HURRICANE
SANDY
IN NEW JERSEY
AND NEW YORK

C Recovery Advisories and Fact Sheets for Hurricane Sandy

FEMA has prepared a series of Recovery Advisories (RAs) and Fact Sheets to describe mitigation measures that can be taken to minimize future flood damage to buildings. These advisories are based on field observations conducted by the FEMA Mitigation Assessment Team (MAT) deployed to evaluate the damage caused by Hurricane Sandy. All RAs and Fact Sheets prepared for Hurricane Sandy recovery activities are included in this appendix and comprise the following:

RA1. Improving Connections in Elevated Coastal Residential Buildings

RA2. Reducing Flood Effects in Critical Facilities

RA3. Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Buildings

RA4. Reducing Interruptions to Mid- and High-Rise Buildings During Floods

RA5. Designing for Flood Levels Above the BFE After Hurricane Sandy

RA6. Protecting Building Fuel Systems from Flood Damage

RA7. Reducing Flood Risk and Flood Insurance Premiums for Existing Residential Buildings in Zone A

Fact Sheet 1. Cleaning Flooded Buildings

Fact Sheet 2. Foundation Requirements and Recommendations for Elevated Homes

The RAs and Fact Sheets are also available online at http://www.fema.gov/building-science/hurricane-sandy-building-science-activities-resources.

Improving Connections in Elevated Coastal Residential Buildings

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA1, February 2013*

Purpose and Intended Audience

FEMA post-disaster assessment teams observed residential buildings damaged during Hurricane Sandy that had inadequate connections between the elevated floor and the pile foundation (Figure 1). This Recovery Advisory describes how to improve connections attaching elevated floors to pile foundations. The improved connection details herein are no substitute for properly elevating a building above the base flood elevation (BFE). Even properly elevated homes may experience an event greater than the base flood. The improved connection details presented in this advisory will reduce potential damage from future wind events and provide added resistance against flood-related structural failure in the event that flood levels exceed the elevated height of the floor. Readers of this Recovery Advisory should consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*, on properly elevating buildings.

Figure 1: Building with insufficient connectors (red circle) washed off its pile foundation when elevated floor-to-pile connectors failed. Stronger connectors were used on the house in the background (Ortley Beach, NJ).

Although the information in this Recovery Advisory is most useful for new construction, the same concepts can be applied to retrofits of existing construction. The intended audience for this Recovery Advisory is builders, architects, and engineers. This Recovery Advisory uses the concept of load paths. Readers unfamiliar with load paths can find an overview in FEMA P-499, *Home Builder's Guide to Coastal Construction*, Category 4 – Load Paths technical fact sheets (refer to Table 1).

Key Issues:

1. Inadequate connections between structural building elements can lead to failure during a flood or high-wind event.
2. The connection between an elevated floor and a pile foundation must be designed to withstand both uplift and lateral loads (Figure 2).
3. Connectors for elevated floor-to-pile foundation elements are often exposed to salt water and must be protected from corrosion. Connectors should be inspected regularly and replaced as needed.

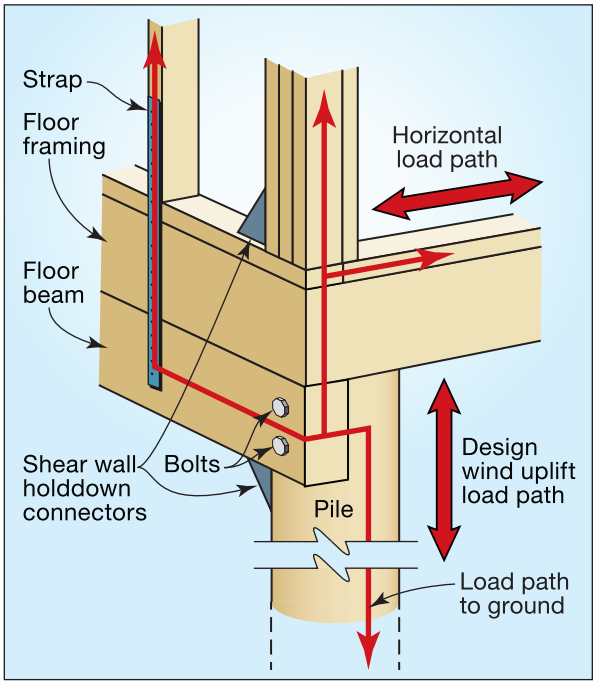

Figure 2: Example load paths through a floor-to-pile foundation connection

This Recovery Advisory Addresses:

