Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings

Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program

NFIP Technical Bulletin 3 / January 2021

FEMA

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Acronyms

ACI	American Concrete Institute
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
BFE	base flood elevation
CFR	Code of Federal Regulations
CMU	concrete masonry unit
DFE	design flood elevation
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
IBC®	International Building Code®
ICC®	International Code Council®
I-Codes®	International Codes®
IRC®	International Residential Code®
LiMWA	Limit of Moderate Wave Action
NFIP	National Flood Insurance Program
ORNL	Oak Ridge National Laboratory
SEI	Structural Engineers Institute
SERRI	Southeast Region Research Initiative
SFHA	Special Flood Hazard Area
USACE	U.S. Army Corps of Engineers

1 Introduction

This Technical Bulletin explains and provides guidance on the National Flood Insurance Program (NFIP) floodplain management requirements for the design and certification of dry floodproofing. This guidance applies to new and substantially improved non-residential buildings and mixed-use buildings in Special Flood Hazard Areas (SFHAs) identified as Zone A (A, AE, A1-30, AH, and AO) on Flood Insurance Rate Maps (FIRMs). This Technical Bulletin includes guidance for certification of dry floodproofed buildings for the purpose of obtaining NFIP flood insurance coverage with floodproofing credit.

The NFIP regulations do not permit the use of dry floodproofing for residential buildings in Zone A, and dry floodproofing is not permitted for any buildings in SFHAs that are subject to high velocity wave action, called coastal high hazard areas and identified on FIRMs as Zone V (V, VE, V1-30, and VO).

The design and certification of dry floodproofing measures involve engineering evaluations and calculations. FEMA P-936, *Floodproofing Non-Residential Buildings* (2013), contains detailed guidance that supplements this Technical Bulletin. ASCE 24, *Flood Resistant Design and Construction*, is referenced throughout this Technical Bulletin because it is the standard of practice for the design of dry floodproofed buildings. ASCE 24 is a referenced standard in the International Codes® (I-Codes®).

1.1 Definition of Floodproofing

The NFIP regulations define floodproofing as "any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents" (Title 44 Code of Federal Regulations [CFR] § 59.1). In the NFIP regulations "floodproofing" is understood to refer to dry floodproofing. For the purposes of this Technical Bulletin, "dry floodproofing" means a combination of measures that make a building and attendant utilities and equipment watertight and substantially impermeable to floodwater, with structural components having the capacity to resist flood loads.

NFIP TECHNICAL BULLETIN 0

NFIP Technical Bulletin 0, *User's Guide to Technical Bulletins*, should be used as a reference with this Technical Bulletin. Technical Bulletin 0 describes the purpose and use of the Technical Bulletins. It includes common concepts and terms, lists useful resources, and includes a crosswalk of the sections of the NFIP regulations identifying the Technical Bulletin that addresses each section of the regulations and a subject index.

Readers are cautioned that the definitions of some of the terms that are used in the Technical Bulletins are not the same when used by the NFIP for the purpose of rating flood insurance policies.

FEMA P-936, *FLOODPROOFING NON-RESIDENTIAL BUILDINGS*

FEMA P-936 provides guidance on regulatory requirements, design considerations, design loads, site characteristics, and descriptions of dry floodproofing methods and equipment. Key information includes:

- Functional, operational, and economic factors to consider
- Tools such as a vulnerability checklist to help the designer or building owner determine the best dry floodproofing option for a particular building
- Case studies of applied dry floodproofing techniques
- Equations for determining flood forces and loads
- Summary of results from dry floodproofing research and testing for new construction

"Wet floodproofing" is not defined in the NFIP regulations. The term is used in FEMA guidance publications and by floodplain management professionals to mean the use of flood damage-resistant materials and construction techniques that intentionally allow floodwater to enter and flow through a structure without causing damage that requires more than cosmetic repairs. "Wet floodproofing" is sometimes used to refer to the requirements for enclosures below elevated building in Zone A when the enclosures are used only for parking of vehicles, storage, and building access.

Wet floodproofing measures are not covered in this Technical Bulletin. For more information on wet floodproofing, see FEMA P-936; NFIP Technical Bulletin 1, *Requirements for Flood Openings in Foundation Walls and Walls of Enclosures*; NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements*; NFIP Technical Bulletin 7, *Wet Floodproofing Requirements*; and FEMA P-2140, *Floodplain Management Requirements for Agricultural Structures and Accessory Structures* (2020a). FEMA P-2140 describes wet floodproofing measures as they apply to specifically defined agricultural structures and small accessory structures.

TERMS USED IN THIS TECHNICAL BULLETIN

- **Active:** Dry floodproofing measures or system components that require human intervention or action before the onset of flooding to be effective (e.g., flood shields that must be installed, valves that must be closed).
- **Ancillary area:** Common area such as a lobby, foyer, office used by building management, exercise space, meeting room, and mail room (FEMA P-2037, *Flood Mitigation Measures for Multi-Family Buildings* [2019a]).
- **Basement:** "Any area of the building having its floor subgrade (below ground level) on all sides" (44 CFR § 59.1). The NFIP regulations do not allow basements to extend below the base flood elevation (BFE) except in dry floodproofed non-residential buildings.
- **Flood protection level:** Elevation to which flood protection measures are designed. The flood protection level is the most restrictive of (1) the BFE plus the prescribed amount of freeboard specified in ASCE 24, (2) the design flood elevation (DFE) if a different flood is used for regulatory purposes, and (3) the elevation relative to the BFE specified in local floodplain management regulations.
- **Flood shield:** Removable or permanent, substantially impermeable protective cover or panel for openings in the portions of a dry floodproofed building that are below the flood protection level (e.g., door, window, louver).
- **Floodproofing:** "Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents" (44 CFR § 59.1).
- **Mixed-use building:** Building that has both residential and commercial or other non-residential uses. The term does not include multi family residential buildings that have ancillary areas but no non-residential uses.
- **Non-residential building:** Building that has a commercial or other non-residential use.
- **Passive:** Dry floodproofing measures or system components that do not require human intervention or action before the onset of flooding to be effective (e.g., specially designed doors that are sealed when closed, designed window systems, flood shields that are designed to close automatically when triggered by rising floodwater).

(continued on page 3)

TERMS USED IN THIS TECHNICAL BULLETIN (continued)

- **Residential building:** Building designated for habitation. Ancillary areas of residential buildings that serve only residents are residential ancillary areas and include laundry facilities, storage rooms, mail rooms, recreational rooms, parking garages, and exercise facilities.
- **Substantially impermeable:** The use of materials and techniques that restrict the passage of water and seepage through pathways (joints, cracks, openings, channels) and points of entry and that limit the accumulation of water during flooding. According to ASCE 24 and the U.S. Army Corps of Engineers (USACE), a structure is considered substantially impermeable if the maximum accumulation of water is not more than 4 inches in a 24-hour period without relying on devices for the removal of the water (USACE, 1995).
- **Zone A:** Flood zones shown on FIRMs as Zone A, AE, A1-30, AH, AO, A99, and AR.
- **Zone V:** Flood zones shown on FIRMs as Zone V, VE, V1-30, and VO.

Other terms used in this Technical Bulletin are defined in the glossary in Technical Bulletin 0.

1.2 Floodproofing Certification

When a building owner proposes dry floodproofing measures for a non-residential building that is in an NFIP-participating community, the owner must provide certification that the structural designs, specifications, and plans for the construction of the dry floodproofing measures were developed and/or reviewed by registered professional engineers or architects (design professionals). The certification must state that the proposed dry floodproofing design and proposed methods of construction are in accordance with accepted standards of practice for achieving the required performance. Design professionals who sign and seal certifications must be licensed to practice in the state where projects are located.

FEMA Form 086-0-34, NFIP Floodproofing Certificate for Non-Residential Structures (FEMA, 2019b), provides information necessary for insurance underwriters to rate dry floodproofed buildings. The same form should be used to satisfy the requirement for design professionals to certify designs and as-built drawings and inspection. The certificate identifies ASCE 24-14 and ASCE 24-05 (or equivalent) as the accepted standard of practice.

The certificate requires the building owner's name and the address or other description of the building location. It has three sections:

- Section I: Site information from the FIRM.
- Section II: Certification of the elevation to which the building is floodproofed. The elevation (where BFEs are provided on FIRMs) or the height above the lowest adjacent grade (where BFEs are not provided) to which the building is floodproofed. Section II must be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information.

ASCE 24 IS THE STANDARD OF PRACTICE FOR DRY FLOODPROOFING DESIGN

ASCE 24, *Flood Resistant Design and Construction*, is a consensus standard that was developed and is maintained by the American Society of Civil Engineers (ASCE). ASCE 24 is a referenced standard in the I-Codes, which means it is considered part of the requirements in these codes.

ASCE 24 represents the standard of practice for the design of buildings and structures in flood hazard areas, including the design of dry floodproofed buildings.

- Section III: Certification by a registered professional engineer or architect that "the structure, based upon development and/or review of the design, specifications, as-built drawings for construction and physical inspection" has been designed and constructed in accordance with "the accepted standards of practice (ASCE 24-05, ASCE 24-14, or their equivalent) and any alterations [of the structure]" meet these standards and specific listed provisions (i.e., are watertight and substantially impermeable and have structural components that are capable of resisting flood forces).

See Appendix A for further instructions on completing the certificate.

1.3 Limitations on the Use of Dry Floodproofing

Dry floodproofing is permitted for new and substantially improved non-residential and non-residential portions of mixed-use buildings in Zone A, but not for residential buildings in Zone A or any building in Zone V. The NFIP regulations and published FEMA guidance use "residential" and "non-residential" but do not define these terms. However, "residential" in general refers to dwelling units and the building systems and ancillary areas that support the units. Building systems include electrical, heating, ventilation, plumbing, and air conditioning equipment and other service equipment. Ancillary areas include areas that are designated or used by on premises guests. "Non-residential" refers to buildings with commercial or other non-residential uses. ASCE 24 has a more extensive definition of "residential" and defines "non-residential" as buildings that are not classified as residential. ASCE 24 commentary defines "mixed-use" and "residential portions of mixed-use buildings."

FEMA considers buildings with both non-residential and residential uses to be mixed-use buildings. The non-residential portions of mixed-use buildings are allowed to be dry floodproofed provided that all residential units, building systems and service equipment that serve residential units, and ancillary areas used by residents are elevated above the required elevation. See FEMA P-2037, *Flood Mitigation Measures for Multi-Family Buildings*, for more information.

In keeping with the requirements for enclosures below elevated residential buildings, lobbies that provide access to both residential and non-residential portions of mixed-use buildings are allowed to be dry floodproofed provided there are separate accesses to the residential portions. When an access to the residential portion of a mixed-use building is below the flood protection elevation and the access is enclosed by walls, the walls must comply with the requirements for enclosures below elevated buildings (sometimes called wet floodproofing).

HOTELS AND MOTELS

Hotels and motels are commercial buildings. For floodplain management purposes, guest rooms and the building systems and service equipment that serve guest rooms are considered residential and are not permitted to be located in areas of the building that are dry floodproofed. The requirements for building systems and service equipment that serve guest rooms and access to guest rooms are the same as the requirements for the residential portions of mixed-use buildings.

The NFIP regulations for dry floodproofing apply only in SFHAs identified on FIRMs as Zone A (A, AE, A1-30, AH, and AO). Dry floodproofing is not permitted in SFHAs identified as Zone V (V, VE, V1-30, and VO). For Zone A, the regulations do not specify limits on the use of dry floodproofing based on flood depth, flood velocity, or the presence of waves. However, FEMA does not recommend use of dry floodproofing systems in areas where:

- The depth of water under base flood conditions is greater than 3 feet.
- Base flood velocities exceed 5 feet per second.
- Moderate wave heights (1.5 to 3 feet) are present during base flood conditions.

1.4 Dry Floodproofing Measures

Dry floodproofing measures include but are not limited to the following:

- Portions of a building, including walls and slabs, reinforced to resist water pressure and floating debris impacts
- Doors and windows that are specially designed to be watertight when closed without flood shields
- Removable or permanently installed, substantially impermeable panels to cover doors, windows, and other openings
- Paints, membranes, gaskets, and other sealants that reduce water seepage
- Sump pumps or self-priming pumps that control the level of seepage water
- Backflow (non-return) valves or shutoff valves that prevent floodwater from entering through sewer and drainage pipes and/or sewage ejectors that pump sewage to above the flood protection level before the pipes connect to a vertical sewer line
- Seals that prevent the entrance of floodwater through joints and utility penetrations
- Electrical equipment and circuits that are protected to the flood protection level
- Backup or emergency power for sump pumps and other seepage control measures that is protected to the flood protection level

The planning considerations in Section 5 should be reviewed before determining which dry floodproofing measures or combination of measures are feasible for specific locations and before undertaking structural designs to ensure that the measures will provide the appropriate level of flood protection. Planning considerations include building location, flood characteristics (flood velocities, depths, duration of flooding, how quickly floodwater rises, and debris impacts), level of protection required, flood warning time, safety and access, flood emergency operations plan, and inspection and maintenance plans.

Questions about dry floodproofing requirements should be directed to the appropriate local official, National Flood Insurance Program State Coordinating Office, or FEMA Regional Office.

LEVEES AND FLOODWALLS

Levees and floodwalls are not considered dry floodproofing measures for buildings because they are separate structures and not part of the buildings. Levees and floodwalls that are designed and constructed to provide flood protection to a single building or a group of buildings are not addressed in this Technical Bulletin. Although levees and floodwalls can be used to mitigate flood damage, they may not be used to bring a building into compliance with NFIP requirements.

2 National Flood Insurance Program Regulations

An important NFIP objective is protecting buildings constructed in SFHAs from damage caused by flooding. The SFHA is the land area subject to flooding by the base flood. SFHAs are shown on FIRMs prepared by FEMA as Zones A and V. The base flood is the flood that has a 1 percent chance of being equaled or exceeded in any given year (commonly called the "100-year" flood). The NFIP floodplain management regulations include minimum building design criteria that apply to:

- New construction
- Work determined to be Substantial Improvements, including improvements, alterations, and additions
- Repair of buildings determined to have incurred Substantial Damage

A defining characteristic of the NFIP regulations applicable in any Zone A is the requirement for the lowest floor (including basement) of residential buildings to be elevated to or above the BFE. Non-residential buildings in Zone A must be elevated or dry floodproofed to or above the BFE. Dry floodproofing is not permitted in Zone V.

The NFIP regulations for dry floodproofing of non-residential buildings are codified in 44 CFR Part 60, Criteria for Land Management and Use. Specific to this Technical Bulletin, 44 CFR § 60.3(c)(3) states that a community shall:

> Require that all new construction and substantial improvements of non-residential structures within Zones A1–30, AE and AH zones on the community's firm [sic] (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) states that in Zone AO (areas of sheet flow with depths of 1 to 3 feet), a community shall:

> Require within any AO 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 [44 CFR} § 60.3(c)(3)(ii).

Section 60.3(c)(4) requires that floodproofing designs 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 under [44 CFR] § 59.22(a)(9)(iii).

NFIP REQUIREMENTS AND HIGHER REGULATORY STANDARDS

State or Local Requirements. State or local floodplain management requirements that are more restrictive or stringent than the minimum requirements of the NFIP take precedence. The Technical Bulletins and other FEMA publications provide guidance on the minimum requirements of the NFIP and describe best practices. Design professionals, builders, and property owners should contact local officials to determine whether more restrictive provisions apply to buildings or sites in question. All other applicable requirements of the state or local building codes must also be met.

