that the lowest floor is not elevated to or above the BFE and fill is not placed to a level above the BFE, the next best method of reducing flood risk is to place the lowest opening into the basement (e.g., window well) at a level higher than the BFE (see Figure 7). This will reduce the chances that surface flooding will enter and inundate the basement. However, the basement walls and floor slab will still be subjected to hydrostatic pressure with the potential for damage and seepage into the basement. In addition, the above-grade basement walls will be exposed to water from floods greater than the Base Flood. For this reason, the lowest opening in the basement walls should be above the BFE, as shown in Figure 7.

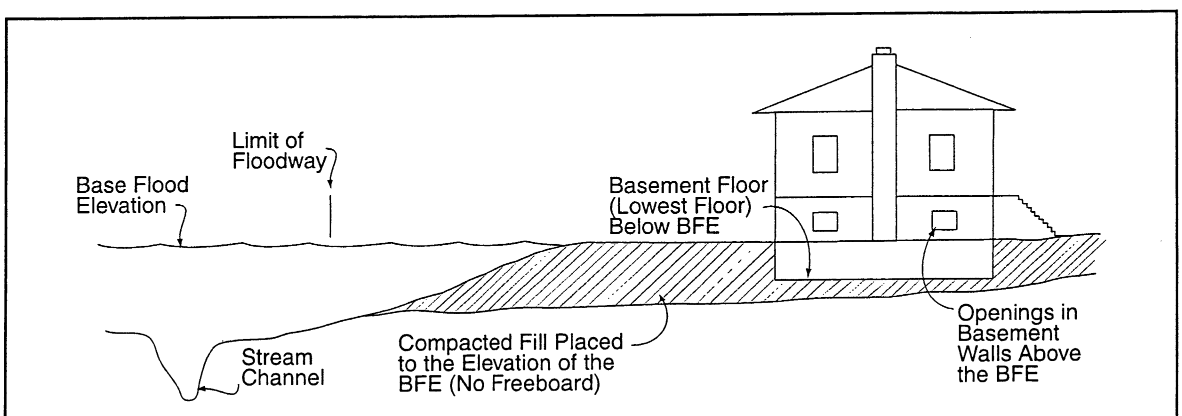


Figure 7 Basement foundation with lowest opening above the BFE. Surface flooding is less likely to enter and inundate the basement.

Basement Foundation With Lowest Opening at BFE

This is the least preferable condition of all because it results in the highest flood risk and is not recommended (see Figure 8). The lack of fill above the BFE, coupled with the lowest floor being below BFE and lowest opening at the BFE, exposes the basement to flooding from both subsurface flooding and any flood greater than the Base Flood.

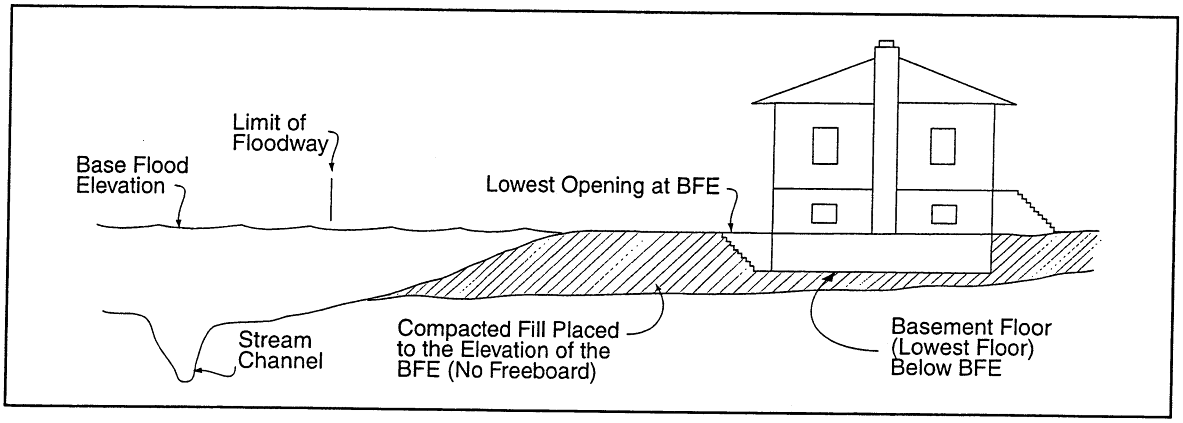


Figure 8 Basement foundation with lowest opening at the BFE. The basement is exposed to flooding from any flood greater than the Base Flood.