- Strengthening elevated floor-to-pile foundation connections
- Protecting metal connectors and brackets from corrosion
- Resources for strengthening connections

Strengthening Elevated Floor-to-Pile Foundation Connections

The FEMA assessment teams deployed after Hurricane Sandy observed damaged connections between elevated floors and pile foundations. These inadequate connections were subjected to flood levels that exceeded the top of the foundation, and these loads exceeded the capacity of the connections. As a result, the buildings experienced simultaneous uplift and lateral loads during the storm and were pushed off their foundations.

As shown in Figure 1, the inadequate connectors failed, resulting in complete separation of the building from the foundation (foreground), while homes with more substantial connectors secured the building to the foundation (background). It was also observed that elevated floor-to-pile foundation connections that were attached near the top edge of the beam with fasteners driven in line with the wood grain resulted in the beam splitting along the grain as shown in Figure 3.

Figure 3: Building with connectors nailed along the grain in the upper edge of the wood beam resulted in the beam splitting (Beach Haven, NJ)

Building Codes

Model building codes do not have standard details to guide the connection of an elevated floor to a pile foundation. These connections are typically designed to resist high-wind forces and, in some cases, seismic forces (lateral loads) or to meet standard practice for connecting and bracing wood members. They are not typically designed to resist uplift from flood-induced buoyancy forces. Strengthening these connections will reduce the likelihood of a building separating from its foundation if flood levels exceed the top of the foundation or wave loads impact the floor system.

While the details presented in this advisory address better floor-to-pile foundation connections, prior to beginning any new construction or retrofit project it is important to consult the local building code to verify that all elements of the building project, not just the foundation connections, will be compliant.

Details of Strengthening Elevated Floor-to-Pile Foundation Connections

Figure 4 shows details for strengthening the connection of an elevated floor-to-pile foundation. The connections are strengthened by:

- Using full-depth solid blocking between joists to brace joists and provide shear resistance
- Using connectors that extend to (or beyond) the mid height of the beam and joist to provide uplift resistance
- Attaching hold-down connectors directly to the pile

Figure 4a illustrates strengthened connections using a combination of metal connectors and full-depth solid blocking between joists. Figure 4b illustrates strengthened connections by using full-depth solid blocking between joists and wood uplift blocks. Both of these methods, when used as part of an engineered design, can address both uplift and lateral loading from flood and wind loads.

To achieve the full-strength capacity of the connection, the connectors need to be secured with fasteners of the suitable size, length, and material specified by the manufacturer.