Substantial Improvement and Substantial Damage. As part of issuing permits, local officials must review not only proposals for new construction but also for work on existing buildings to determine whether the work constitutes Substantial Improvement or repair of Substantial Damage. If the work is determined to constitute Substantial Improvement or repair of Substantial Damage, the buildings must be brought into compliance with the NFIP requirements for new construction. Some communities modify the definitions of Substantial Improvement and/or Substantial Damage to be more restrictive than the NFIP minimum requirements. For more information on Substantial Improvement and Substantial Damage, see FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010a), and FEMA 213, *Answers to Questions About Substantially Improved/Substantially Damaged Buildings* (2018a).

Higher Building Elevation Requirements. Some states and communities require that non-residential buildings be elevated or dry floodproofed (allowed only in Zone A) above the NFIP minimum requirement. The additional elevation is called freeboard. Design professionals, builders, and property owners should check with local officials to determine whether a state or community has freeboard requirements. References to building elevations in the Technical Bulletin, including the required flood protection level, should be construed as references to the community's elevation requirement where freeboard is required.

3 Building Codes and Standards

In addition to complying with NFIP requirements, all new construction, Substantial Improvements, and repair of Substantial Damage must comply with the applicable building codes and standards adopted by states and communities.

The I-Codes, published by the International Code Council® (ICC®), are a family of codes that includes the International Residential Code® (IRC®), International Building Code® (IBC®), International Existing Building Code® (IEBC®), and codes that govern the installation of mechanical, plumbing, fuel gas service, and other aspects of building construction. FEMA has deemed that the latest published editions of the I-Codes generally meet or exceed NFIP requirements for buildings and structures in flood hazard areas. Excerpts of the flood provisions of the I-Codes are available on FEMA's Building Science – Flood Publications webpage (https://www.fema.gov/emergency-managers/risk-management/building-science/flood).

INTERNATIONAL BUILDING CODE AND ASCE 24 COMMENTARIES

The ICC publishes companion commentary for the IBC, and ASCE publishes a companion commentary for ASCE 24. Although not regulatory, the commentaries provide information and guidance that is useful for complying with, interpreting, and enforcing requirements.

3.1 International Residential Code

The International Residential Code (IRC) applies to one- and two-family dwellings and townhomes not more than three stories above grade plane. The IRC does not allow dry floodproofing of buildings within its scope.

3.2 International Building Code and ASCE 24

The International Building Code (IBC) applies to all applicable buildings and structures. While used primarily for buildings and structures other than dwellings within the scope of the IRC, the IBC may also be used to design dwellings.

The flood provisions of the latest published editions of the IBC generally meet or exceed NFIP requirements for buildings through reference to the standard ASCE 24, *Flood Resistant Design and Construction.*

ASCE 24 applies to structures that are subject to building code requirements. ASCE 24 requirements for dry floodproofing, summarized in Table 1, are similar to the NFIP requirements. Table 1 refers to selected dry floodproofing requirements of the 2018 IBC and ASCE 24-14 and notes changes from 2015 and 2012 IBC and ASCE 24-05 along with a comparison to the NFIP requirements. Subsequent editions of the IBC and ASCE 24 should include comparable requirements.

ASCE 24 AND NFIP DRY FLOODPROOFING REQUIREMENTS

FEMA interprets the NFIP regulations to be more restrictive than ASCE 24 in two respects:

- Temporary flood protection systems that cover exterior walls cannot be used in lieu of a substantially impermeable wall (see “ÁSCE Interpretation of ASCE 24-14 Flood Shield Requirements and FEMA Position on Whether a Flood Shield Configuration Meets NFIP Dry Floodproofing Requirements” at the end of Section 3.2 of this Technical Bulletin).
- Flood damage-resistant materials are required where seepage would collect inside dry floodproofed areas up to at least 4 inches above the floor.

Table 1: Comparison of Selected 2018 IBC and ASCE 24-14 Requirements with NFIP Requirements

Topic	Summary of Selected 2018 IBC / ASCE 24-14 Requirements and Changes from 2015 and 2012 IBC / ASCE 24-05	Comparison with NFIP Requirement
Definition of dry floodproofing	**2018 IBC Section 202 Definitions.** Defines dry floodproofing as a combination of design modifications resulting in a building, including the attendant utilities and equipment and sanitary facilities, being watertight with walls that are substantially impermeable and able to resist the loads required by ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. <u>Change from 2015 to 2018 IBC</u>: No change. <u>Change from 2012 to 2015 IBC</u>: Added “and equipment.” **ASCE 24-14 Section 1.2 Definitions.** Defines dry floodproofing as a combination of measures that results in making a structure and its utilities and equipment watertight with all elements substantially impermeable and with structural components having the capacity to resist flood loads. <u>Change from ASCE 24-05</u>: Expands the definition to require building and utilities and equipment serving the building to be watertight with walls substantially impermeable and able to resist flood loads rather than only requiring the building envelope to be substantially impermeable.	The definition of “dry floodproofing” (IBC and ASCE 24) is equivalent to the NFIP definition of “floodproofing” in NFIP 44 CFR § 59.1.

Table 1: Comparison of Selected 2018 IBC and ASCE 24-14 Requirements with NFIP Requirements (cont.)

Topic	Summary of Selected 2018 IBC / ASCE 24-14 Requirements and Changes from 2015 and 2012 IBC / ASCE 24-05	Comparison with NFIP Requirement
General flood hazard area requirements	**2018 IBC Section 1612.2 Design and construction.** Requires buildings and structures located in flood hazard areas to be designed and constructed in accordance with Chapter 5 of ASCE 7 and ASCE 24. Change from 2015 to 2018 IBC: Section renumbered from 1612.4 to 1612.2. Change from 2012 to 2015 IBC: Applies coastal high hazard area requirements in Coastal A Zones, if delineated.	Exceeds NFIP 44 CFR § 60.3(a)(3) with more specificity.
Flood hazard documentation	**2018 IBC Section 1612.4(1.3) Flood hazard documentation.** Requires submission of a certification statement prepared and sealed by a registered design professional that dry floodproofing is designed in accordance with ASCE 24. Change from 2015 to 2018 IBC: Section renumbered from 1612.5 to 1612.4. Change from 2012 to 2015 IBC: Applies coastal high hazard area requirements in Coastal A Zones, if delineated.	Equivalent to NFIP 44 CFR § 60.3(c)(4).
Elevation	**ASCE 24-14 Section 1.5.2 Elevation Requirements.** Allows for dry floodproofing of non-residential and the non-residential portions of mixed-use buildings below the BFE plus specified freeboard or the DFE, whichever is higher, provided the dry floodproofing measures meet the requirements in Chapter 6. **ASCE 24-14, Section 2.3, Elevation Requirements.** Allows for dry floodproofing of non-residential and the non-residential portions of mixed-use buildings below the BFE plus specified freeboard or DFE, whichever is higher, provided the dry floodproofing measures meet the requirements in Chapter 6. Change from ASCE 24-05: Requires Flood Design Class 4 buildings to be elevated or to be protected to BFE plus 2 feet, or DFE, or 500-year flood elevation, whichever is highest.	Exceeds NFIP 44 CFR § 60.3(c)(3) and (8) by requiring freeboard
Dry floodproofing	**ASCE 24-14 Section 6.2 Dry Floodproofing.** • Permits dry floodproofing of non-residential buildings and non-residential portions of mixed-use buildings when the buildings are located outside High Risk Flood Hazard Areas, Coastal High Hazard Areas, and Coastal A Zones • Requires techniques that make structures substantially impermeable and requires the use of flood damage-resistant materials, except on the interior of structures • Requires sump pumps to remove water that accumulates from the passage of vapor and seepage during flooding • Limits dry floodproofing to flood hazard areas with flood velocities that are less than or equal to 5 feet per second during the design flood • Requires walls below the minimum elevations of dry floodproofing specified in Table 6-1 to be substantially impermeable to passage of water	Exceeds NFIP 44 CFR § 60.3(c)(3) with more specificity, except (1) the NFIP requires the use of flood damage-resistant materials in areas where seepage can accumulate and (2) FEMA deems that temporarily installed means of flood protection that cover walls are inconsistent with the requirement that walls be substantially impermeable (see text box "ASCE Interpretation of ASCE 24-14 Flood Shield Requirements and FEMA Position on Whether a Flood Shield Configuration Meets NFIP Dry Floodproofing Requirements" on page 10).

Table 1: Comparison of Selected 2018 IBC and ASCE 24-14 Requirements with NFIP Requirements (cont.)

Topic	Summary of Selected 2018 IBC / ASCE 24-14 Requirements and Changes from 2015 and 2012 IBC / ASCE 24-05	Comparison with NFIP Requirement
Dry floodproofing (cont.)	• Requires walls, floors, and flood shields to resist hydrostatic, hydrodynamic, and other flood loads, including the effects of buoyancy • Specifies that soil or fill adjacent to a structure must be compacted and protected from erosion and scour • Requires that at least one door, window, or other opening for emergency escape and rescue be above the elevation specified in Table 6-1 • Specifies several limitations when human intervention is necessary to activate or implement dry floodproofing measures Change from ASCE 24-05: Does not require flood damage-resistant materials on the interior of dry floodproofed portions of buildings.	

ASCE INTERPRETATION OF ASCE 24-14 FLOOD SHIELD REQUIREMENTS AND FEMA POSITION ON WHETHER A FLOOD SHIELD CONFIGURATION MEETS NFIP DRY FLOODPROOFING REQUIREMENTS

In November 2016, ASCE issued a formal interpretation of whether a specific configuration of flood shields meets the dry floodproofing requirements of ASCE 24-14.[1] The configuration is described as a building that is supported by an impermeable reinforced concrete stem wall (foundation) with permeable exterior walls such as glass curtain walls. The question was whether the use of removable flood shields as a component of the exterior building façade would render the exterior walls impermeable along the entire length of the façade. Diagrams included in the request for the interpretation show flood shields attached at the base to the impermeable foundation stem wall and attached to vertical, structural columns between spans of the glass curtain wall system.

The ASCE interpretation determined that the flood shield configuration described and shown in the request meets the dry floodproofing requirements of ASCE 24-14 provided the building and shields meet all other dry floodproofing requirements, provided the flood shields are “close to and attached to the building façade,” and provided the shield attachment is “via guides, fasteners or supports that are permanent parts of the building façade.”[2]

The FEMA position is that the ASCE interpretation is contrary to the NFIP requirements because exterior wall sections that are neither substantially impermeable nor able to resist flood loads will not meet the intent of 44 CFR § 60.3(c)(3) that walls must be “substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy.” Therefore, any temporarily installed means of flood protection that cover such walls would not be considered compliant.

1 Jonathan C. Esslinger, Director, Technical Advancement and Codes & Standards, ASCE, written communication, November 29, 2016.

2 Ibid, Page 5.

3.3 ANSI/FM 2510, *American National Standard for Flood Mitigation Equipment*

ANSI/FM 2510, *American National Standard for Flood Mitigation Equipment* (ANSI/FM, 2020), describes performance and testing requirements that must be met for flood mitigation equipment and products, as defined in the standard, to be approved. Performance testing criteria are established for each type of equipment and products. The following types of equipment and products are addressed in the standard:

> **ANSI/FM 2510, AMERICAN NATIONAL STANDARD AND APPROVED EQUIPMENT AND PRODUCTS**
>
> ANSI/FM 2510: www.fmapprovals.com
>
> FM Approved equipment and products: https://nationalfloodbarrier.org

- Opening barriers (called flood shields in this Technical Bulletin)
- Flood glazing (permanent, passive barrier of reinforced glass material that is set and sealed within a structural frame)
- Flood mitigation valves (called backflow, non-return, or shutoff valves in this Technical Bulletin)
- Flood mitigation pumps (sump pumps, self-priming pumps, and other types of pumps used for seepage control)
- Penetration sealing devices
- Perimeter barriers (not applicable to this Technical Bulletin)

4 NFIP Flood Insurance Implications

Careful attention to compliance with the NFIP requirements, local building codes and standards, and floodplain management regulations is important during design, plan review, construction, and inspection. Compliance influences both vulnerability to flood damage and the cost of NFIP flood insurance.

> **NFIP FLOOD INSURANCE FOR DRY FLOODPROOFED BUILDINGS**
>
> While current owners and developers who are considering constructing dry floodproofed non-residential buildings may not intend to purchase NFIP flood insurance coverage, the cost of the coverage may be a factor for future owners.

An insurance agent with NFIP experience should be consulted during the design phase of buildings with dry floodproofing to estimate the cost of NFIP flood insurance. The consultation is particularly important when considering whether to include dry floodproofing of non-residential portions of mixed-use buildings or dry floodproofing of below-grade parking areas under non-residential and mixed-use buildings (see NFIP Technical Bulletin 6, *Requirements for Dry Floodproofed Below-Grade Parking Areas Under Non-Residential and Mixed-Use Buildings*).

Designers should pay particular attention to the flood protection level (level to which buildings will be dry floodproofed). The NFIP regulations applicable to non-residential structures in Zone A require the lowest floor (including basement) to be elevated to or above the BFE or the structures may be dry floodproofed below the

BFE. However, the NFIP flood insurance rating procedures provide credit for dry floodproofing only if the dry floodproofing measures are certified to be at least 1 foot above the BFE, even if that level of protection is not required by local floodplain management regulations. The NFIP also requires applications for insurance coverage for dry floodproofed buildings to include the NFIP Floodproofing Certificate (see Section 1.2 and Appendix A of this Technical Bulletin).

The methodology used by the NFIP to determine the NFIP flood insurance rate for dry floodproofed non-residential buildings and non-residential portions of mixed-use buildings is based on the "non-subsidized" rate with a credit (percentage discount) applied to that rate. The amount of credit is based on the information about the dry floodproofing components that must be included with NFIP flood insurance applications. Building owners and designers should consult with flood insurance providers before starting design work to understand how design decisions can impact NFIP flood insurance premiums.

5 Planning Considerations

Many factors and planning considerations influence the decision-making process when determining the feasibility of dry floodproofing options for specific buildings. Whether buildings are new construction designed to be dry floodproofed or existing buildings being considered for retrofitting with dry floodproofing measures, the dry floodproofing options that are examined and selected should:

- Comply with the applicable floodplain management and design requirements
- Reduce flood damage below the flood protection level
- Provide for the safety of personnel responsible for the deployment of components that require human intervention
- Be feasible to implement, maintain, and operate
- Be usable following recommended cleaning after flood events
- Result in a level of residual risk that is acceptable to the owner

Design professionals should assess the site during the planning phase to determine site-specific flood hazards that will influence the design of dry floodproofing measures, building vulnerability, and how well the building may perform during flood events (see Section 5.1). The assessment should include a flood vulnerability assessment to examine site conditions and, for existing buildings, the vulnerability of architectural and structural systems, building envelope, and utility systems (mechanical, plumbing, gas, electrical).

Other important planning considerations include determining the available warning time prior to the onset of flooding (see Section 5.2), functional use requirements (see Section 5.3), safety and access before and during flooding (see Section 5.4), and early consideration of required plans (Section 5.5), including flood emergency operations plans and maintenance and inspection plans.

The design professional should review the assessment findings with the building owner to determine whether dry floodproofing is appropriate and whether the results indicate any constraints on the design. Determining the flood warning time, described in Section 5.2 of this Technical Bulletin, is critical before deciding whether active dry floodproofing measures are feasible or appropriate, or whether passive measures or elevation should be considered.