Flood Risk by Foundation Type

Table 1 summarizes the foundation construction methods described in this bulletin and ranks them in order of increasing flood risk—the safest foundation types appear near the top; the less safe foundation types appear near the bottom. The foundation construction methods that result in a building that is reasonably safe from flooding are shown in the dark gray area of the table. If the basement construction methods shown in the light gray area are used, the requirements described in the following sections of this bulletin must be met in order for the building to be considered reasonably safe from flooding.

Table 1 Flood Risk by Foundation Construction Method

Foundation Flood Risk														
Flood Risk During the Base Flood	Fill		Foundation Construction Method											
			Stem Walls		Crawlspace		Slab-On-Grade		Basement					
									Floor Level			Openings		
	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Above BFE	At BFE	Below BFE	Above BFE	At BFE
Increasing Level of Flood Risk ↓	■		■										
	■				■								
	■						■						
		■		■									
		■				■							
		■						■					
	■								■			■	
	■									■		■	
		■								■		■	
		■								■			■
	■										■	■	
		■									■	■	
		■									■		■

Reasonably Safe From Flooding (dark gray area: first 8 rows)

Follow Guidance in This Bulletin To Ensure That Building Is Reasonably Safe From Flooding (light gray area: last 5 rows)

Basement Construction Guidance

For those who have chosen to accept the additional risk associated with basement construction below the Base Flood on filled land that has been removed from the SFHA, this bulletin provides technical guidance about measures that can be taken to protect basements and meet the requirement that buildings be made reasonably safe from flooding. A simplified approach, including the requirements that must be met for its use, is presented first. For buildings that do not meet the criteria for the simplified approach, this bulletin provides technical guidance for the development of an engineering design tailored to the site conditions.

Structural Design

Design of foundation elements is addressed in model building codes. This technical bulletin does not address the structural design of basement walls or foundations. Floors and slabs should be designed for the hydrostatic pressures that can occur from the Base Flood. For the structural design, it is recommended that the full hydrostatic pressures be assumed unrelieved by the drainage system. Foundation walls that have not been designed for hydrostatic pressures, such as unreinforced masonry or pressure-treated wood wall systems, should not be used (see Figure 9).

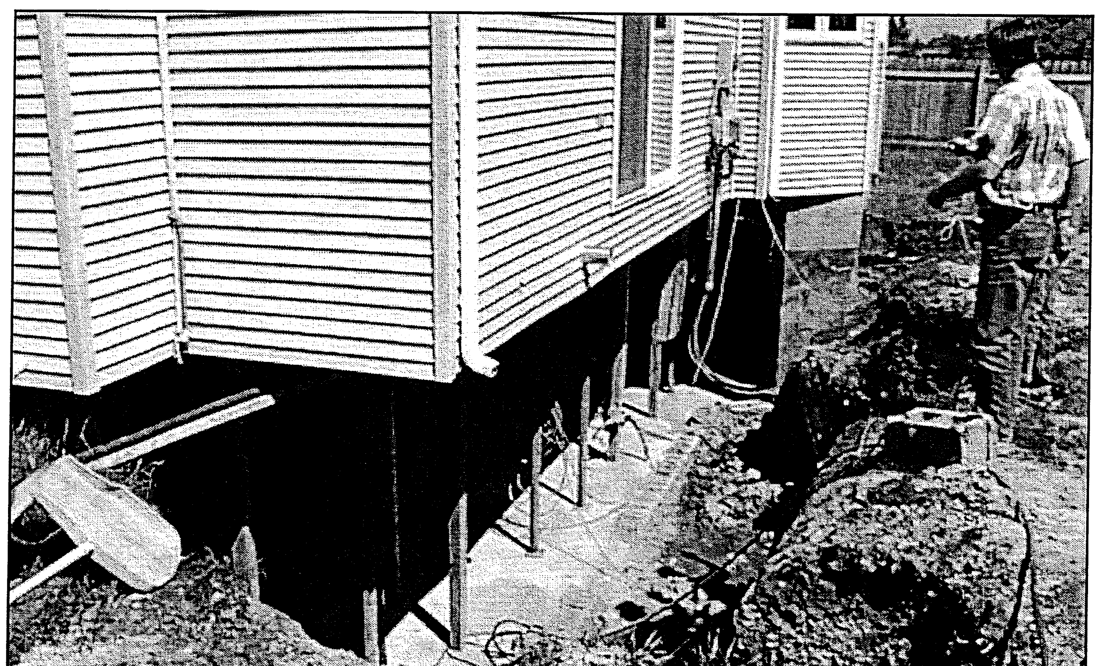


Figure 9 Failure of this unreinforced masonry basement during flooding in East Grand Forks, MN, in 1997 caused approximately $32,000 in damage.