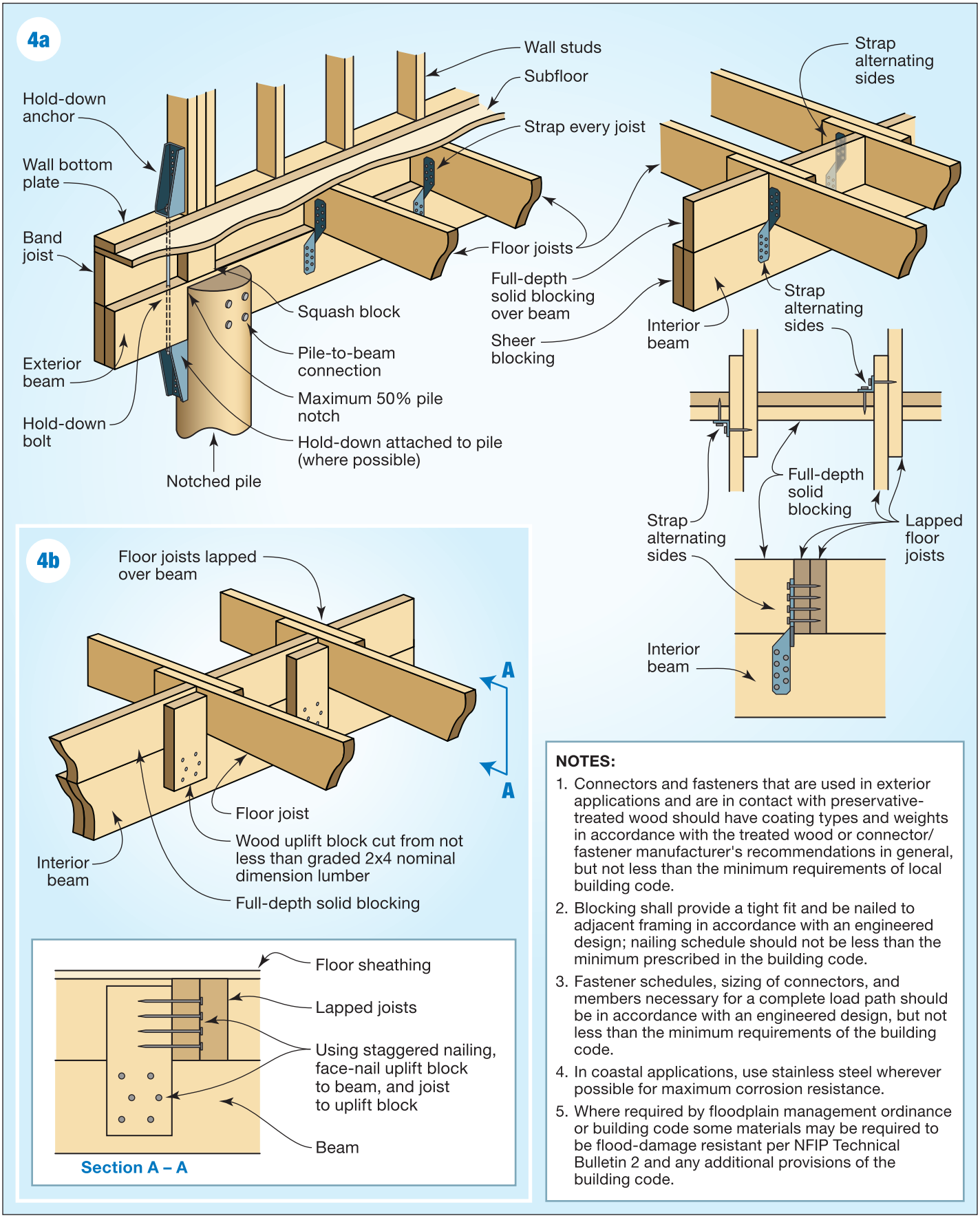

Figure 4. Detail of an elevated floor-to-pile connection using metal connectors and full-depth solid blocking (4a); detail of an elevated floor-to-pile connection using wood uplift blocking and full-depth solid blocking (4b).

Protecting Metal Connectors and Brackets from Corrosion

Metal connectors and fasteners must be adequately protected from corrosion to retain their design capacity. Metal corrosion is most pronounced in coastal buildings within 3,000 feet of the ocean and should be considered a potential issue in all coastal areas (Figure 5).

Minimizing corrosion should be an objective when selecting new connectors. Most often, corrosion resistance can be achieved by using connectors and fasteners that are hot-dip, zinc-coated galvanized steel or stainless steel; see notes above in Figure 3. It is important to verify with the connector manufacturer that the treated wood, fasteners, and connectors are compatible and will not result in an increased rate of corrosion when brought into contact with each other. For example, galvanized fasteners (nails/screws) should be used with galvanized connectors, and stainless steel fasteners should be used with stainless steel connectors. Connections assembled with a mixture of materials will accelerate corrosion if the different metals come into contact with each other. For more information on corrosion protection, see FEMA Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (FEMA, 1996).

Figure 5. Corroded connectors (red circles) and lack of blocking mean there is no longer a continuous load path providing uplift and shear transfer to foundation piles (Fire Island, NY)

Deteriorated connectors should be replaced. Existing fasteners not yet corroded can be protected by applying corrosion-resistant paints such as zinc or epoxy-polyamide. However, the effectiveness of an applied paint is not completely predictable because its effectiveness is not necessarily correlated to paint thickness, and it is only effective on the painted areas. Unpainted areas and hard-to-reach portions of the connectors and fasteners will remain susceptible to corrosion.