Active dry floodproofing measures require human intervention or action before the onset of flooding and passive dry floodproofing measures do not require human intervention.

Building owners should also consider residual risk as part of determining whether dry floodproofing is an appropriate solution. Residual risk is the remaining exposure to loss after the designed floodproofing measures have been implemented. For example, losses could be higher than expected. Dry floodproofing systems are designed for a selected flood protection level, but during extreme events, floodwater may rise higher than the selected flood protection level and high water may affect some sites for longer than the anticipated periods of inundation. In addition, dry floodproofing systems can fail. Common causes of failure are unidentified points of entry for floodwater, poorly maintained components of a system, components with insufficient resistance to flood loads, and failure to implement active measures that require human intervention (especially for complex systems).

PLANNING, DESIGN, AND OPERATIONAL CONSIDERATIONS

For guidance on conducting a flood vulnerability assessment and designing dry floodproofing measures to reduce flood damage and interruption of building operations, see:

- FEMA P-936, Appendix C, "Checklist for Vulnerability of Flood-Prone Sites and Buildings"
- FEMA P-2022, *Mitigation Assessment Team Report: Hurricane Harvey in Texas*, Appendix C, "Dry Floodproofing: Planning and Design Considerations (Recovery Advisory 1)" (FEMA, 2018c)

For guidance on how to effectively implement dry floodproofing measures, see:

- FEMA P-2023, *Mitigation Assessment Team Report: Hurricane Irma in Florida*, Appendix C, "Dry Floodproofing: Operational Considerations (Recovery Advisory 1)" (FEMA, 2018b)

Designers and owners should evaluate the residual risks associated with dry floodproofing measures, and owners should consider the financial impacts if the dry floodproofing system fails. Added costs include down time, clean up, and repairs. Some financial risk can be offset by purchasing flood insurance.

5.1 Flood Hazards and Site Conditions

Selecting effective dry floodproofing measures requires evaluating the flood hazard conditions at the site for the flood used for design purposes, typically at least the base flood (1-percent-annual-chance flood). The assessment should determine flood velocity, depth of flooding, rate of floodwater rise and fall, frequency of flooding, duration of flooding, and possible debris impacts.

Design professionals and building owners should review Chapter 2 in FEMA P-936 for guidance on determining design loads and the site characteristics that need to be identified in order to determine whether dry floodproofing is feasible and to successfully design and construct a dry floodproofed building.

RESTRICTIONS BASED ON FLOOD ZONE AND CONDITIONS

The NFIP regulations do not allow dry floodproofing in Zone V. ASCE 24 restricts the use of dry floodproofing in Zone V and in Coastal A Zones if a Limit of Moderate Wave Action (LiMWA) is delineated on flood maps. Communities may have additional requirements, such as not allowing dry floodproofing to be used in floodways.

A factor that may influence the decision to use dry floodproofing is flood velocity. The USACE recommends in its *Flood Proofing Regulations* (1999) that dry floodproofing not be used where expected flood velocities exceed 5 feet per second. ASCE 24 limits the use of dry floodproofing to where expected flood velocities adjacent to a structure are less than or equal to 5 feet per second, although ASCE 24 commentary suggests that local officials may accept certified designs that demonstrate resistance to higher velocities. In this Technical Bulletin, see Section 6, Step 3B, for possible sources of data for determining expected flood velocities.

5.2 Flood Warning Time

Flood warning time is an important factor when considering active dry floodproofing measures. Flood warning time is the length of time between the recognition that flooding may occur and when floodwater begins to affect a site. Designers should determine whether warnings issued by credible sources would provide enough time to implement any active dry floodproofing measures.

The first step is to determine the flood warning time, which is site specific. The next step is to determine whether the flood warning time would be sufficient to implement the measures the designer is considering (see Section 5.5.1 of this Technical Bulletin) and to provide time to safely evacuate the site.

Flood warning time varies depending on the source of flooding and the capabilities of the entities that are responsible for monitoring flood conditions or issuing flood warnings. Flood warning times can vary widely:

- Small watersheds, especially those in mountain and hilly regions, may be subject to flash flooding with very little or no warning before the onset of flooding.
- Larger rivers and waterways may take hours, days, or weeks for floodwater to crest.
- Flooding in coastal areas usually has several days of warning, although storm paths can change abruptly, which can shorten or lengthen warning times.

SOURCES FOR ESTIMATES OF FLOOD WARNING TIME

Possible sources of information about flood warning time are state or local emergency management agencies, local floodplain managers, river basin authorities and drainage districts, state water resources agencies, National Weather Service, U.S. Geological Survey, and USACE District Offices.

Dry floodproofing measures are active or passive. Active measures require human intervention to install, deploy, or otherwise activate. When feasible, building owners and designers should consider passive measures because effectiveness does not depend on human intervention. Examples of passive measures are specially designed doors that are always sealed when closed, designed window systems, and flood shields that are designed to automatically close when triggered by rising floodwater on the site.

A key consideration for determining flood warning time is not the time it takes for floodwater to reach the flood protection level but the time it takes for flooding to begin to affect the site and reach the point where water enters the building if dry floodproofing measures have not been deployed. For example, if floodwater reaches the lowest point of entry

DESIGN LIMIT ON HUMAN INTERVENTION

Active dry floodproofing measures should be designed to meet the limit for human intervention specified in ASCE 24—a minimum of 12 hours of flood warning time unless the community operates a flood warning system, in which case the designer should determine how much time may be available.

during a 10-percent-annual-chance event, the flood warning time must be sufficient to allow the implementation of active measures prior to floodwater reaching the 10-percent-annual-chance elevation.

The amount of time needed to implement active dry floodproofing measures varies depending on factors such as the number and complexity of the measures that require timely action to function as designed. Determining whether the flood warning time would be adequate requires estimating the total time needed to:

- Recognize the threat, including whether anticipated storm conditions will have high winds that could hamper installation
- Notify persons or contractors responsible for installation or deployment
- Travel to building locations
- Locate, activate, deploy, and install the measures, which may require heavy equipment not typically on site, such as forklifts
- Evacuate people implementing the measures using predetermined evacuation routes, taking into account whether roads or bridges may be closed by state or local officials (e.g., when high winds or overtopping by floodwater are anticipated)

For more information on flood warning time, see FEMA P-936, Chapter 2.

5.3 Functional Use Requirements

The functional use of buildings and the spaces within them must be evaluated when considering dry floodproofing measures. If extended interruption of function would be detrimental, building owners should consider whether dry floodproofing is a viable option compared to elevating buildings. The location, purpose, and frequency of use of entrances may dictate the type of dry floodproofing measure that is selected. For example, doorways that are used often may not be suitable for special doors that are designed to seal when closed because the gaskets may wear more quickly. Another example is vehicle openings and delivery doors where accidental vehicle impact may damage permanently mounted brackets for flood shields.

Mixed-use buildings have additional functional use considerations because separate access must be provided to the elevated residential portions of these buildings when shared accesses (lobbies to residential and non-residential portions) are dry floodproofed. When the separate access to the residential portions of a mixed-use building is enclosed by walls, the walls must comply with the requirements for enclosures below elevated buildings (sometimes called wet floodproofing).

5.4 Safety and Access

For safety, dry floodproofed buildings should not be occupied during flood conditions. Safety and access considerations are especially important when evaluating mixed-use buildings and whether it is appropriate to design dry floodproofing measures for the non-residential portions of these buildings. Flooding may rise higher than the flood protection level or dry floodproofing system components may fail, endangering the occupants.

Flooding may limit access and timely response by emergency personnel. ASCE 24 requires an exit door, exterior door, or window at or above the flood protection level that can be used as an emergency escape and rescue opening. The opening must be capable of providing human ingress and egress during flooding.

5.5 Required Plans

Buildings that will be dry floodproofed should have both flood emergency operations plans and inspection and maintenance plans. When active dry floodproofing measures are specified (human intervention is required to implement), ASCE 24, Chapter 6, requires flood emergency plans that are approved by local officials. See Section 5.5.1 of this Technical Bulletin.

Communities are encouraged to require submission of these plans along with the construction documents and design certifications required as part of an application for a building permit. The required submission of a flood emergency operations plan and inspection and maintenance plan may be specified in local floodplain management regulations or building codes.

Emergency operations plans and inspection and maintenance plans are required to be submitted with applications for NFIP flood insurance coverage to receive credit for dry floodproofing measures (see Section 4 of this Technical Bulletin).

5.5.1 Flood Emergency Operations Plans

Flood emergency operations plans address the implementation of active dry floodproofing measures when flood events are anticipated. Design professionals engaged in designing dry floodproofed buildings should evaluate flood warning time and the estimated time and level of effort necessary to install and deploy various measures that require human intervention well in advance of the onset of flooding or high winds (see Section 5.2 of this Technical Bulletin). When there may be insufficient time to implement specific measures and evacuate, designers should re-examine the measures and specify those that can be installed safely within the available warning and evacuation time. If the entire dry floodproofing system cannot be implemented and personnel safely evacuated in the available time, designers should specify alternative dry floodproofing system components or advise owners to consider elevation when compliance is required.

FACTORS THAT CONTRIBUTE TO THE FAILURE OF DRY FLOODPROOFING SYSTEMS

The Mitigation Assessment Teams that FEMA deploys after some major disasters issue reports that include observations of damage and factors that contributed to flood damage. The reports issued after Hurricane Harvey in Texas (FEMA, 2018c) and Hurricane Irma in Florida (FEMA, 2018b) identify the following factors that may have contributed to the failure of dry floodproofing systems:

- Lack of plans that detail installation requirements for active dry floodproofing measures or operations and inspection and maintenance plans with insufficient detail
- Occupants and building managers who were not aware of the dry floodproofing systems
- Missing, damaged, degraded, and leaking gaskets around flood shields
- Modification of dry floodproofing components by uninformed maintenance contractors

PERIODIC PLAN REVIEWS, DRILLS, AND INSPECTIONS

An annual review of flood emergency operations plans, with exercises for personnel to practice installing and deploying measures that require human intervention, is critical for success when flooding occurs.

Some communities conduct periodic inspections of dry floodproofed buildings, and some require the submission of reports documenting third-party inspections.

Building owners, operators, and responsible personnel must be able to implement the plan and make sure that occupants are aware of what is required when plans are activated. Flood emergency operations plans must be tailored for each dry floodproofed building. At a minimum, plans should specify the following:

REQUIRED POSTING OF FLOOD EMERGENCY OPERATIONS PLANS IN VISIBLE LOCATIONS

ASCE 24, Chapter 6, requires flood emergency operations plans to be permanently posted in dry floodproofed buildings in at least two clearly visible locations.

- The personnel, equipment, tools, and supplies needed to deploy all dry floodproofing system components with sufficient time prior to the onset of flooding or conditions such as high winds that could interfere with efficient deployment of measures
- Clearly defined chain of command and assigned responsibilities for personnel involved in the installation of dry floodproofing measures
- Procedure for notifying personnel responsible for installing dry floodproofing measures, along with a list of duty requirements
- Decision tree that identifies the sequence, timeline, and responsible parties for installing the dry floodproofing components, including the triggers or benchmarks that will initiate procedures
- Written description and map of the storage locations and types of dry floodproofing measures to be installed or deployed, along with any equipment, tools, and materials required for installation
- Conditions that require the deployment of active dry floodproofing measures (e.g., installation of flood shields, closing of flood doors, closing of manual valves, staging of pumps)
- Instructions for installing or deploying each dry floodproofing measure and the order of installation if important for effectiveness
- Repair procedures and component maintenance procedures that may be necessary during a flooding event
- Instructions for connecting standby (emergency) power source (e.g., generator) for critical equipment such as sump pumps and egress lighting
- Contact information for the manufacturer and designer to expedite obtaining replacement parts and support as needed
- Evacuation plans for all personnel (see Section 5.2)
- Requirements for installation and deployment drills and training program (at least once a year)
- Requirement for regular review and update of the plan procedures

5.5.2 Inspection and Maintenance Plans

A comprehensive inspection and maintenance plan for the entire dry floodproofing system is needed to ensure that the system components, measures, materials, and equipment required for the system to function as intended are inspected and maintained periodically. The design professionals who design and certify dry floodproofing systems should prepare the inspection and maintenance plans. It is good practice for building owners or operators to engage design professionals to coordinate regular inspections and address significant deficiencies identified during inspections.

Observations by FEMA Mitigation Assessment Teams after significant flood events indicate that some dry floodproofing systems did not provide the intended level of protection in part because components of the systems were not regularly tested or properly maintained. For additional information, see Appendix C in FEMA P-2022 and Appendix C in FEMA P-2023.

Inspection and maintenance plans should include a schedule for regular inspection and maintenance of the components, materials, and equipment that are needed to activate dry floodproofing measures. Manufacturer manuals typically provide recommendations for the aspects that need to be checked during inspections and maintenance, the frequency of inspections, and ordering information for replacement parts.

FEMA Form 086-0-34, NFIP Floodproofing Certificate for Non-Residential Structures, lists the minimum information that maintenance plans must have in order to obtain NFIP flood insurance coverage (see Section 4 and Appendix A of this Technical Bulletin). The content of a comprehensive inspection and maintenance plan depends on the elements of the specific dry floodproofing system. At a minimum, the following should be addressed:

- Exterior envelope of the structure, such as wall and foundation systems, to identify possible structural and waterproofing deficiencies such as cracks, water staining, and penetrations
- Slabs and wall/slab joints, including structural and drainage deficiencies
- Flood shields, gates, panels, doors, glazing, and other components designed to provide dry floodproofing protection, including seals, gaskets, fasteners, and mounting hardware and tools
- Sump pumps (or self-priming pumps) and interior drain system
- Testing of emergency generators, sump pumps, and other drainage measures
- Backflow (non-return) valves or shutoff valves
- Location of all flood shields, gates, panels, and other components including all hardware along with any materials or tools needed to seal the dry floodproofed area
- Contact information for the manufacturer of the shields and other components to determine the availability of replacement gaskets, seals, and other parts and to ask questions
- Cadence of inspection and maintenance plan

Inspections should be performed regularly, usually once a year. Inspections can be coordinated with regular drills during which responsible personnel practice deploying measures that require human intervention and other actions specified in flood emergency operations plans. The inspection should identify items that are deficient, items in need of repair or replacement, and the materials and equipment needed to implement repairs. Building owners and operators should examine the inspection reports and promptly make repairs and address deficiencies.

ANNUAL INSPECTION AND MAINTENANCE

Performing annual inspections also helps increase personnel and occupant awareness of the presence and importance of the dry floodproofing systems.

6 Dry Floodproofing Design Process

Section 1.2 of this Technical Bulletin explains that communities must require dry floodproofing designs to be certified and that the NFIP Floodproofing Certificate for Non-Residential Structures (FEMA Form 086-0-34) should be used for this purpose (see Appendix A of this Technical Bulletin). The certificate requires registered design professionals to certify that dry floodproofing measures have been designed and constructed in accordance with ASCE 24 or its equivalent. The certificate requires certification of designs and "as-built drawings for construction and physical inspection." Certification of as-built dry floodproofed systems provides increased assurance to building owners and operators.