Simplified Approach

Design Requirements

If, for a building and building site, **all** the requirements listed below are met (see Figure 10), the building is reasonably safe from flooding. If all of these requirements are not met, the more detailed analysis described under Engineered Basement Option, on page 19 of this bulletin, should be performed to determine whether the building is reasonably safe from flooding.

- ☐ The ground surface around the building and within a defined setback distance from the edge of the SFHA (see next item) must be at or above the BFE.
- ☐ The setback is the distance from the edge of the SFHA to the nearest wall of the basement. The minimum allowable setback distance is 20 feet.
- ☐ The ground around the building must be compacted fill; the fill material—or soil of similar classification and degree of permeability—must extend to at least 5 feet below the bottom of the basement floor slab.
- ☐ The fill material must be compacted to at least 95 percent of Standard Laboratory Maximum Dry Density (Standard Proctor), according to ASTM Standard D-698. Fill soils must be fine-grained soils of low permeability, such as those classified as CH, CL, SC, or ML according to ASTM Standard D-2487, *Classification of Soils for Engineering Purposes*. See Table 1804.2 in the 2000 *International Building Code* (IBC) for descriptions of these soil types.
- ☐ The fill material must be homogeneous and isotropic; that is, the soil must be all of one material, and the engineering properties must be the same in all directions.
- ☐ The elevation of the basement floor should be no more than 5 feet below the BFE.
- ☐ There must be a granular drainage layer beneath the floor slab, and a ¼-horsepower sump pump with a backup power supply must be provided to remove the seepage flow. The pump must be rated at four times the estimated seepage rate and must discharge above the BFE and away from the building. This arrangement is essential to prevent flooding of the basement or uplift of the floor under the effect of the seepage pressure.
- ☐ The drainage system must be equipped with a positive means of preventing backflow.
- ☐ Model building codes (such as the 2000 International Residential Code) also address foundation drainage (IRC Section R405) and foundation walls (IRC Section R404). Model building codes generally allow foundation drains to discharge through either mechanical means or gravity drains. In addition, there is often an exception to the requirement for drainage systems in well-drained soils. However, in or near floodplains, well-drained soils can, in fact, help convey groundwater towards the building foundation. Therefore, this exception should not apply in or near floodplains.

☐ In some cases in or near floodplains, even with standard drainage systems, hydrostatic pressures from groundwater against the basement can result. When a standard drainage system is unable to eliminate hydrostatic pressure on the foundation, model building codes, including the 2000 International Residential Code (IRC Section R404.1.3), require that the foundation be designed in accordance with accepted engineering practice. **The simplified approach contained in this Technical Bulletin assumes no hydrostatic pressure on the foundation and should be used only when a standard drainage system, discharged by a sump pump that is equipped with backup power and that discharges above BFE, is employed.** For other drainage systems, the designer should use the engineered basement option presented on page 19 of this bulletin and other appropriate building code requirements.