Metal connectors and fasteners, and protective coating if used, should always be installed in accordance with the manufacturers' or engineers' specifications.

Resources and Useful Links

- ICC (International Code Council). 2012. International Building Code. Country Club Hills, IL. The ICC offers a free viewer that shows the codes at http://www.iccsafe.org/content/pages/freeresources.aspx.
- ICC. 2012. *International Residential Code for One- and Two-Family Dwellings.* Country Club Hills, IL.
- FEMA. 1996. Technical Bulletin 8. *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. Available at http://www.fema.gov/library/viewRecord.do?id=1721.
- FEMA. 2013. Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy.* Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/30966?id=6994.
- American Wood Council. *Wood Frame Construction Manual.* Leesburg, VA.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

The connection between an elevated floor and a pile foundation is only one of many connections that must be strong enough to transfer loads without failing. Other connections are equally important for reducing the likelihood of damage for high winds or floods. Table 1 lists FEMA documents that have information related to load path connections in residential buildings. Although these resources may not have sufficient information to size specific connections, they will introduce readers to the concepts necessary to properly anchor a coastal building. All of the documents listed in Table 1 can be downloaded from the publications section of the FEMA Building Science Web site: http://www.fema.gov/building-science-publications.

Table 1: FEMA Resources for Connection Information

Resource Title	Connections and Fasteners	Wood-Frame Construction	Masonry Construction	Foundations	Walls and Roofs
FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010)					
Fact Sheet 1.1: Coastal Building Success and Failures		✔	✔	✔	✔
Fact Sheet 1.2: Summary of Coastal Construction Requirements and Recommendations		✔	✔	✔	✔
Fact Sheet 1.5: V Zone Design and Construction Certificate		✔	✔	✔	
Fact Sheet 1.6: Designing for Flood Levels Above the BFE		✔	✔	✔	
Fact Sheet 1.7: Coastal Building Materials	✔	✔	✔	✔	✔
Fact Sheet 1.8: Alternative Construction Materials		✔	✔	✔	✔
Fact Sheet 3.1: Foundations in Coastal Areas		✔	✔	✔	
Fact Sheet 3.2: Pile Installation	✔	✔		✔	
Fact Sheet 3.3: Wood-Pile-to-Beam Connections	✔	✔		✔	
Fact Sheet 3.4: Reinforced Masonry Pier Construction	✔	✔	✔	✔	
Fact Sheet 3.5: Foundation Walls		✔	✔	✔	
Fact Sheet 4.1: Load Paths	✔	✔	✔	✔	✔
Fact Sheet 4.2: Masonry Details	✔		✔	✔	✔
Fact Sheet 4.3: Use of Connectors and Brackets	✔	✔		✔	✔
Fact Sheet 8.1: Enclosures and Breakaway Walls	✔	✔	✔	✔	
Fact Sheet 9.1: Repairs, Remodeling, Additions and Retrofitting (Flood)	✔	✔	✔	✔	✔
Fact Sheet 9.2: Repairs, Remodeling, Additions and Retrofitting (Wind)	✔	✔	✔	✔	✔
Technical Bulletin 2: Flood Damage-Resistant Materials Requirements (2008)	✔	✔	✔	✔	✔
Technical Bulletin 5: Free-of-Obstruction Requirements (2008)		✔	✔	✔	
Technical Bulletin 8: Corrosion Protection for Metal Connectors in Coastal Areas (1996)	✔				
Technical Bulletin 9: Design and Construction Guidance for Breakaway Walls (2008)		✔	✔	✔	
Technical Bulletin 11: Crawlspace Construction for Buildings Located in Special Flood Hazard Areas (2001)		✔	✔	✔	
FEMA P-55, *Coastal Construction Manual* (2011)	✔	✔	✔	✔	✔
FEMA P-762, *Local Officials Guide for Coastal Construction* (2009)	✔	✔	✔	✔	✔
FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (2010)	✔	✔	✔	✔	✔

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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Reducing Flood Effects in Critical Facilities

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA2, April 2013*

Purpose and Intended Audience

In the hours and days after Hurricane Sandy struck, damage to essential equipment, including mechanical, electrical, and plumbing systems prevented many critical facilities in New York and New Jersey from serving their communities when those communities needed them most. In numerous instances, critical facilities could not function because essential equipment was placed in basements, sub-basements, or ground floor levels that flooded. In some cases, components of essential systems were elevated well above the floodwaters, while other critical system elements (transformers, transfer switches, fuel tanks, pumps, etc.) were placed at lower levels and therefore were vulnerable to flooding. When those vulnerable critical elements failed, the systems were rendered inoperative and the functionality of the critical facilities suffered as a result.