USE OF ANSI/FM 2510 APPROVED EQUIPMENT AND PRODUCTS

The use of equipment and products that are tested and approved in accordance with ANSI/FM 2510, *American National Standard for Flood Mitigation Equipment*, is not required for compliance with the NFIP or ASCE 24. However, specifying approved equipment and products may provide designers with more assurance when developing designs for dry floodproofing systems.

ANSI/FM 2510, described in Section 3.3 of this Technical Bulletin, specifies the flood conditions for the testing of each type of equipment and product. Designers should verify applicability of approved equipment and products for site-specific flood conditions.

The accepted standard of practice for the design of dry floodproofing measures is ASCE 24. This section provides a step-by-step guide for developing dry floodproofing designs that comply with ASCE 24. Designers should first evaluate the planning considerations described in Section 5 of this Technical Bulletin and review additional guidance in FEMA P-936. The process is applicable to the design of new construction with dry floodproofing systems and retrofitting of existing buildings with dry floodproofing measures.

An overview of the design steps is shown in Figure 1.

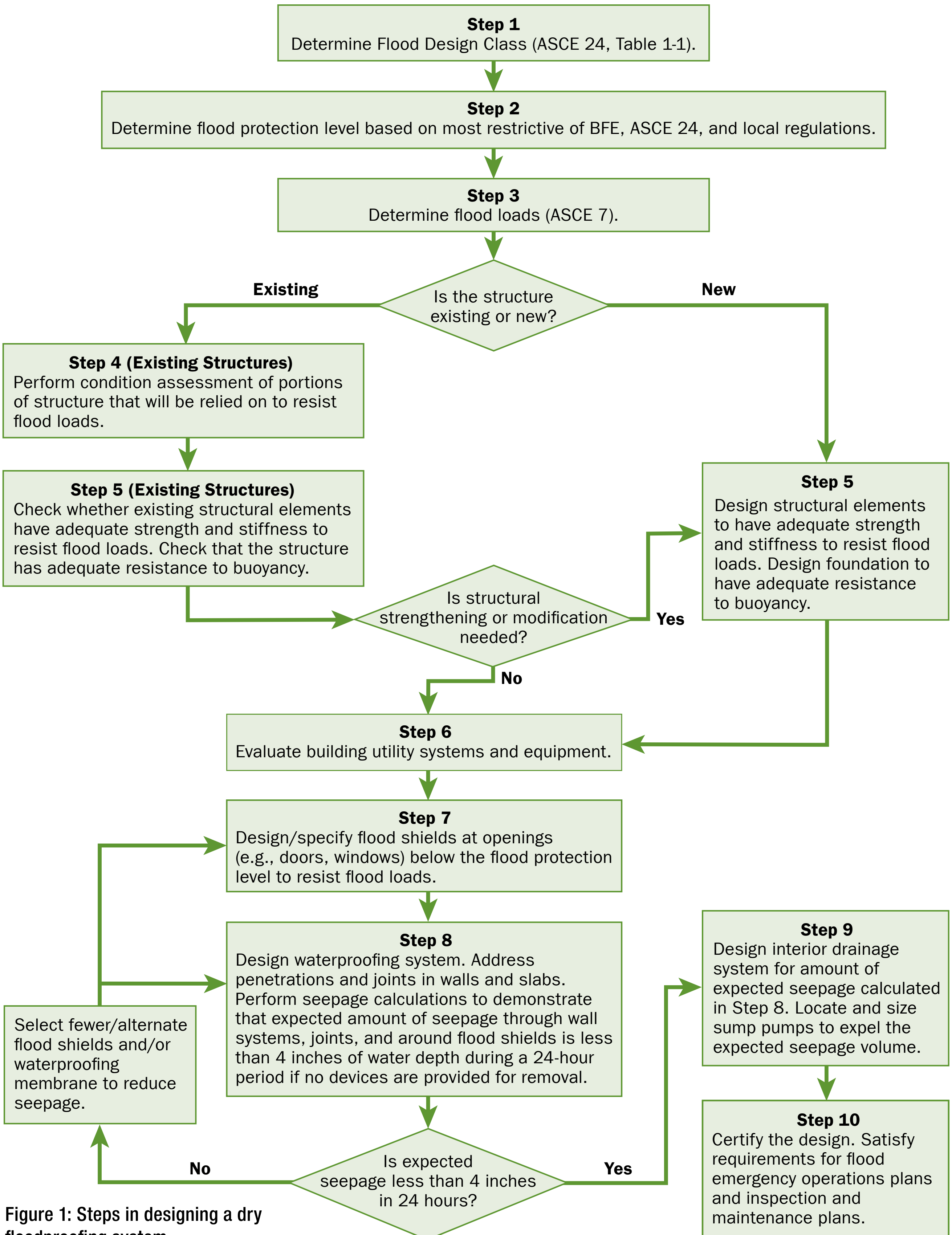

Figure 1: Steps in designing a dry floodproofing system

6.1 Step 1: Determine Flood Design Class

When designing in accordance with ASCE 24, the design professional begins the design process by determining the Flood Design Class (called "classification" in the 2005 edition). Flood Design Class is based on the use or occupancy of a building or structure, and the risk to the public should the building be damaged or the occupancy function be impaired by flooding. ASCE 24, Table 1-1, defines four Flood Design Classes.

6.2 Step 2: Determine the Flood Protection Level

The flood protection level is the elevation to which flood protection measures will be designed. The NFIP regulations specify that when non-residential buildings are dry floodproofed, the structures must be watertight and substantially impermeable below the base flood level or BFE.

ASCE 24 requires the minimum flood protection level to be the elevations listed in ASCE 24, Table 6-1, but state or local floodplain management regulations may require higher levels. ASCE 24 specifies flood protection levels based on the assignment of one of four Flood Design Classes (similar to risk categories).

The minimum flood protection level for Flood Design Class 2 and Class 3 buildings is the BFE plus 1 foot or the design flood elevation (DFE), whichever is higher. The minimum flood protection level for Flood Design Class 4, considered critical and essential facilities, is the highest of the BFE plus 2 feet, the DFE, or the 500 year flood elevation. Flood Design Class 1 includes temporary structures, accessory storage structures, small parking structures, and certain agricultural structures and also requires protection to BFE plus 1 foot or the DFE, whichever is higher. Local floodplain management officials should be consulted to determine whether local regulations require the flood protection level to be higher than the minimum elevations in ASCE 24.

"DESIGN FLOOD ELEVATION" IN ASCE 24

ASCE 24 defines and uses the terms "design flood" and "design flood elevation" (DFE) to account for communities that elect to adopt flood hazard maps based on floods that are higher than the base flood (the 1-percent-annual-chance flood) or to include additional areas not shown on FIRMs. Adding freeboard above the BFE as an additional factor of safety is also a common practice for establishing a minimum elevation requirement.

When communities simply adopt FEMA FISs and FIRMs and use the base flood and BFE for regulatory purposes, the DFE is the same as the BFE.

The BFE is the computed water surface elevation for the 1-percent-annual-chance flood. When shown on FIRMs, the BFE is often rounded to the nearest whole number. Designers should also check elevations shown in Floodway Data Tables and Flood Profiles included in Flood Insurance Studies (FISs) when FEMA has developed engineering analyses. Figure 2 shows a sample FIRM marked to show a building location and applicable BFE.

Some FISs and FIRMs do not provide detailed information and/or BFEs for all sources of flooding, particularly smaller streams and tributaries. When a FIRM panel does not show a BFE or when detailed flood elevation information is not available, designers will need to take additional steps to determine the BFE. Local officials may have information from other sources or may direct designers to other sources, including USACE District Offices and FEMA Regional Offices. Additional steps may be necessary when 500-year flood elevations are not included in the FIS but are needed for the design of critical facilities. Statistical methods or engineering analyses may be required to identify critical flood characteristics.

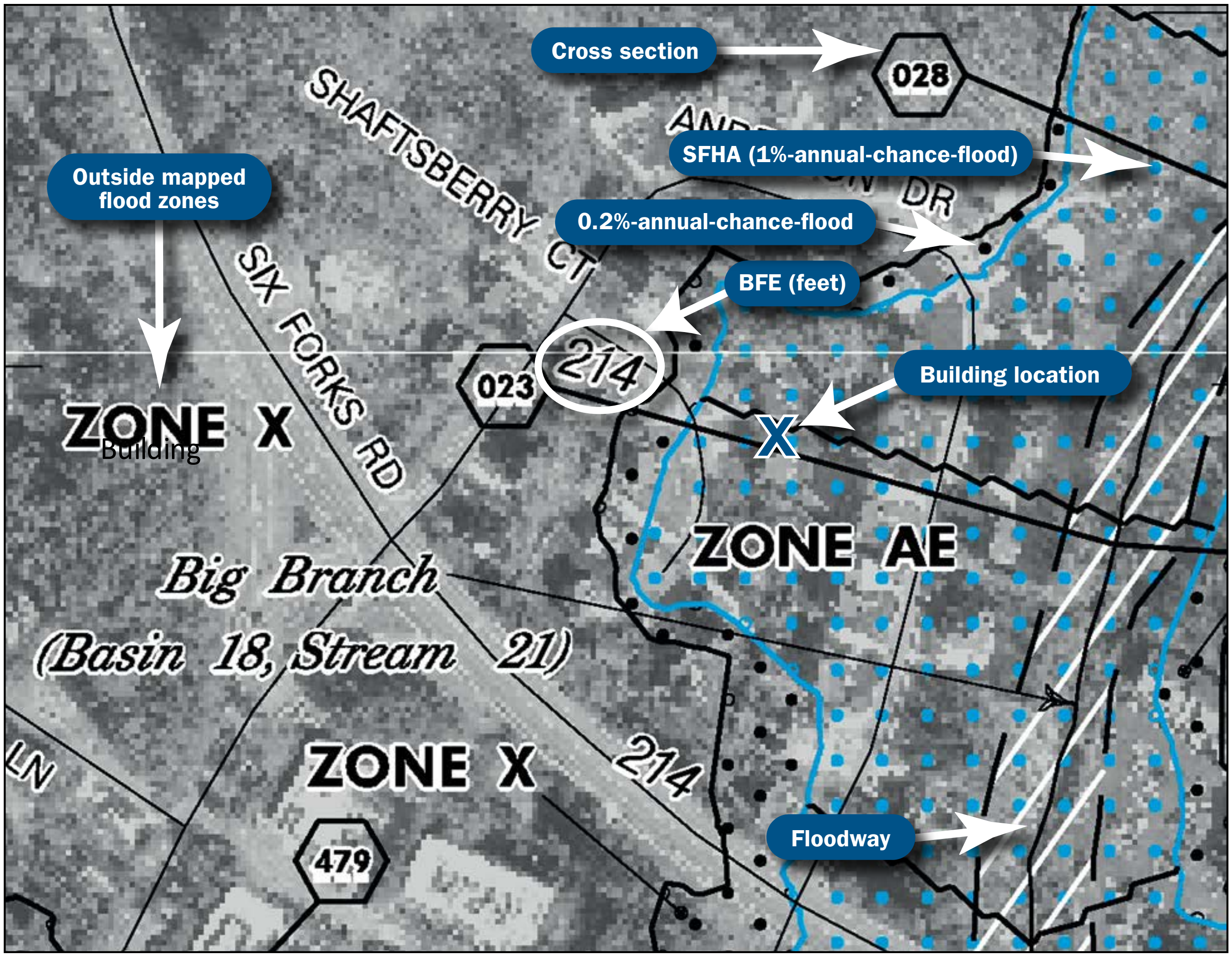

Figure 2: Example FIRM showing building location and BFE

An important consideration is that the flood protection level specified in ASCE 24 or local regulations is the minimum level to which buildings must be dry floodproofed. There is no restriction on designing dry floodproofing to provide protection for a higher flood elevation than what is required. Incorporating additional freeboard could help accommodate increases in future flood elevations, which may be caused by changes in storm intensity, increased development of surrounding areas, or ground subsidence. Owners and designers should discuss the acceptable level of protection given the value of the buildings, contents, occupancies, availability of replacement equipment, costs associated with business interruption and function, and cost-effectiveness of dry floodproofing. Owners may decide that a higher level of protection is appropriate.

6.3 Step 3: Determine Flood Loads

After the flood protection level has been determined, the next step is to determine the flood loads that would act on a building at the selected location. For design purposes, flood loads are the result of floodwater rising to the flood protection level and moving past an object such as a building or component of a building foundation. Flood loads are discussed in ASCE 7, which should be the primary source for calculating flood loads. Resources such as FEMA P-936 and FEMA P-55, *Coastal Construction Manual* (2010b), provide helpful information on determining site-specific loads. The four types of flood loads are:

- Hydrostatic loads, including buoyancy, which is the vertical hydrostatic force resulting from the displacement of a given volume of floodwater (Step 3A)
- Hydrodynamic loads (Step 3B)
- Wave loads (Step 3C)
- Impact loads (Step 3D)

Step 3E is load combinations, which are combinations of all types of loads, including flood loads.

All applicable flood loads must be considered over the entire dry floodproofing system below the flood protection level, including the portion above the BFE. Flood loads act on above-grade portions of buildings when floodwater is present and on below-grade foundation walls and slabs when saturated soil conditions may be present or may occur during flooding.

An overview of the types of flood loads is provided in Step 3A through Step 3E.

DETERMINING DEPTH OF FLOODING

The depth of flooding is critical in calculating flood loads. Designers of dry floodproofing systems should use the flood protection level elevation rather than the BFE or DFE when determining the depth of flooding for the calculation of flood loads.

6.3.1 Step 3A: Hydrostatic Loads

Hydrostatic loads are imposed by standing water on an object or building. Hydrostatic loads on specific buildings are determined using the flood protection level and must be applied to all building surfaces, both above and below the ground surface. Hydrostatic loads, also called pressures, are oriented horizontally on wall elements and increase linearly with depth of water (see Figure 3). For buildings with below-grade areas (basements), hydrostatic loads extend to the bottom of below-grade walls and are calculated using a saturated soil condition (see ASCE 7, Chapters 3 and 5).

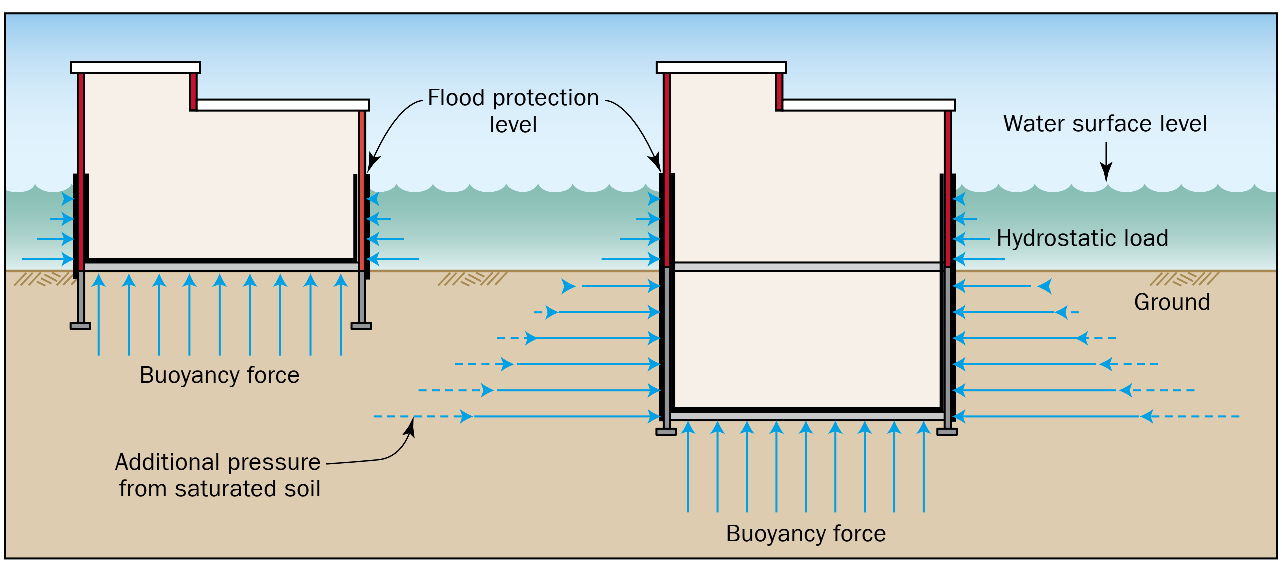

Figure 3: Hydrostatic loads

Vertical hydrostatic force (buoyancy) can be determined by multiplying the specific weight of water and the volume of floodwater displaced by a submerged object. Buoyant forces act upward on the bottom of foundation walls and base slabs and are resisted by the weight of the building and the structural capacity of the slab to resist uplift loads.