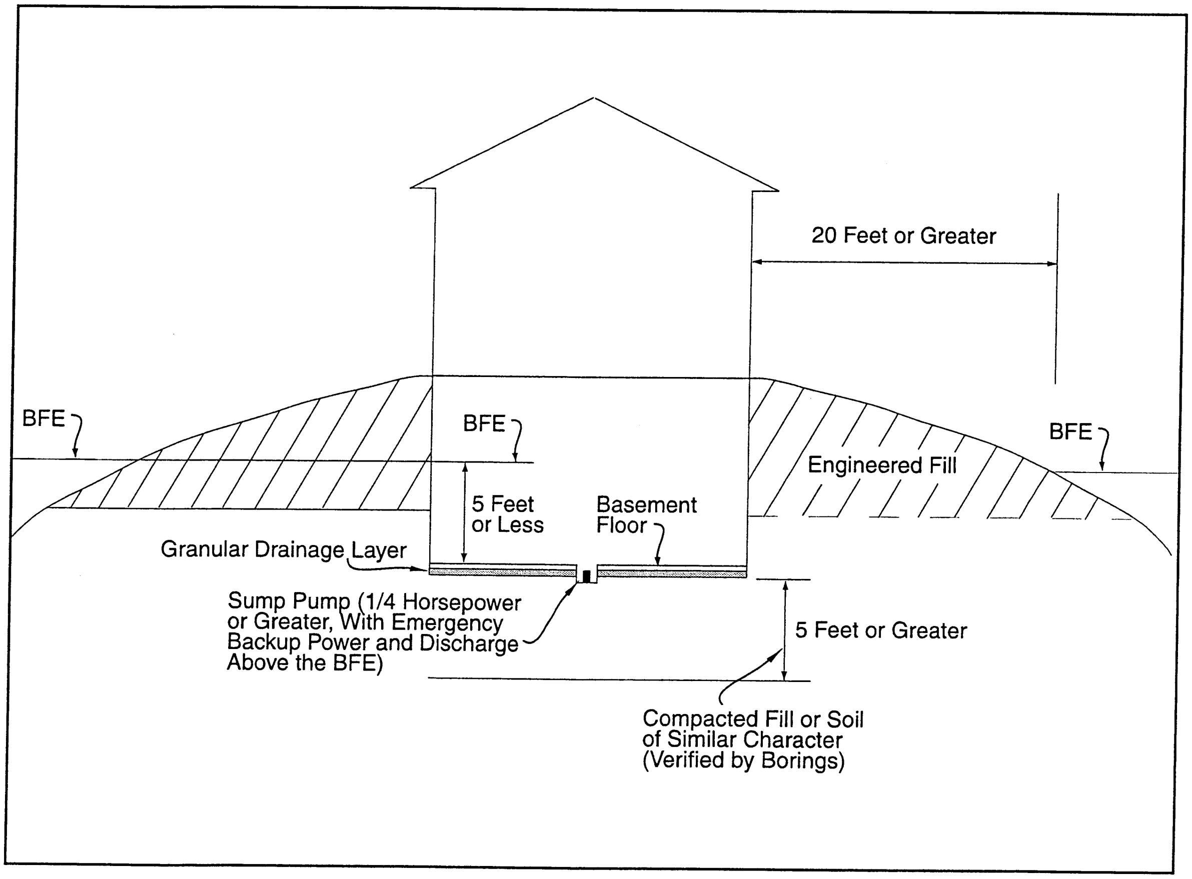


Figure 10 Requirements for use of the simplified approach to basement construction.

Technical Background for the Simplified Approach

The simplified approach is based on the following conditions:

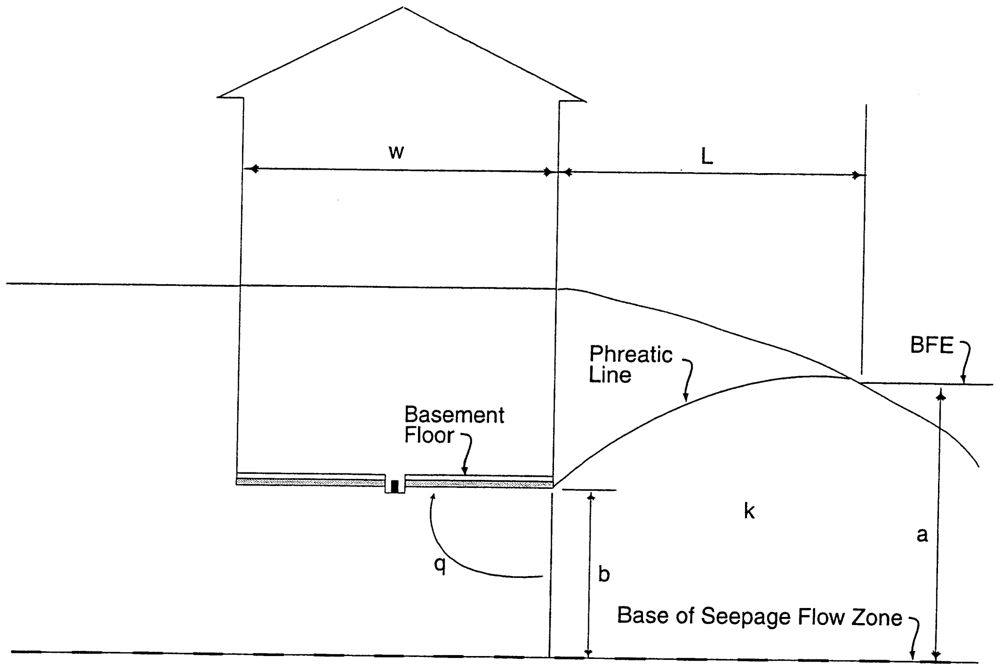
1. The area of the footprint of the basement is less than or equal to 1,200 square feet.

2. The soil is saturated; therefore, there is no time lag in the development of the seepage pattern with a change in flood water level. The groundwater table in floodplains is typically very shallow, and fine-grained soils have a substantial potential for maintaining saturation above the water table by capillary rise.

3. The tailwater level is at the elevation of the BFE. For this bulletin, "tailwater" is defined as the groundwater level beyond the structure, on the side away from the flood water surface. This is a reasonably conservative assumption because the flood would raise the groundwater level in the general area. In some cases, the tailwater level can be higher than the flood level because there is higher ground, as a valley wall, that feeds the groundwater into the floodplain soils.