This Recovery Advisory provides information and recommendations to improve the functionality of critical facilities by reducing the vulnerability of essential systems and equipment to flooding. Critical facilities include hospitals and other health care facilities; fire and police stations; emergency operations centers; communication and data centers; essential government buildings; and other critical facilities and their contents, machinery, and equipment therein, that serve the community or affect the safety, health, or welfare of the surrounding population. In some cases, the community may determine that wastewater treatment plants, water treatment plants, electrical substations, transportation facilities, and buildings such as schools or community centers are critical or essential for their community. In these situations, the recommendations in this advisory should be applied to those buildings. This Recovery Advisory describes how essential equipment must be protected from flooding to allow a critical facility to perform its primary function during and after a flood event. To accomplish this, facility owners and operators should work with a design professional, emergency manager, and their facility manager to help identify vulnerabilities in essential facility systems and equipment using a holistic approach well in advance of an event so that identified vulnerabilities can be reduced.

> For more information on category classification requirements, see Occupancy Category Table 1-1 ASCE 7-05 and Risk Category Table 1.5-1 in ASCE 7-10, as well as the guidance in FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*, January 2007. Note: ASCE 7-05 and ASCE 7-10 use different category classifications; also, check for any modifications made by your State or local jurisdictions.

The information in this Recovery Advisory is most useful for new construction, although the same concepts can be applied to retrofits of existing construction. Although the focus of this advisory is on critical facilities, many of the recommendations can also be applied to other types of facilities. The intended audience for this Recovery Advisory includes facility owners and operators and other individuals involved in making decisions for critical facilities. If reconstructing a critical facility, FEMA recommends relocating the facility outside of the floodplain in addition to applying the other mitigation options described in this advisory.

Key Issues:

1. Major components of essential systems and equipment are frequently placed on the lowest floors or subgrade (basement) levels potentially well below the base flood elevation (BFE). Equipment located on lower floors and basements is often vulnerable to flood damage even when the building is located outside of mapped Special Flood Hazard Areas (SFHA) or is above the BFE.

2. Although critical facility managers typically understand which systems and equipment are essential to the functionality of their facility, they may not have a complete understanding of all the different system components and the vulnerabilities to flooding that may be present in their facility.

This Recovery Advisory Addresses:

- The importance of maintaining critical facility functionality for community resilience
- Protecting components of essential systems and equipment
- Code requirements and FEMA recommendations
- Mitigation measures to help protect essential systems and equipment
- Design considerations for protecting essential systems and equipment
- Vulnerability assessments
- Conclusions and recommendations

Importance of Maintaining Critical Facility Functionality to Community Resilience

The services and functions provided by critical facilities are essential to a community, especially during and after a disaster. For a critical facility to function, it must be supplied with essential utilities (typically power, water, waste disposal, and communications, but occasionally also natural gas and steam). Furthermore, building systems and equipment needed for the facility to function must remain operational.

Any interruption to essential utilities or damage to essential systems and equipment can jeopardize the ability of the critical facility to function. The loss of municipal utilities prevented some critical facilities from functioning during and immediately after Hurricane Sandy and in some cases, loss of municipal water and waste disposal prevented facilities from being able to operate weeks after the event. However, damage to essential systems and equipment within those facilities had a much greater impact on their ability to function than loss of utilities.