See FEMA P-936, Chapter 2, for information on determining hydrostatic loads and analyzing buoyancy forces.

When flood shields are included in dry floodproofing systems to prevent floodwater from entering openings in the building envelope (such as windows and doors), the shields must extend up to at least the flood protection level. A common practice is to extend flood shields an additional foot or more since even small amounts of splash or overtopping of a shield could result in a significant volume of floodwater entering the building. Flood shields must be designed to resist the hydrostatic load applied over the entire shield, and there must be a continuous load path through mounting systems to the walls and ultimately to foundations. See Step 7 for additional information on designing flood shields.

6.3.2 Step 3B: Hydrodynamic Loads

Hydrodynamic loads are imposed by water flowing around fixed objects such as buildings. These loads are a function of flow velocity and the geometry of the object or building. Upstream surfaces receive positive (frontal) pressures, side surfaces experience the effects of drag, and downstream surfaces have negative (suction) pressures (see Figure 4).

Hydrodynamic loads are determined by basic fluid mechanics. They increase as the size of the object around which the flow passes increases and with the square root of the flow velocity. Hydrodynamic loads vary with the shape of the object and associated drag coefficients.

ASCE 24, Chapter 6, limits the use of dry floodproofing to areas where flood velocities are less than or equal to 5 feet per second. ASCE 24 commentary acknowledges that effective designs may account for higher velocities and notes that it is the community's decision as to whether to accept dry floodproofing proposals in areas with velocities higher than 5 feet per second.

Determining the flood velocity can be a challenging part of estimating hydrodynamic loads on structures. Local, state, and federal government agencies and the Floodway Data Tables in FEMA FISs developed for waterways where FEMA performed detailed analyses are potential resources of velocity information.

ASCE 7 provides guidance on how to determine hydrodynamic loads and makes allowances for conditions when it is possible to calculate hydrodynamic loads as an equivalent hydrostatic load. FEMA P-936, Chapter 2, also describes hydrodynamic forces and how to determine a drag coefficient based on the shape of buildings and produce the total hydrodynamic force against a building or a given surface area.

DETERMINING FLOOD VELOCITY

Possible sources of data for determining expected flood velocity include studies by government agencies, hydraulic calculations, historical measurements, and Floodway Data Tables in FEMA FISs, among others. The Floodway Data Tables represent conditions during a 1-percent-annual-chance event. Where the flood protection level is higher, designers should consider that flood velocities for an event equaling the flood protection level may be higher. When data are not available for estimating flow velocities for a specific site, designers should contact experienced hydrologists or hydraulic or civil engineers to develop estimates.

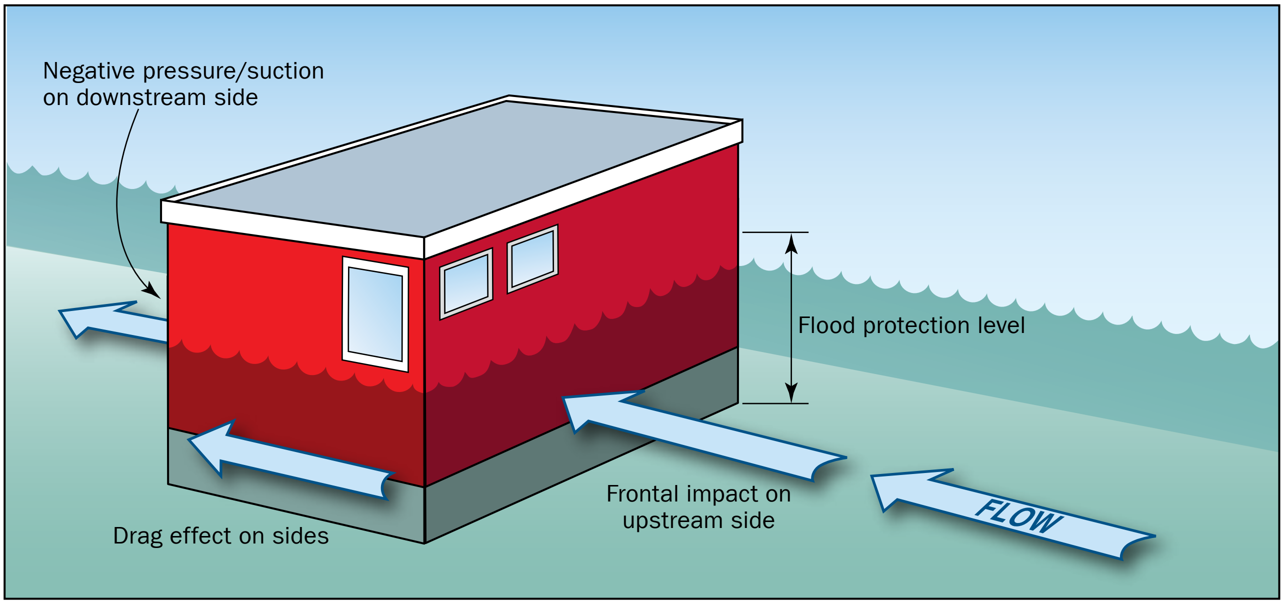

Figure 4: Hydrodynamic forces on a building

6.3.3 Step 3C: Wave Loads

The NFIP regulations do not permit the use of dry floodproofing in SFHAs that are subject to high velocity wave action, called coastal high hazard areas and identified on FIRMs as Zone V (V, VE, V1-30, and VO). FEMA does not identify other areas that may experience waves, including expansive riverine floodplains.

ASCE 24 does not permit dry floodproofing in Zone V or in Coastal A Zones when a Limit of Moderate Wave Action (LiMWA) is delineated on a FIRM. In addition, ASCE 24, Section 3.7.2, requires structures in noncoastal flood hazard areas subject to wind-driven waves that are equal to or greater than 3 feet high to be designed in accordance with the requirements for coastal high hazard areas. While wave loads are typically not considered in dry floodproofing designs, ASCE 24 commentary cautions that waves less than 3 feet in height can cause damage and should be considered in calculating flood loads. These waves may occur inland of the Zone V boundary where a LiMWA has not been delineated and in other floodplains where wind-driven waves may develop. Critical facilities could be located landward of Zone V and Coastal A Zones but under a design condition where the flood depth could support higher wave heights, which should be addressed in the design.

Design professionals should investigate historical flood damage near the site to determine whether wave forces could be present and could be significant enough to address in determining flood loads. Investigating historical flood damage is also appropriate for sites that are landward of Zone V boundaries if a LiMWA has not been delineated. Guidance on evaluating and determining appropriate wave loads and how to calculate the forces on various structural elements is included in ASCE 7, and additional information is provided in FEMA P-55.

6.3.4 Step 3D: Impact Loads

Impact loads result from debris that is transported by floodwater and strikes buildings. Such debris includes trees, boulders, ice floes, unsecured tanks and containers, vehicles, and material from damaged buildings. The magnitude of impact loads is difficult to predict due to the uncertainty of the size and weight of the objects. Determining the magnitude of debris impact loads should be based on a rational approach. The loads should be applied as a horizontal, concentrated load acting at the most critical location at or below the flood protection level.

ASCE 7 should be used as the source of how to calculate debris impact loads with FEMA P-936 as the source of helpful information and guidance on evaluating debris impact loads.

6.3.5 Step 3E. Load Combinations

Buildings need to be designed to resist all loads and load combinations. The applicable flood loads that are described above must be combined with other loads in accordance with ASCE 7. The design professional is permitted to combine loads by using Allowable Stress Design (ASD) or Strength Design (also known as Load Resistance Factor Design [LRFD]).

6.4 Step 4: Perform a Condition Assessment (Existing Structures)

When considering retrofitting an existing structure for dry floodproofing measures, design professionals must perform a condition assessment of the portions of the structures that will be relied on to resist the flood loads determined in Step 3. The assessment should be performed in two steps. The first step is a preliminary assessment consisting of a visual examination of the building and a review of available structural and architectural drawings.

If the preliminary assessment suggests that dry floodproofing may be possible, the second step is a more thorough assessment involving a review of as-built drawings (if available) and any plans or other documents related to any modifications of the structural elements after initial construction. Where adequate plans are not available, invasive testing to determine the structural aspects and condition of the building may be necessary. Cracks and penetrations through walls and slabs must be identified and examined to determine whether they would become pathways for seepage. The assessment results should be documented in written reports.

CONDITION ASSESSMENTS OF EXISTING STRUCTURES

See ASCE 11-99, *Guide for Structural Condition Assessment of Existing Buildings*, and Appendix C of FEMA P-936 for useful information on performing condition assessments of existing structures.

Design professionals use condition assessments to design modifications to existing structures that will satisfy dry floodproofing performance requirements. Modifications and key areas to identify include:

- Strengthening structural walls or floor systems
- Sealing wall penetrations
- Installing waterproofing membranes
- Locating where flood shields are needed
- Locating where seepage will accumulate and sump pumps are needed

If soil boring information for the site is not available, a geotechnical investigation may be necessary to determine lateral earth pressures and allowable soil-bearing capacities. Other geotechnical issues that may need to be considered include the presence of expansive or collapsible soils, potential for scour, permeability of soils, and compaction behavior of soils. See the discussion of site factors in FEMA P-936, Section 2.4, for additional information.

6.5 Step 5: Design or Check Structural Components for Resistance to Flood Loads

After flood loads have been determined in Step 3 and for existing buildings, the condition has assessed in Step 4, design professionals should next demonstrate that the structural elements (walls, foundations, and slabs) within areas to be dry floodproofed will have adequate strength to resist flood loads. To comply with ASCE 24, the structural components of new construction must be designed in accordance ASCE 7 to resist combined flood and other loads (e.g., dead load, live load, wind loads, seismic loads).

For existing buildings, the structural components that will resist flood loads need to be checked to determine whether they have adequate strength and stiffness. Structural components such as exterior walls, foundation elements, and diaphragms will likely experience substantial increases in loads after dry floodproofing measures are applied. Exterior walls commonly require strengthening with supplemental vertical or horizontal structural members to resist flood loads. Existing cracks and penetrations below the flood protection level must be sealed to limit seepage during flooding.

Another aspect of resistance to flood loads is whether building elements, such as slabs, have adequate resistance to uplift caused by buoyancy. ACI 350.4R-04, *Design Considerations for Environmental Engineering Concrete Structures* (ACI, 2004), is a helpful resource in determining the appropriate factor of safety to use to check uplift due to buoyancy. Some building elements may require strengthening or other modification to accommodate uplift pressures caused by buoyancy.

6.6 Step 6: Evaluate Building Utility Systems and Equipment

Designers must determine the needs of building utility systems and equipment in dry floodproofed buildings and identify the appropriate ways to satisfy floodplain management and building code requirements. The requirements apply to building utility systems (mechanical, electrical, and plumbing) and equipment (including fire controls and emergency power or generators).

The preferred solution is to locate building utility systems and equipment above the flood protection level. Building utility systems and equipment that serve non-residential buildings and non-residential portions of mixed-use buildings are allowed in dry floodproofed areas. If dry floodproofing systems fail or are overtopped by floodwater rising above the flood protection level, building utility systems and equipment may be damaged and not repairable, which could contribute to loss of building functionality. Backflow (non-return) valves or shutoff valves should be installed to prevent floodwater from entering through sewer and drainage pipes, and sewage ejectors should be installed to pump sewage to above the flood protection level before connecting to a vertical sewer line.

The NFIP regulations and ASCE 24 permit equipment and service facilities to be below the flood protection level when "designed … to prevent water from entering or accumulating within the components during conditions of flooding" (44 CFR § 60.3(a)(3)(iv)). The expectation is that after being submerged, equipment and facilities below the flood protection level will be able to be restored to functioning with minimal cleaning and repair. Unless equipment and service facilities are specifically designed to be submerged, they should be elevated on platforms or located on the roof, inside a freestanding engineered dry floodproofed walled area, or inside the dry floodproofed building. A good practice is to install connections for temporary equipment above the flood protection level or design interior core areas, as discussed in Section 3.3 of FEMA P-936. Additional guidance is available in FEMA P-348, *Protecting Building Utility Systems from Flood Damage* (2017).

When non-residential portions of mixed-use buildings are designed with dry floodproofing systems, the building utility systems and equipment that serve the residential uses are required to be elevated above the flood protection level and not located in areas that are protected with dry floodproofing (see Figure 5).