4. The effective elevation of the base of the seepage flow zone can be defined (see Figure 11). This elevation is needed to permit calculation of the quantity of seepage flow. If the base elevation is not known, its depth below the base of the floor slab can be conservatively approximated as one-half of the building width most nearly perpendicular to the shoreline of the flood water. This would approximate the boundary effects of the three-dimensional seepage flow, in that it would represent the flow coming in from all sides and meeting in the center beneath the floor slab. This approach assumes a constant soil type and density over the flow zone. If the site has stratified soil layers, the engineered basement option should be used (see page 19 of this bulletin).

5. The quantity of seepage flow can be calculated by a simplified method based on Dupuit's assumption that equipotential lines are vertical. (The Dupuit method uses Darcy's law with specific physical characteristics. A more detailed description can be found in the first two references listed under "Further Information," on page 23 of this bulletin.) The elements of the method are presented in Figure 11. The entry surface, with hydraulic head "a," is a vertical line extending downward from the edge of the flood surface. The exit surface, with hydraulic head "b," is a vertical line extending downward from the side of the structure closest to the flood water's edge. The length of the flow path, "L," is the setback distance. Flow is assumed to be horizontal, and the horizontal coefficient of permeability is the effective permeability. For simplicity, the small inclined entry zone at the river bank and the exit zone below the basement floor are ignored. This is a reasonably conservative measure. The phreatic line, or the line below which the seepage flow occurs under positive pressure, extends from the edge of the flood water to the elevation of the bottom of the basement floor slab. If the exit zone below the basement floor were included, the hydraulic head at "b" would be higher. As shown in Figure 11, the phreatic line is not a straight line, but within the limits of the assumed boundary values, it is close to a straight line.



(1) $q = k(a^2 - b^2)/2L$

where: q = flow in cfs for a 1-foot width of seepage zone
k = soil permeability in feet per second
a = head at entry surface in feet
b = head at drain surface in feet
L = length of seepage zone (setback distance) in feet

(2) $Q = Pq$

where: Q = total seepage flow into drain in cfs
P = 2(basement length + width)
(for a square basement, $P = 4w$)

(3) Required sump pump capacity = 4Q for a safety factor of 4

Figure 11 Method for calculation of seepage flow.

The Dupuit equation for the quantity of seepage flow is:

$$q = k(a^2 - b^2)/2L$$

where: q is the flow in cubic feet per second for a 1-foot width of seepage zone

k is the soil permeability in feet per second (fps) (maximum value of k is $1x10^{-3}$ fps)

a and b are hydraulic heads in feet ($a < b + 5$)

L is the length of the flow zone in feet ($L > 20$ feet)

To obtain Q, the total seepage flow, in cubic feet per second, q must be multiplied by the length around the periphery of the four sides of the structure. This is a simplifying approach that obviates the need for a three-dimensional flow net calculation and is reasonably conservative.

It should be noted that the soil permeability does not affect the geometry of the seepage zone or the geometry of the phreatic line. The permeability does have a significant effect on the quantity of seepage that must be collected and discharged by the drainage layer and the sump pump. The calculation of the quantity Q provides a basis for the selection of a sump pump of adequate capacity. To allow for possible errors in the estimation of the soil permeability, the pump should have a capacity of at least four times the calculated value of Q. As noted in the requirements section, a standard sump pump of ¼ horsepower or greater will generally satisfy the requirements of seepage removal for the conditions described above.

Engineered Basement Option

If the requirements specified for the simplified approach are not met, a licensed soils engineer or geologist should perform a detailed engineering analysis to determine whether the structure will be reasonably safe from flooding. The analysis should consider, but is not limited to, the issues described in the following sections.

Depth, Soil Type, and Stratification of Subsurface Soils

The depth, soil type, and stratification of the subsurface soils may be complex. Four potential generalized scenarios are shown in Figures 12 and 13. Figure 12 shows two cases of homogeneous soil. The depth of penetration of the basement and the depth of the flow zone are not limited to the assumptions on which the simplified approach is based. Case I represents a foundation consisting of clayey soils, either fill or natural deposits or a combination, which are more or less homogeneous because they have similar engineering properties. If an adequate setback distance is provided, the seepage quantity would be relatively low, and uplift pressure beneath the slab could be controlled by an appropriately sized sump pump because of low permeability.

Case II represents a foundation consisting of sandy soils, either fill or natural soil deposits or a combination, which are more or less homogeneous because they have similar engineering properties. The seepage quantity would be fairly large, and more attention would have to be given to the setback distance and to the provision of an adequately sized sump pump to prevent excessive uplift pressure beneath the floor slab because of high permeability.