To prevent interruptions in critical services, it is important for facility operators to identify and mitigate vulnerabilities in utilities, essential systems, and essential equipment. Mitigation can reduce vulnerabilities in one of two ways: (1) ***improve equipment to reduce risk*** or (2) ***establish redundancies***. Elevating equipment is an example of improving equipment to reduce risk, and providing alternate methods of supplying critical services is an example of redundancy. Redundancies can either be internal or external. For example, redundant patient care can be provided using alternative sites within a facility (internal redundancy) or establishing memorandums of understanding with other facilities to provide services when a critical facility is unable to do so (external redundancy). Creating redundancies requires emergency planning and explicit documentation in a disaster plan based on a comprehensive understanding of system capacity.

Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SFHA and BFE are both shown on FIRMs.

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.

Disaster Plans

Traditional disaster plans often center on how a facility will mitigate a single event. The events of Hurricane Sandy illustrate the importance of expanding disaster planning to account for simultaneous events like flooding and loss of power.

Protecting Components of Essential Systems and Equipment

For a critical facility to function during and after a flood event, essential utility systems and essential equipment within the facility must be protected from flooding. ***Electrical systems*** are needed for lighting, life-safety equipment (emergency evacuation, recovery, and response equipment), fire alarms and fire pumps, elevators, and mechanical systems. ***Mechanical systems*** are needed to provide heating, ventilation, and air conditioning (HVAC); distribute hot and cold potable water; discharge waste; and control groundwater and floodwater infiltration. ***Essential equipment*** is any equipment required for the facility to serve its critical function. The following may be considered essential, depending on the specific services offered by the facility:

- Electrical systems (e.g., primary/utility power, power from emergency generators, communications, information technology [IT] equipment, switchgear, and transformers)
- Mechanical systems (domestic water, sanitary sewer, sump pumps, drainage systems, and HVAC equipment)
- Conveyance systems (elevators and escalators)
- Fuel systems (fuel pumps, lines, and tanks)
- Data systems (IT servers, networks, and wiring)
- Communication systems (land-based phone, cellular communication, radio transmitters, and receivers)
- Specialized equipment (medical diagnostic equipment, oxygen, nitrous oxide, medical air systems, critical equipment that is costly or is difficult to replace)
- Life-safety equipment (fire alarm systems, fire pumps, and smoke control systems)

Facility operators and owners should consider not only the essential systems and equipment, but also all ancillary elements required for each system to function. For example, for an HVAC system to function, individual pieces of HVAC equipment must be protected from damage and all supplies to that equipment (like hot water from boilers, chilled water from chillers, and power from the electrical system) must be also protected.

Major components of essential systems and equipment are often placed on the lowest floors or subgrade (basement) levels in buildings (Figures 1 and 2). In some cases, equipment is installed on lower floors because of physical requirements or policy mandates.

Figure 1: Hospital fuel oil pump (red circle) was flooded, resulting in failure of the emergency generator (Manhattan, NY)

Figure 2: Unelevated fuel pumps and controls were flooded when floodwater reached the high water mark shown by the red line, causing the emergency power generator to fail (top). New pumps, located on the back side of the unit, were installed but not elevated to reduce venerability to flooding (bottom) (Long Beach, NY).

For example, the main storage tanks that supply fuel oil to buildings are often required to be placed on the lowest floor to reduce fire hazards. Another example is when large, heavy components of mechanical and electrical equipment are placed at low elevations to facilitate maintenance and replacement. More often, mechanical and electrical equipment is placed on the lowest floor because the upper floors are more valuable for other uses.

Equipment located on lower floors is more vulnerable to flood damage, particularly when the facility is located in or near a mapped SFHA. Critical facility owners should be aware that essential utility systems and equipment installed below grade can be vulnerable to flooding even when the building is outside of the SFHA. Properties outside of high-risk flood areas account for over 20 percent of NFIP claims and one-third of disaster assistance for flooding.[1] People often mistakenly believe a building located outside of a mapped flood hazard area has no risk of flooding. Hurricane Sandy demonstrated the fallacy of this assumption. Many of the buildings damaged or destroyed by flooding, including numerous critical facilities, were located outside the SFHA. Figure 3 shows a fire station that was outside the SFHA, but was still inundated with 2.3 feet of floodwater. Incorrect conclusions about flood risk can lead to design decisions similar to those that made facilities vulnerable to the extraordinary flooding during Sandy in 2012. Actions taken now can help to reduce damage from future flood events.