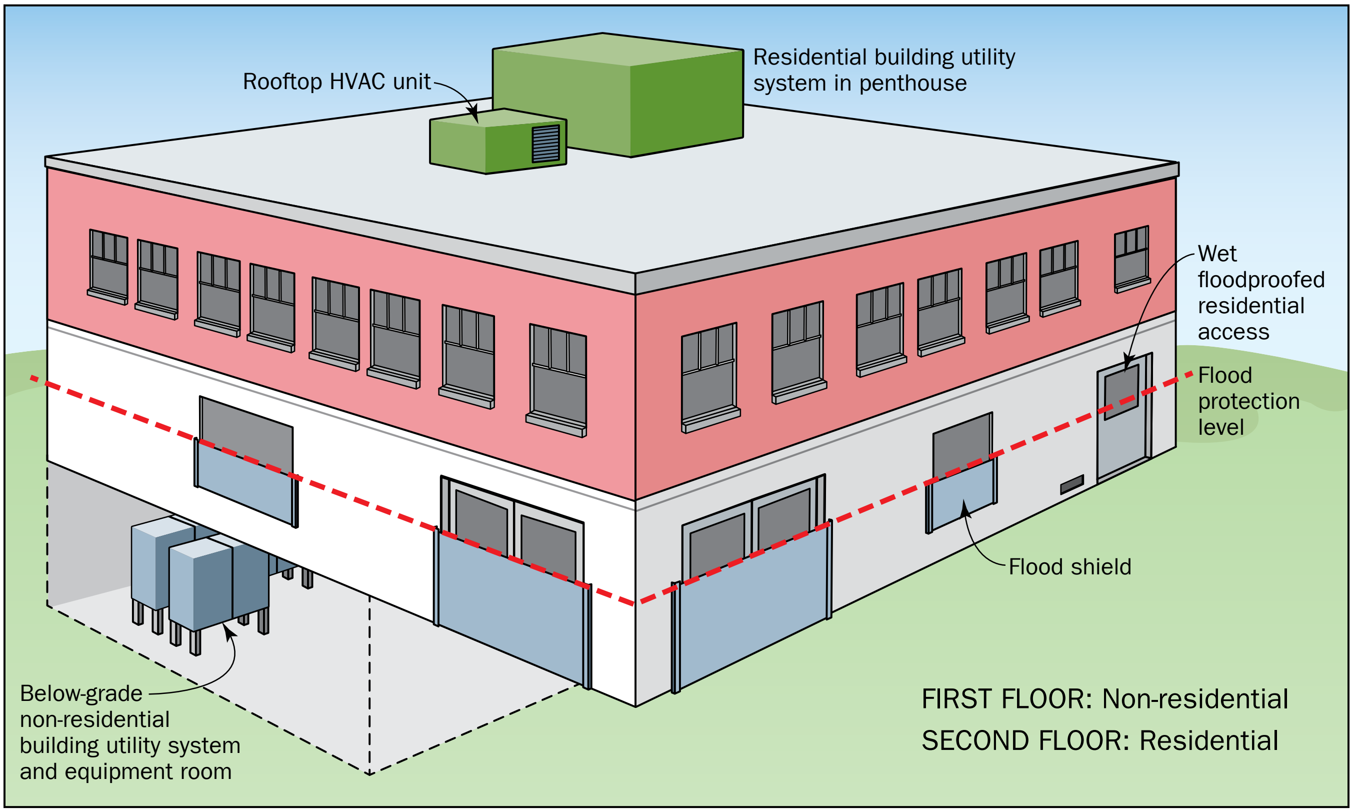

Figure 5: Mixed-use building with non-residential building utility systems and equipment in a dry floodproofed below-grade equipment room and elevated systems that serve the residential uses

6.7 Step 7: Design and Specify Flood Shields

When dry floodproofing systems are designed with doors, windows, or other openings below the flood protection level, design professionals must design or specify flood shields so the entire system performs as intended. Before finalizing designs, designers must determine the available warning time and the likely ability of personnel who would be responsible for deploying active dry floodproofing measures. Designers must also understand the requirements for installing different types of shields (see Section 5.2 of this Technical Bulletin).

Flood shields must be strong enough to resist all imposed flood loads. It is also critical to determine whether the shields will be mounted on structural elements of buildings or on door and window frames. When mounted on door and window frames, the frames must be capable of carrying the loads exerted on the shields. Designers should consider specifying flood shields that are tested and certified to the requirements of ANSI/FM 2510 (see Section 3.3 of this Technical Bulletin).

SPECIAL GLAZING SYSTEMS

Some manufacturers produce glazing (window) systems with laminated glass, seals, and frames designed to resist flood loads while meeting occupant needs for natural light. These window systems (sometimes called submarine or aquarium glass) are passive dry floodproofing measures because installing flood shields is not required when flooding is anticipated.

To limit seepage, flood shields typically have flexible gaskets around their perimeter. Various manufactured products are available. Figure 6 illustrates common types of shields, although other types may be available. Some permanent doors can be designed to function as flood shields when closed, although this may not be a viable option when doors are used frequently because of wear on gaskets and seals. Some flood shields are mounted next to openings to facilitate rapid deployment. Many flood shields are modular, can be stored nearby, and installed when needed.

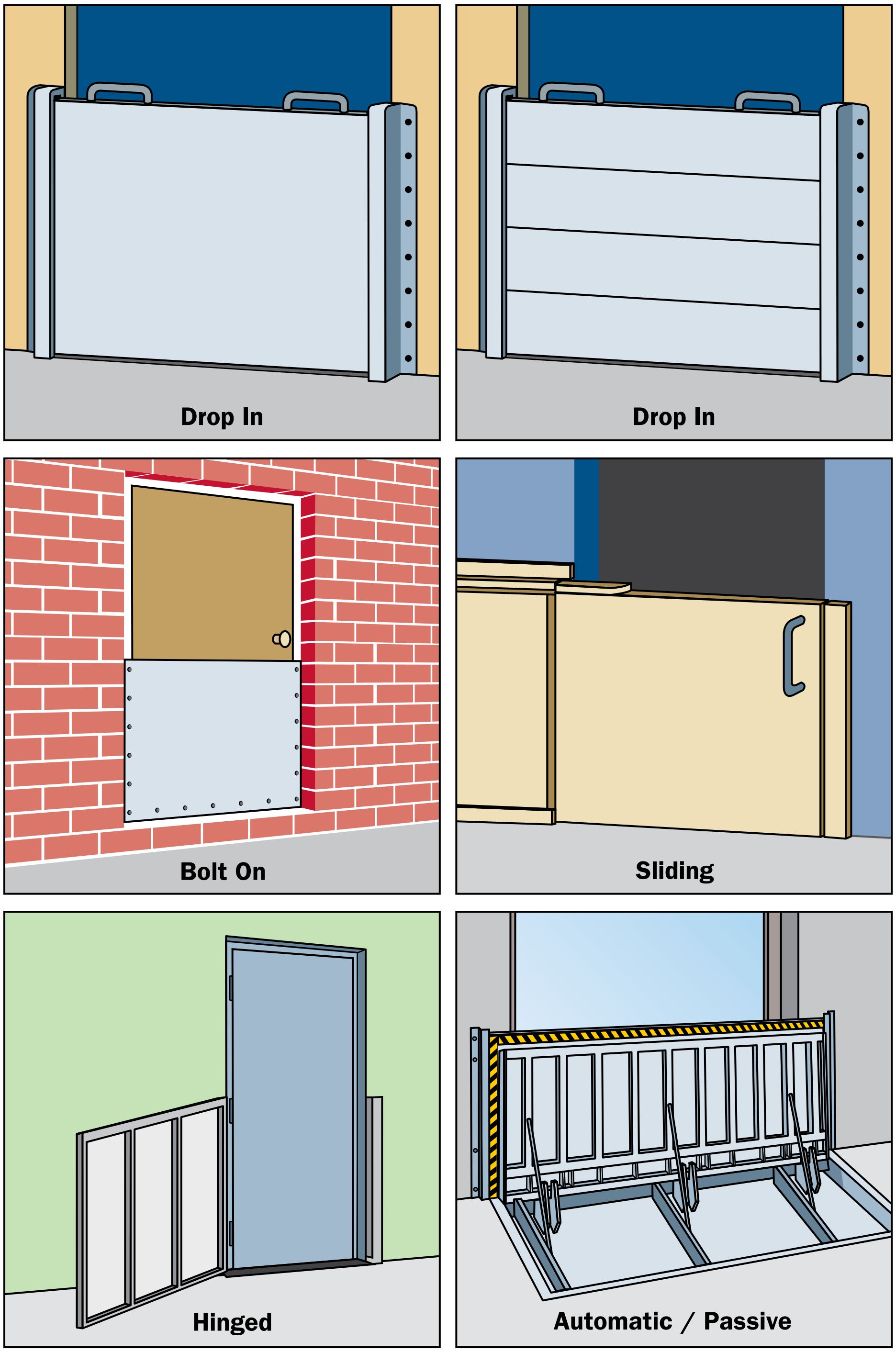

Figure 6: Common types of flood shields

Building owners and designers are cautioned that FEMA does not consider temporarily installed flood protection that covers walls, including glass curtain walls, to meet the NFIP minimum requirement that walls must be “substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy” (44 CFR § 60.3(c)(3)).

6.8 Step 8: Design Waterproofing System

In addition to ensuring that structures are capable of withstanding flood loads, design professionals need to ensure that areas below the flood protection level are watertight and substantially impermeable. To be considered substantially impermeable, the waterproofing system below the flood protection level must limit seepage through walls, floors, utility penetrations, joints, cracks, and around flood shields. The system must not allow more than 4 inches of water depth from seepage to accumulate during a 24-hour period without relying on devices to remove the water (e.g., sump pumps). Estimating seepage from each component of the waterproofing system is an important step because designers may need to alter designs to be able to certify that the designs stay within the accumulation limit.

6.8.1 Step 8A: Estimate Seepage through Wall Systems

Estimating the total seepage accumulation through a given wall system is challenging due to the many types of systems and the lack of available testing information for each type. However, in 2011, Oak Ridge National Laboratory (ORNL) tested 11 common wall assemblies under a simulated hydrostatic load for a 3-foot water depth to measure seepage when exposed to flooding over a 24-hour period. SERRI [Southeast Region Research Initiative] Report 80024-01, *Floodproof Construction: Working for Coastal Communities*, describes the test methodology and measured seepage accumulation for the 11 wall assemblies (ORNL, 2011).

The wall systems considered in the SERRI study included concrete masonry unit blocks with sprayed- and sheet-applied water-resistive membranes, insulated concrete formwork, and metal structural insulated panels. Designers should review the SERRI report to determine whether one of the tested wall systems could be considered similar enough to the wall system under consideration. If the wall systems are similar enough, the measured seepage accumulation results documented in the SERRI report could be used to derive approximate seepage values over a 24 hour period. Appendix B of this Technical Bulletin provides an example that illustrates the use of the SERRI results to estimate the seepage rate through a wall system to determine whether the dry floodproofed space is substantially impermeable.

The total seepage through a given wall system can be estimated by applying seepage rates to the area of wall exposed to floodwater. When using the SERRI report, the designer should recognize that the amount of seepage accumulation recorded in the study may not be fully representative of actual seepage volumes when there are differences in construction materials and methods from those described in the study and when flood conditions differ, such as flood depths other than 3 feet. When greater precision of wall seepage rates is desired, it may be necessary to construct a mockup for a particular wall assembly to test under hydrostatic load to measure seepage rates.

For an example calculation of seepage through walls, see Steps 1a and 1b in Appendix B.

6.8.2 Step 8B: Estimate Seepage through Joints and Penetrations

Various joints and gaps around utility penetrations are typically present in below-grade foundation systems and, in particular, the joints between foundations and lowest slabs. Because of the difficulty of sealing the joint between the exterior wall and slab, this joint is the most prone to allowing seepage into dry floodproofed areas (see Figure 7). In new construction, designers should specify and detail waterstops or joint seals that can resist the anticipated hydrostatic pressures.

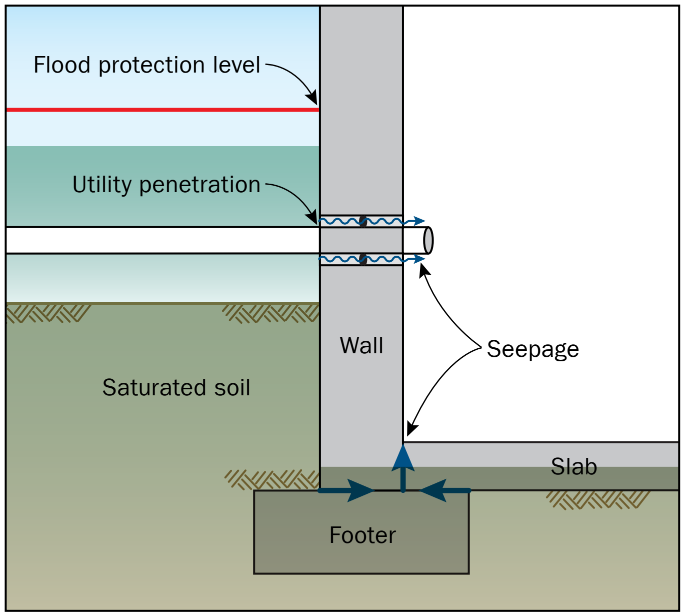

Figure 7: Typical seepage paths for water entering through joints between wall, footer, and slab

A common approach for existing buildings is to inject chemical grout into joints, wall penetrations, and cracks. The grout reacts with water and expands to form watertight, flexible seals. When determining whether this method is appropriate for expansion joints, the designer should evaluate whether the chemical grout would allow the joints to perform as intended. Alternative sealing products use a flexible material that fills the space between the utility penetration and the wall when fasteners are tightened. If known cracks or joints are not sealed, the designer will need to take these seepage sources into account when determining total seepage in a 24-hour period.

During the design of floodproofing systems for new buildings and when assessing the condition of existing buildings, designers should identify all joints and penetrations in the walls and slabs. Seepage through joints and penetrations must be estimated. An example of the calculation of seepage through expansion joints is shown in Appendix B. Manufacturers of some of the materials that are used to seal expansion joints and other penetrations may provide information that can be used to estimate seepage rates. When seepage rates under flood conditions are not provided or deemed inadequate for the purpose of dry floodproofing, designers may decide that it is necessary to perform mock-up testing of joints or penetration assemblies using the anticipated hydrostatic pressures.

For an example calculation of seepage through expansion joints, see Step 2 in Appendix B.

6.8.3 Step 8C: Estimate Seepage around Flood Shields

When flood shields are included in dry floodproofing systems, designers need to estimate the expected seepage around the wetted perimeter of each shield, which typically has a gasket that seals the shield to the building walls, frames around openings, or foundations. The amount of seepage depends on several factors, including the duration of flooding and integrity of the seal which, in turn, depends on maintenance and installation. Designers may need to adjust the initial designs, reduce the number of flood shields, or specify a different types of flood shield if the calculations indicate that the seepage will exceed the total allowed accumulation of seepage (4 inches over a 24-hour period).

> **GASKET AND SEAL MAINTENANCE: CRITICAL FOR PERFORMANCE**
>
> Post-disaster assessments have indicated that poorly maintained shield gaskets and seals are a common source of excessive water leakage. This situation can occur when gaskets and seals deteriorate due to weather or dry rot or are torn during handling or storage and are not replaced.

Manufacturers of various types of flood shields with gaskets and seals have tested some products under hydrostatic load to measure seepage rates (see Section 3.3 of this Technical Bulletin). Testing information should be obtained from manufacturers to estimate the volume of seepage, which may be provided as gallons per hour per linear foot of wetted perimeter.

For an example calculation of seepage around flood shields, see Step 3 in Appendix B.

6.8.4 Step 8D: Estimate Total Seepage through Waterproofing System

After estimates of seepage through wall systems, through joints and penetrations, and around flood shields are calculated, the total seepage can be estimated. For buildings to be certified as meeting the substantially impermeable requirement, the maximum accumulation in the dry floodproofed portion of the buildings must not exceed 4 inches of water depth over a 24-hour period without relying on devices for removal of water. If the total seepage estimate exceeds the 24-hour limit, the designer must adjust the design and selected components as necessary to satisfy the accumulation limit. Although sump pumps are required to handle seepage (see Step 9), sump pumps cannot be relied on to meet the maximum accumulation limit of 4 inches over a 24-hour period.

For an example calculation estimating total seepage, see Step 4 in Appendix B.

6.9 Step 9: Design Interior Drainage

Most spaces below the flood protection level of dry floodproofed buildings will not stay completely dry during flood events. Therefore, interior drainage systems should be designed to limit the accumulation of seepage. Designs must specify the paths along which seepage will flow and collect and where drains and sumps will be installed. ASCE 24 requires the use of sump pumps to remove water accumulation due to any passage of vapor and seepage of water during flooding events, described in Step 8.

If a building loses power, backup power fails to work properly, or sump pumps fail to operate, significant amounts of seepage could accumulate. For this reason, sump pumps cannot be relied on as the sole or primary means of meeting the dry floodproofing requirements. Sump pumps should only be relied on to address minor seepage and leaks that were not properly identified during condition assessments of existing buildings.