Figure 13 shows two simple cases of stratified soils, with impervious clays overlying pervious sands. This is a common occurrence in natural floodplain deposits. In Case III, the contact between the two soil strata is at some distance **below** the basement floor. This case would involve a moderate quantity of seepage, depending on the thickness, d, of the impervious stratum below the basement floor. There is also a potential for excessive uplift pressure beneath the floor, at the level of the bottom of the clay stratum. If d is equal to h, the net hydraulic head between the flood level and the floor level, the safety factor against uplift would be approximately 1.0. If d is less than h, there would be excessive uplift, with a safety factor equal to less than 1.0.

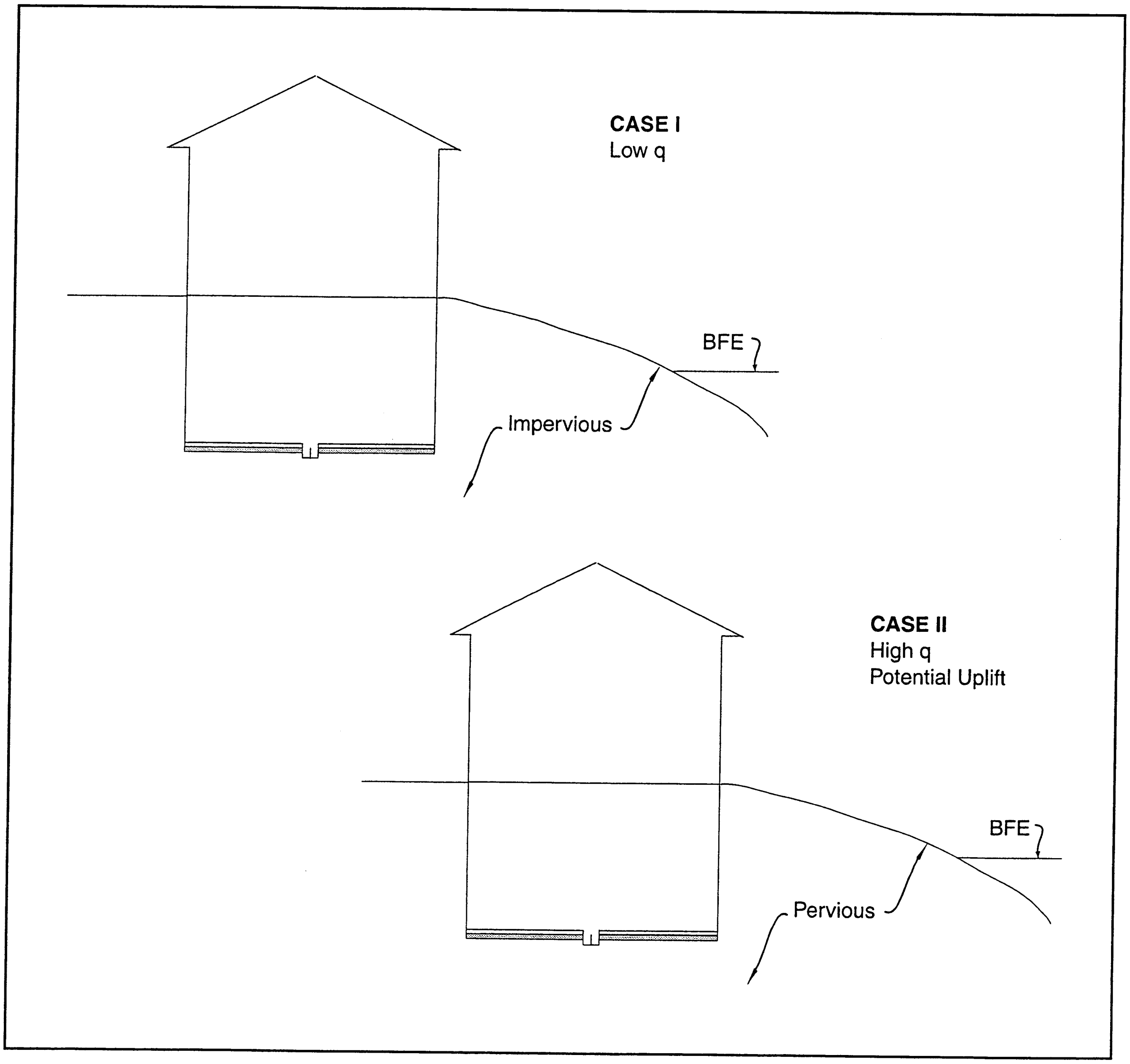


Figure 12 Case I and Case II – homogeneous soil.

Case IV shows impervious soils overlying pervious soils, with the contact between the soil strata at some distance **above** the basement floor. This case would involve a large quantity of seepage and potential for excessive uplift beneath the basement floor.