Sump pumps should be located at the point of lowest slab elevation, with the bottom of sump pits positioned well below the bottom of base slabs. A typical sump pump detail is shown in Figure 8. In large below-grade areas, it is common practice to install piping in gravel-filled trenches below the base slab at the perimeter of the foundation

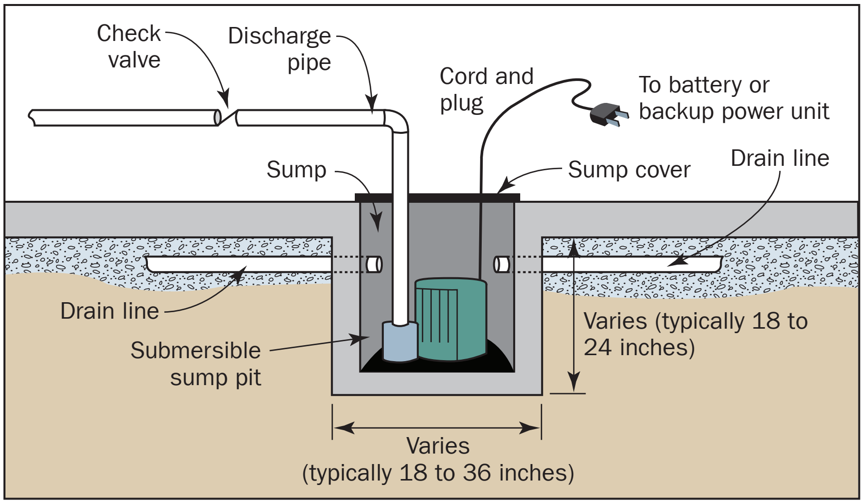

Figure 8: Typical sump pump detail

walls to provide a path for groundwater to access one or more sump pumps. A quickly rising water table or saturation from surface water, which occurs in many flood conditions, can produce enough seepage to overwhelm sump pumps if seepage rates into dry floodproofed spaces are high. Backup or emergency power for sump pumps is necessary due to the potential for power outages during flood events.

To select a sump pump as part of a dry floodproofing system, the designer should consider the advantages of each pump type and make the selection based on the estimate of total seepage rate (Step 8), pump capacity (gallons per minute), pump head, and electrical power required to operate the pump.

6.10 Step 10: Certify the Design and Satisfy Requirements for Plans

The final step in the dry floodproofing design process is for registered professional engineers or architects to certify designs. FEMA Form 086-0-34, NFIP Floodproofing Certificate for Non-Residential Structures, is used by most communities to meet the NFIP requirement that communities obtain certifications for dry floodproofing designs. See Section 1.2 of this Technical Bulletin for additional information on the certificate and Appendix A for instructions on completing the certificate.

When human intervention is required to implement any component of dry floodproofing systems, ASCE 24 requires designers to meet specific requirements related to flood warning time (see Section 5.2 of this Technical Bulletin), flood shield design (Step 7, above), and flood emergency operations plans (see Section 5.5 of this Technical Bulletin). These requirements are also discussed in FEMA P-936. When dry floodproofing system designs are complete, designers should verify that flood emergency operations plans address all required elements and should review the plans with building owners.

REQUIRED DOCUMENTS FOR NFIP FLOOD INSURANCE POLICIES FOR DRY FLOODPROOFED BUILDINGS

When building owners apply for NFIP flood insurance policies for a dry floodproofed building, the NFIP requires a signed and sealed NFIP Floodproofing Certificate, flood emergency operations plan, and inspection and maintenance plan.

Inspection and maintenance plans, described in Section 5.5 of this Technical Bulletin, are necessary for the long-term functioning of dry floodproofing systems. When dry floodproofing system designs are complete, designers should verify that inspection and maintenance plans address all required elements and should review the plans with building owners.

7 References

This section lists references cited in the Technical Bulletin. Additional resources related to NFIP requirements are provided in Technical Bulletin 0.

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- Technical Bulletin 0, *User's Guide to Technical Bulletins*
- Technical Bulletin 1, *Requirements for Flood Openings in Foundation Walls and Walls of Enclosures*
- Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements*
- Technical Bulletin 6, *Requirements for Dry Floodproofed Below-Grade Parking Areas Under Non-Residential and Mixed-Use Buildings*
- Technical Bulletin 7, *Wet Floodproofing Requirements*

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Appendix A: FEMA Form 086-0-34, National Flood Insurance Program Floodproofing Certificate for Non-Residential Structures

Appendix A of the National Flood Insurance Program's Technical Bulletin 3, *Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings*, includes guidance on completing FEMA Form 086-0-34, National Flood Insurance Program Floodproofing Certificate for Non Residential Structures. Communities that participate in the National Flood Insurance Program (NFIP) must require that designs for dry floodproofing be certified by a registered professional engineer or architect. The registered design professional must develop or review the structural designs, specifications, and plans for the construction of dry floodproofed buildings and must certify that the designs and methods of construction are in accordance with accepted standards of practice for achieving the required performance. Communities must maintain the certifications in their permanent records. These requirements are established in the Floodplain Management Criteria section of Title 44 Code of Federal Regulations (CFR) §§ 60.3(c)(3) and (4).

The following instructions are based on the NFIP Floodproofing Certificate that was issued in Dec. 2019, and that is scheduled to expire on Nov. 30, 2022. Design professionals must use the current NFIP Floodproofing Certificate or an equivalent statement to comply with the requirement.

TOP OF THE FORM

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.

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

Instructions:

A Enter the building owner's name and the address of the building.

SECTION I

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 AO Zones, Use Depth)
B					C
D Indicate elevation datum used for Base Flood Elevation shown above: ☐ NGVD 1929 ☐ NAVD 1988 ☐ Other/Source:					

Instructions:

B Enter the following information from the Flood Insurance Rate Map (FIRM) and Map Index:

- Community Number – Six-digit identification number assigned to the community (also referred to as the community identification number or CID). Shown in the title block of the FIRM (see Figure A-1).
- Panel Number and Suffix –Identification of the FIRM panel that includes the subject property, shown in the title block of the FIRM (see Figure A-1).
- Date of FIRM Index – Most recent revision date for the community's FIRMs is the date on the FIRM Map Index, which may or may not be the date on the FIRM panel for the property (see Figure A-2).
- FIRM zone – The flood zone in which the building is located, obtained from the FIRM.

C Enter the base flood elevation (BFE) at the location of the building. Special Flood Hazard Areas (SFHAs) identified as Zone AO do not have BFEs; instead, a depth number may be shown (use depth of 2 feet if no depth number is shown).

D Select the elevation datum used for the BFE. The vertical datum is shown on the FIRM map legend or in "Notes to Users" on the FIRM.

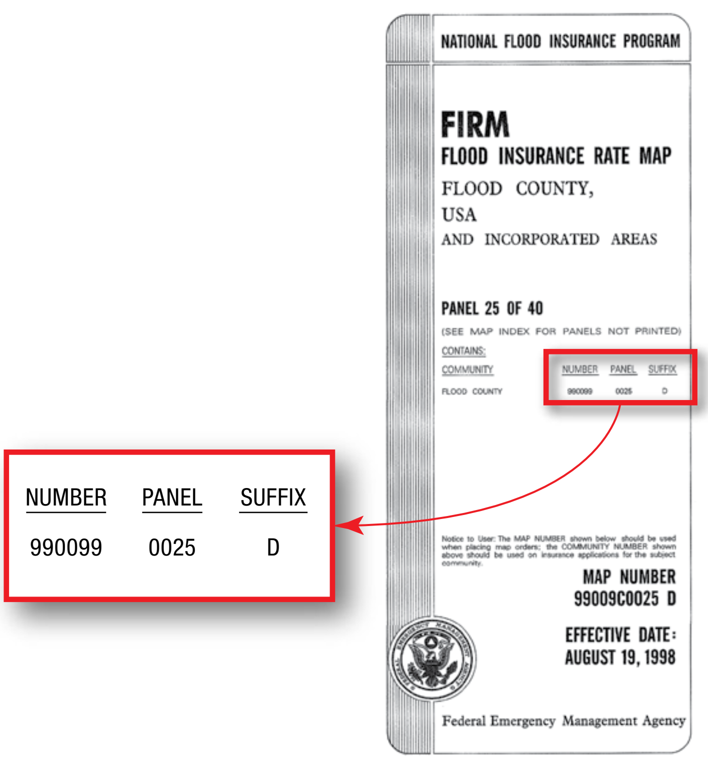

Figure A-1: Typical FIRM title block

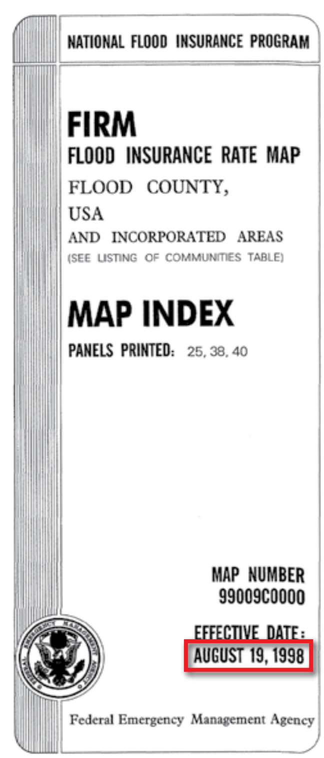

Figure A-2: Typical FIRM map index

SECTION II

Section II is used to certify the elevation (where BFEs are provided on FIRMs) or the height above the lowest adjacent grade (where BFEs are not provided) to which the building is floodproofed. Section II is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. Persons who sign and seal elevation information must be licensed or authorized to practice surveying in the state where projects are located.

SECTION II – FLOODPROOFED ELEVATION CERTIFICATION (By a Registered Professional Land Surveyor, Engineer, or Architect)

All elevations must be based on finished construction.

Floodproofing Elevation Information:

Building is floodproofed to an elevation of **E** . feet (In Puerto Rico only: . meters).

F ☐ NGVD 1929 ☐ NAVD 1988 ☐ Other/Source:

(Elevation datum used must be the same as that used for the Base Flood Elevation.)

Height of floodproofing on the building above the lowest adjacent grade is **G** feet (In Puerto Rico only: meters).

For Unnumbered A Zones Only:

Highest adjacent (finished) grade next to the building (HAG) **H** . feet (In Puerto Rico only: . meters).

I ☐ NGVD 1929 ☐ NAVD 1988 ☐ Other/Source:

(NOTE: For insurance rating purposes, the building's floodproofed design elevation must be at least 1 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. See the Instructions section for information on documentation that must accompany this certificate if being submitted for flood insurance rating purposes.)

Instructions:

E Enter the floodproofing elevation in whole and decimal units. The floodproofing elevation is the top of the floodproofing measures ("height of floodproofing").

The floodproofing elevation must be referenced to the same vertical datum as the BFE identified in Section I.

F Enter the vertical datum the floodproofing elevation is referenced to (NGVD 1929, NAVD 1988, or a locally adopted vertical datum). For a locally used vertical datum, check "Other/Source" and describe the datum and provide the source.

G Enter the height of the floodproofing measures above the lowest adjacent grade. The lowest adjacent grade is the lowest ground next to the building.

H For unnumbered A Zones, enter the elevation of the highest finished grade adjacent (HAG) next to the building.

I Enter the vertical datum the HAG is referenced to (NGVD 1929, NAVD 1988, or a locally adopted vertical datum). For a local vertical datum, check "Other/Source" and describe the datum and provide the source.

SECTION II (cont.)

FLOODPROOFING CERTIFICATE FOR NON-RESIDENTIAL STRUCTURES

Non-Residential Floodproofed Elevation Information Certification:

Section II certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information

I certify that the information in Section II on this Certificate represents a true and accurate interpretation and determination by the undersigned using the available information and data. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.

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

Instructions:

J Enter the name, license number, title, company name, and address and phone number of the individual completing Section II. Section II is to be completed (signed, dated, and sealed) by a land surveyor, engineer, or architect authorized by law to certify floodproofed elevation information.

SECTION III

Section III is used by a registered professional engineer or architect to certify that "the structure, based upon development and/or review of the design, specifications, as-build drawings for construction and physical inspection" has been designed and constructed in accordance with "the accepted standards of practice (ASCE 24-05, ASCE 24-14, or their equivalent) and any alterations [of the structure]" meet those standards, are watertight and substantially impermeable and will perform in accordance with 44 CFR § 60.3(c)(3). The designer also certifies the structure has structural components that are "capable of resisting hydrostatic and hydrodynamic flood forces, including the effects of buoyancy, and anticipated debris impact forces."

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

Non-Residential Floodproofed Construction Certification:

K

I certify the structure, based upon development and/or review of the design, specifications, as-built drawings for construction and physical inspection, has been designed and constructed in accordance with the accepted standards of practice (ASCE 24-05, ASCE 24-14 or their equivalent) and any alterations also meet those standards and the following provisions.

The structure, together with attendant utilities and sanitary facilities is watertight to the floodproofed design elevation indicated above, is substantially impermeable to the passage of water, and shall perform in accordance with the 44 Code of Federal Regulations (44 CFR 60.3(c)(3).

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 in Section III on this certificate represents a true and accurate determination by the undersigned using the available information and data. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.

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

Instructions:

K The signer of Section III certifies that floodproofing has been designed and constructed to meet accepted standards of practice. Accepted standards of practice must ensure that the criteria of the 2005 or 2014 editions of ASCE 24, *Flood Resistant Design and Construction* (or the equivalent), are met and that the two specific design statements are valid.

ASCE 24 contains several criteria for dry floodproofing. Design professionals who prepare designs for dry floodproofed buildings and certify NFIP Floodproofing Certificates should review all ASCE 24 criteria before completing and signing the certificate. Also see Technical Bulletin 3 and FEMA P-936, *Floodproofing Non-Residential Buildings*.

L Enter the name, license number, title, company name, and address and phone number of the individual completing Section III. Section III is to be completed (signed, dated, and sealed) by a registered professional engineer or architect authorized by law to certify structural designs.

END OF THE FORM

The end of the NFIP Floodproofing Certificate lists information that must be attached. The information is needed by the program's underwriters to provide credit for floodproofing. The information also helps to ensure compliance and provide reasonable assurance that due diligence has been applied in designing and constructing floodproofing measures. When the Floodproofing Certificate is used to obtain flood insurance coverage from the NFIP, building owners should consult with flood insurance providers to determine additional required documentation described in the *National Flood Insurance Program Flood Insurance Manual* (FEMA, 2020b).

FLOODPROOFING CERTIFICATE FOR NON-RESIDENTIAL STRUCTURES

Instructions for Completing the Floodproofing Certificate for Non-Residential Structures

To receive credit for floodproofing, a completed Floodproofing Certificate for Non-Residential Structures is required for non-residential and business buildings in the Regular Program communities, located in zones A1–A30, AE, AR, AR Dual, AO, AH, and A with BFE.

M In order to ensure compliance and provide reasonable assurance that due diligence had been applied in designing and constructing floodproofing measures, the following information must be provided with the completed Floodproofing Certificate:

- Photographs of shields, gates, barriers, or components designed to provide floodproofing protection to the structure.
- Written certification that all portions of the structure below the BFE that will render it watertight or substantially impermeable to the passage of water and must perform in accordance with Title 44 Code of Federal Regulations (44 CFR 60.3 (c)(3)).
- A comprehensive Maintenance Plan for the entire structure to include but not limited to:
    - Exterior envelope of the structure
    - All penetrations to the exterior of the structure
    - All shields, gates, barriers, or components designed to provide floodproofing protection to the structure
    - All seals or gaskets for shields, gates, barriers, or components
    - Location of all shields, gates, barriers, and components as well as all associated hardware, and any materials or specialized tools necessary to seal the structure.

Instructions:

M The additional information listed in the "Instructions for Completing the Floodproofing Certificate for Non-Residential Structures" at the end of the Floodproofing Certificate must be included.

Appendix B: Example Calculation for Estimating Total Seepage

Appendix B of the National Flood Insurance Program's Technical Bulletin 3, *Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings*, contains an example calculation for estimating the total expected seepage into a dry floodproofed area. Total seepage is the combination of seepage through the wall system, seepage around flood shields (barriers), and seepage through joints and penetrations. A description of the calculation of seepage that is illustrated in this appendix is provided in the Technical Bulletin, Section 6.8, Step 8: Design Waterproofing System.

To be able to design and certify that a building is substantially impermeable, the design professional needs to estimate the total expected seepage into dry floodproofed areas. A dry floodproofed building that is made substantially impermeable through the use of materials and techniques allows limited accumulation of water to pass or seep through pathways (e.g., cracks, openings, channels) and points of entry during flooding. Water is allowed to accumulate to a depth of not more than 4 inches in a 24-hour period without relying on devices for removal of water.

The estimate of expected total seepage is used to determine whether the proposed dry floodproofing measures will meet the requirement (expected depth of accumulated water is not more than 4 inches). If the expected total seepage accumulation exceeds the maximum allowance, the designer must select one or more alternatives to meet the requirements, such as a different wall system, fewer openings that require flood shields, different types of shields, or relocating utility penetrations.

The example calculation in this appendix illustrates how to calculate seepage for an example building. To estimate the seepage through the wall system, the example applies the results of a seepage study by Oak Ridge National Laboratory, which were published in SERRI Report 80024-01, *Floodproof Construction: Working for Coastal Communities* (ORNL, 2011). The study tested a series of "pods" constructed of different materials using different methods by exposing them to 3 feet of water over more than 24 hours.

The wall system selected for the example calculation is identified in the SERRI report as "Test Pod H." Test Pod H was constructed of 8-inch concrete masonry unit (CMU) blocks with elastomeric weatherproofing membrane sprayed onto the exterior of the CMU block face. Excerpts from the SERRI report are included in this appendix, including a diagram of Test Pod H and observations from the flood simulation tests.

SERRI REPORT BASED ON 3-FOOT FLOOD DEPTH

It is important to note that the seepage accumulation in the SERRI report is based on a 3-foot flood depth (ORNL, 2011).

Designers should use caution when estimating total seepage rates for greater flood depths because the seepage rate may be higher because hydrostatic loads would be greater.

Calculation of Expected Seepage in an Example Building

Table B-1 and Calculation Steps 1 through 4 illustrate the calculation of the expected seepage for an example building with a wall system that is similar to the one used for Test Pod H in the SERRI report (CMU block with liquid membrane sprayed onto the exterior of the CMU face). Figure B-1 is the plan view of the example building.

Table B-1: Example Building Information

Description	Example Value	Notes
Flood depth Building length Building width	h = 3 feet L = 30 feet W = 40 feet	
Exterior doors Number Width	 n_{door} = 3 W_{door} = 6 feet	 Each door is 6 feet wide.
Length of joints in exterior wall through which seepage is expected	L_{EJ} = 48 feet	The assumption of 48 feet for the example building is based on the likely placement of expansion joints.

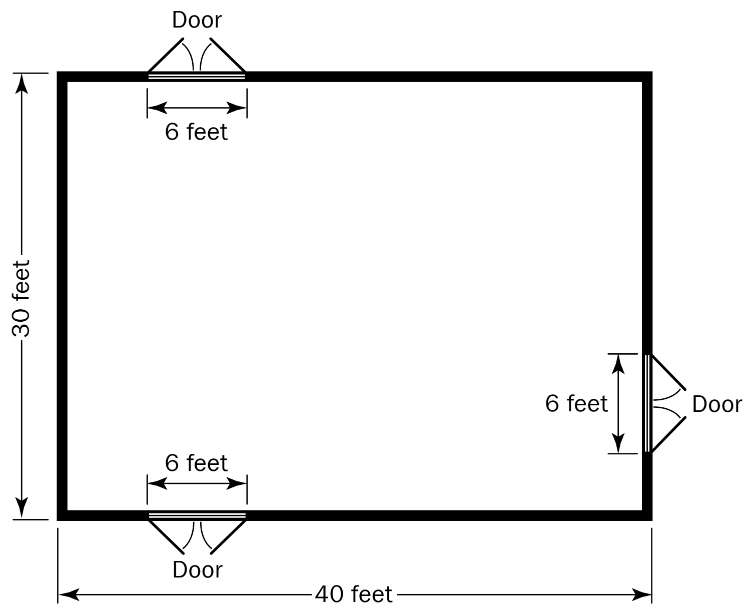

Figure B-1: Example building plan view

Calculation Step 1a. Estimate the seepage rate through the wall system.

This example uses the seepage rate through the wall system of Test Pod H from SERRI Report 80024-01. The seepage rate through the walls of Test Pod H is calculated using the volume of seepage that accumulated during a 24-hour period, divided by the area of the pod.

Area of test pod	$A_{pod} = 6\text{ ft} \times 6\text{ ft} = 36\text{ ft}^2$
Test pod wetted perimeter	$p_{pod\_w} = 6\text{ ft} + 6\text{ ft} + 6\text{ ft} + 6\text{ ft} = 24\text{ ft}$
Test pod wetted area (flood depth is 3 feet)	$A_{pod\_w} = 3\text{ ft} \times p_{pod\_w} = 72\text{ ft}^2$
Depth of water (inches) in test pod in 24 hours	$d_w = 15.5\text{ in} = 1.3\text{ ft}$ Note: Depth of water selected from the SERRI report, page A-5, Table A.2 (shown below)
Volume of seepage in test pod in 24 hours	$V_{pod\_s} = d_w \times A_{pod} = 46.8\text{ ft}^3$
Seepage rate through walls of test pod	$R_{wall} = V_{pod\_s} \div A_{pod\_w} = 0.65\text{ ft}^3/\text{ft}^2$ per 24 hours

Calculation Step 1b. Apply the estimated seepage rate to the example building to determine the volume of seepage through the walls of the example building in 24 hours

This example uses the seepage rate determined in Calculation Step 1 for the wall system of Test Pod H from the SERRI Report 80024-01.

Example building area	$A_{bldg} = L \times W = 1{,}200\text{ ft}^2$
Total width of doors	$L_{door} = n_{door} \times w_{door} = 18\text{ ft}$
Building wall wetted perimeter	$p_w = (2 \times L) + (2 \times W) - L_{door} = 122\text{ ft}$
Building wall wetted area	$A_{wall} = p_w \times h = 366\text{ ft}^2$
Seepage through wall system	$S_{wall} = A_{wall} \times R_{wall} = 238\text{ ft}^3$ per 24 hours

Calculation Step 2. Determine the volume of seepage around flood barriers (shields) installed over doors of the example building in 24 hours

Some manufacturers test flood shields and gaskets under varying conditions to determine seepage rates (see Section 3.3 in the Technical Bulletin). Seepage rates are often reported in the volume of seepage per length of gasket in a given period of time (ft³/ft-hr or gal/ft-hr).

Door wetted length	$L_{door\_w} = n_{door} \times (h + h + w_{door}) = 36$ ft
Flood barrier (shield) seepage rate	$R_{FB} = 0.08$ gal/ft-hr $= 0.011\ ft^3/$ft-hr Note: 0.08 gal/ft-hr is based on a manufacturer's technical specification. Designers must determine the actual rate based on specified flood shield(s).
Seepage through flood barriers (shields)	$S_{FB} = L_{door\_w} \times R_{FB} \times 24\ hr = 10\ ft^3$ per 24 hours

Calculation Step 3. Determine the seepage volume through expansion joints in the example building over 24 hours

Determination of the seepage rate through expansion joints may be difficult and may require more research than wall seepage estimates or flood shield gasket seepage rates. Some manufacturers may provide sufficient product information to allow the designer to estimate the amount of seepage through joint sealants under flood conditions. When seepage rates under flood conditions are not provided or are deemed inadequate for this purpose, designers may decide that it is necessary to perform mock-up testing of joints or penetration assemblies using the anticipated hydrostatic pressures (see Section 6, Step 8B, in the Technical Bulletin).

This example considers only seepage through expansion joints. Additional estimates must be made if there are penetrations and cracks below the flood protection level.

Seepage rate at expansion joints	$R_{EJ} = 0.80$ gal/ft-hr $= 0.107\ ft^3/$ft-hr Note: 0.80 gal/ft-hr is based on testing of similar joint sealants. Designers must determine an appropriate seepage rate based on specified sealants.
Seepage through all expansion joints	$S_{EJ} = L_{EJ} \times R_{EJ} \times 24\ hr = 123\ ft^3$ per 24 hours

Calculation Step 4. Calculate the total estimated seepage for the example building

Seepage through walls, plus flood barriers (shields), plus expansion joints	$S_{Total} = S_{wall} \times S_{FB} + S_{EJ} = 371\ ft^3$ per 24 hours
Depth of seepage per 24 hours	$d_{Seep} = S_{Total} \div A_{bldg} = 0.31$ feet or 3.72 inches per 24 hours

Conclusion

For the example building, the total estimated seepage is less than 4 inches in 24 hours, which means the example building meets the requirement to be considered substantially impermeable. The designer must also satisfy other requirements including determining where the seepage will accumulate and the paths along which seepage water will flow to get to the accumulation area. The interior drainage collection system must be designed to limit the accumulation of seepage (see Section 6, Step 9, of the Technical Bulletin).

SERRI Report Excerpts

4.2.8 Test Pod H: Weatherproofed Block

Test pod H: weatherproofed block (Fig. 4.15) was a CMU block structure with a liquid membrane sprayed onto the exterior of the CMU face.

- First course (8″ in height) of CMU cells filled with mortar.
- Fully grouted CMU cells located at corners and at the middle of each wall.
- The flood resistive layer was an elastomeric waterproofing coating for masonry and concrete, applied in four thick coats.
- Design was developed as an inexpensive alternative to test pod A: sealed block which performed well with a high-end spray-applied water resistive layer.
- Elastomeric coating was applied with a residential sprayer.

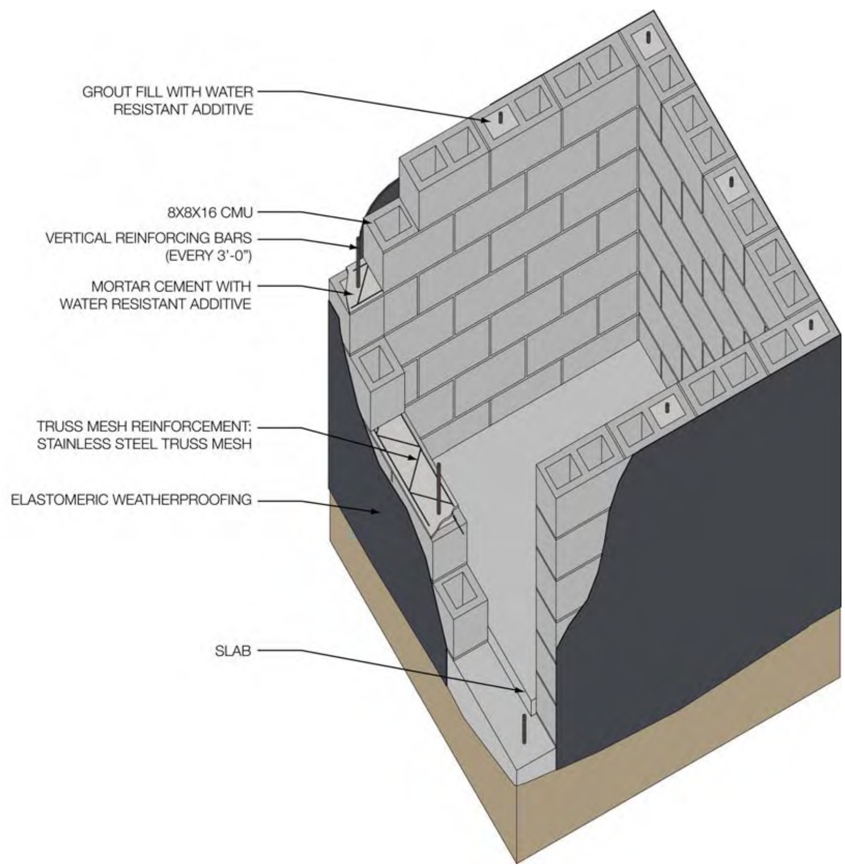

Fig. 4.15. DIAGRAM: test pod H: weatherproofed block.

A.2 Observations From Flood Simulation 2

Table A.2 is a log of the visual observations taken during flood simulation 1, which took place between June 28th, 2011 and June 29th, 2011. At specific time intervals, which are noted in the second column of this table, interior water depths were recorded for each test pod. Also, key observations regarding assembly changes are noted where applicable.

Table A.2. Observations from flood simulation 2.

Date	Time	Flooding Simulated Depth (in)	Test Pod G Interior Water Depth (in)	Test Pod H Interior Water Depth (in)	Test Pod A Interior Water Depth (in)	Test Pod B2 Interior Water Depth (in)	Test Pod D2 Interior Water Depth (in)	Test Pod F2 Interior Water Depth (in)
28-Jun	7:45 AM	0	0	0	0	0	0	0
	8:36 AM	10	*seepage south wall*	0	0	0	*seepage two corners*	*seepage two corners*
	8:50 AM	14	*more seepage, capillary action*	*seepage started*	0	0	*more seepeage*	*more seepage*
	9:45 AM	24	0	seepage	0	*seepage, early cells are seepaging more*	seepage	0.13
	10:45 AM	36	0.25	1.5	0	0.5	0.5	0.25
	11:45 AM	36	0.5	3.75	*corner seepage*	1.5	0.5	0.25
	12:45 PM	36	0.75	***6***	0	2.25	0.5	0.25
	1:45 PM	36	1	*6.5*	0	3	1	0.25
	2:45 PM	36	1	*8*	0	***4***	1.25	0.25
	3:45 PM	36	1.25	*9*	0	*5*	1.25	0.25
	5:45 PM	36	1.5	*10*	0	*7*	3	0.5
	7:45 PM	36	1.5	*12*	0.25	*8*	3	0.5
	9:45 PM	36	2.5	*12.5*	0.25	*9*	2.5	0.5
	11:45 PM	36	2.5	*14*	0.25	*10*	2.5	0.5
29-Jun	1:45 AM	36	3	*13.5*	0.25	*10*	3	0.5
	3:45 AM	36	3	*15*	0.25	*13.5*	3	0.5
	5:45 AM	36	3	*15.5*	0.25	*13.5*	3	0.5
	7:45 AM	36	3.5	*15.5*	0.25	*13.5*	3	0.5
	9:45 AM	36	3.5	*16*	0.25	*14*	3.5	0.5
	10:45 AM	36	3.75	*16.5*	0.25	*14.5*	3.75	0.5
	11:45 AM	31	3.75	*16.75*	0.25	*14.5*	3.75	0.5
	1:45 PM	12	3.75	*17*	0.25	*15.5*	3.75	0.5
	5:00 PM	0	**3.75**	*17*	**0.25**	*15.5*	**3.75**	**0.5**