Geotechnical Investigations

Geotechnical investigations must be made for cases that do not conform with the assumptions on which the simplified approach is based. Information that is needed to permit an adequate engineering analysis includes the following:

- The BFE, which is to be used as the design flood water surface for calculating expected seepage.

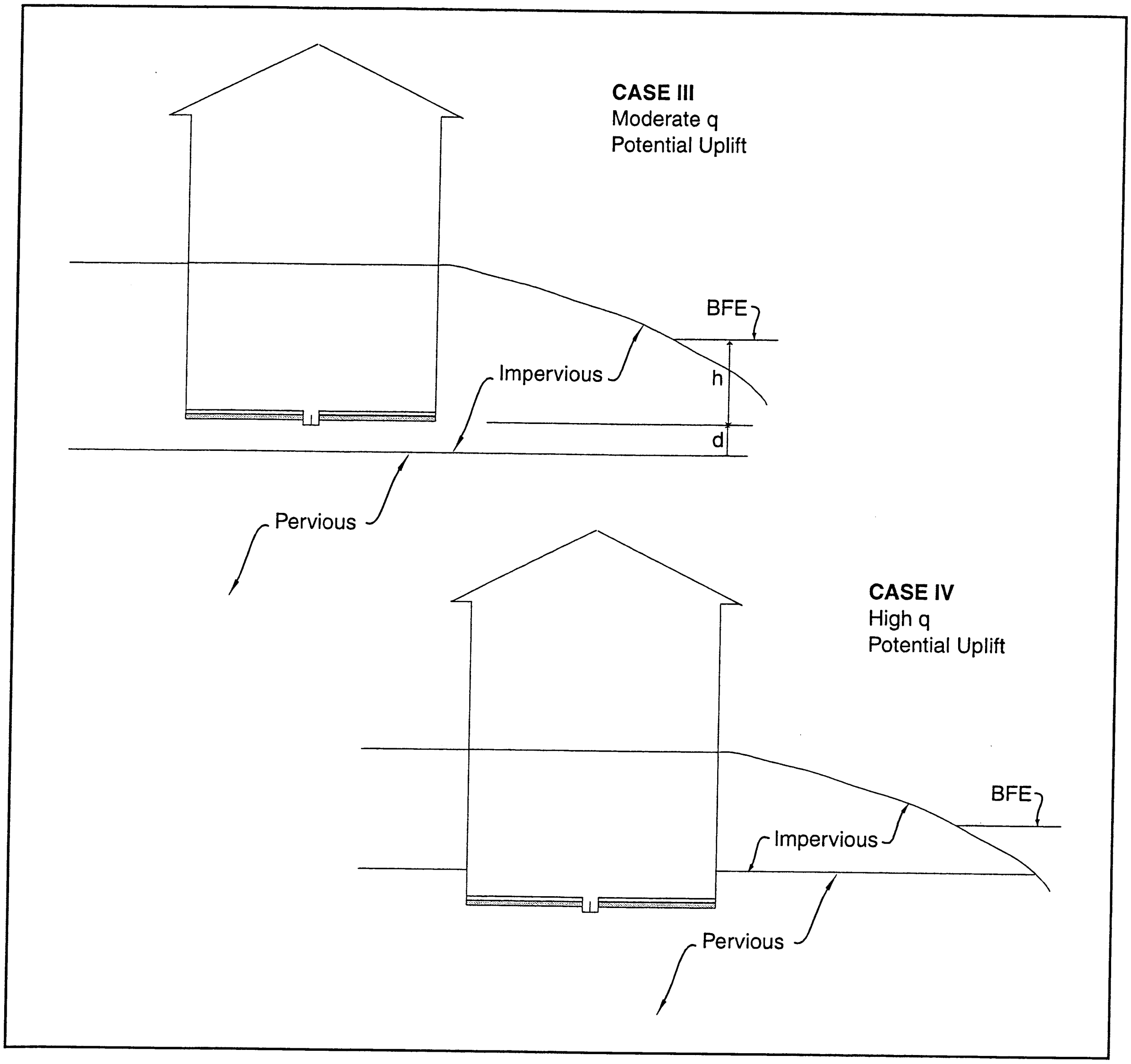


Figure 13 Case III and Case IV – stratified soils.

- The elevation of the **bottom** of the basement floor. This can be adjusted as needed to achieve more suitable conditions.
- The setback distance of the basement wall from the edge of the flood water. This can be adjusted to achieve more suitable seepage control or to accommodate available space restraints.
- The elevation of the groundwater table and its seasonal variations. A high water table would cause problems with groundwater control during construction of a basement, even without a flood event.
- The stratification of the subsurface materials, for both natural and fill soils. In general, borings should be drilled to a depth below the bottom of the floor slab that is at least two times as great as the depth of the bottom of the floor slab below the BFE.

- The engineering classification of the soils, for both natural and fill soils. This must be done in accordance with ASTM D2487, *Classification of Soils for Engineering Purposes*. This is the Unified Soil Classification System that is universally used throughout the United States. Local or county agricultural soil survey maps should not be used, because they do not give specific information about location and depth of soils, and their designations are not pertinent to civil engineering use.

- Subsurface conditions landward from the structure. This includes information about the location of the water table, whether it is higher or lower than the flood level, and information about any penetrations of the soil, such as ponds. Attention should be given to the possibility that higher ground, such as valley walls, could contribute to the groundwater level in the floodplain, either perennially or during periods of heavy rain.

- Information about any penetrations through the basement walls below the BFE, such as utility lines and other openings.

- Analysis of seepage quantity. The analysis can be made by the conservative simplified method described in Item 5 in the section titled Technical Background for the Simplified Approach (illustrated in Figure 11), or by the construction of a flow net that takes into account all of the boundary conditions more rigorously. A flow net may be required to permit analysis of uplift pressures. Uplift pressures may be more significant in laminated or stratified soil deposits.

Buildings in Existing Filled Areas

In evaluating buildings in existing filled areas, the two approaches already described—the simplified approach or the engineered basement option—can be used. If the simplified approach is used, all the requirements for the use of this approach must be met. Some possible means for evaluating whether these requirements are met include soil tests and investigations, including soil borings and hand augers; field records from the time the fill was placed; and soil surveys. If the requirements for the simplified approach are not met, a licensed soils engineer or geologist should perform a more detailed engineering analysis as described under Engineered Basement Option on page 19. More extensive soil investigations and testing may be required to complete the analysis.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood coverage was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the Federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community, provided the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria set forth in Part 60 of the NFIP Floodplain Management Regulations (44 CFR 60). Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management

ordinances or laws, communities adopt the NFIP performance standards for new, substantially improved, and substantially damaged buildings in floodprone areas identified on FEMA's FIRMs.

Technical Bulletins

This publication is one of a series of Technical Bulletins that FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in 44 CFR 60.3. The bulletins are intended for use primarily by state and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for conforming with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office or the local floodplain administrator. NFIP Technical Bulletin 0, the *User's Guide to Technical Bulletins,* lists the bulletins issued to date, provides a key word/subject index for the entire series, and lists addresses and telephone numbers for FEMA's 10 Regional Offices.

Ordering Information

Copies of FEMA Technical Bulletins can be obtained from the FEMA Regional Office that serves your area. In addition, Technical Bulletins and other FEMA publications can be ordered from the FEMA Publications Distribution Facility at 1-800-480-2520. The Technical Bulletins are also available at the FEMA web site at www.fema.gov.

Further Information

The following publications contain information related to the guidance presented in this bulletin:

American Society of Civil Engineers. 1998. SEI/ASCE 24-98, *Flood Resistant Design and Construction.*

Cedergren, H. R. 1977. *Seepage, Drainage and Flow Nets.* Wiley. New York.

Harr, M. E. 1977. *Mechanics of Particulate Media.* McGraw Hill. New York.

International Code Council. 2000. *International Building Code.* Birmingham, AL.

International Code Council. 2000. *International Residential Code.* Birmingham, AL.

U.S. Department of the Army, Corps of Engineers. 1986. EM 1110-2-1901, *Seepage Analysis and Control for Dams.* Washington, DC.

U.S. Department of the Army, Corps of Engineers. 1978. EM 1110-2-1913, *Design and Construction of Levees.* Washington, DC.

Glossary

Base Flood – The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Basement – Any area of a building having its floor subgrade (below ground level) on all sides.

Community – Any state or area or political subdivision thereof, or any Indian tribe or authorized tribal organization, or Alaska Native village or authorized native organization, which has the authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction.

Federal Emergency Management Agency (FEMA) – The independent Federal agency that, in addition to carrying out other activities, administers the NFIP.

Federal Insurance Administration (FIA) – The component of FEMA directly responsible for administering the flood insurance aspects of the NFIP.

Flood Insurance Rate Map (FIRM) – The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analysis, areas of 100-year flood hazard in a community.

Floodprone area – Any land area susceptible to being inundated by flood water from any source.

Mitigation Directorate – The component of FEMA directly responsible for administering the flood hazard identification and floodplain management aspects of the NFIP.

New construction/structure – For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes subsequent improvements to the structure. For flood insurance purposes, these structures are often referred to as "post-FIRM" structures.

Special Flood Hazard Area (SFHA) – Area subject to inundation by the base flood, designated Zone A, A1-30, AE, AH, AO, V, V1-V30, or VE.