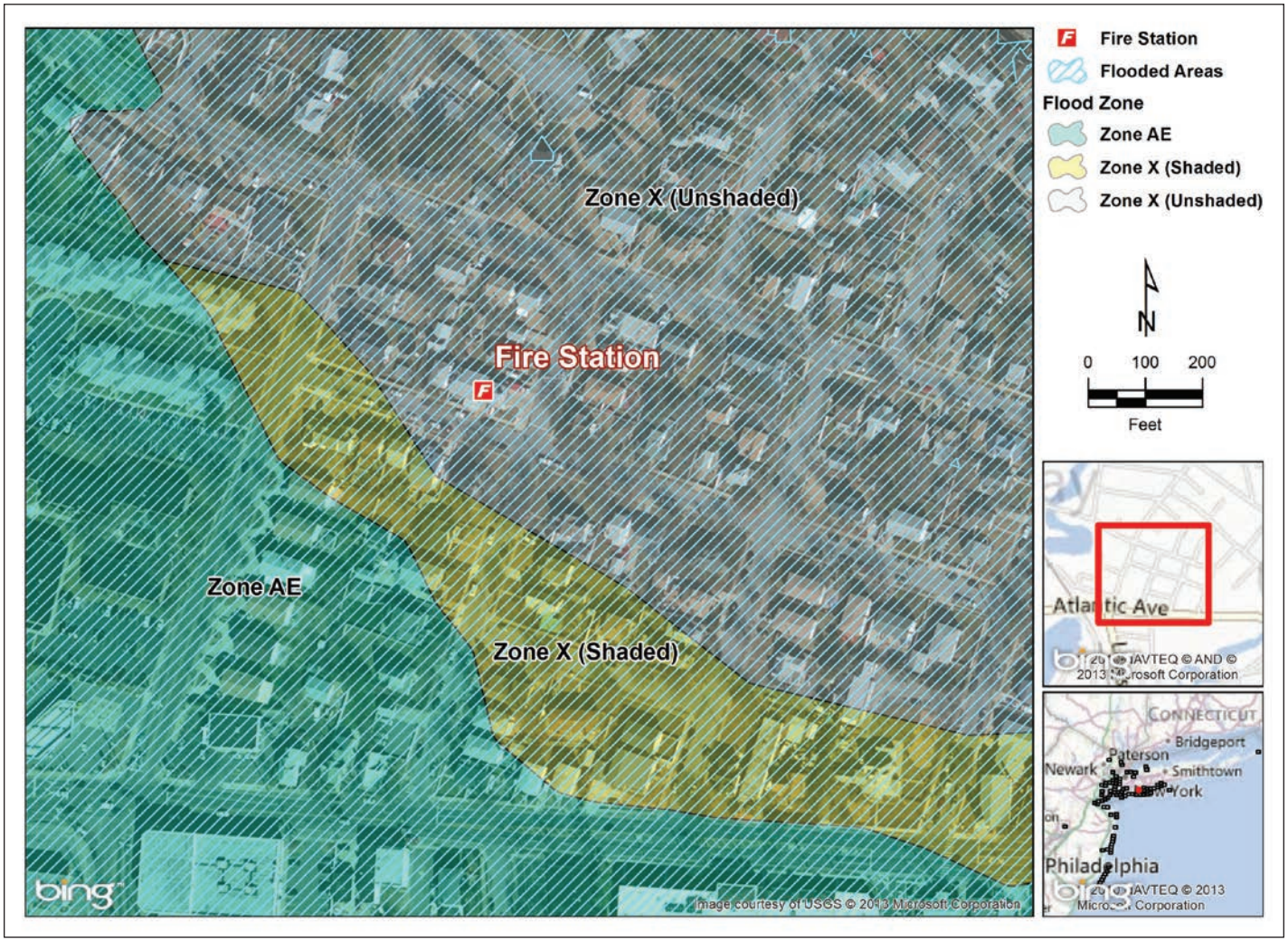

Figure 3. Map showing flood extent of Hurricane Sandy and effective flood zones. The fire station was not located in an SFHA (Zone AE shown on map), but was inundated with 2.3 feet of floodwater.

1 http://www.fema.gov/pdf/media/factsheets/2011/mit_natl_flood_ins.pdf

Assessing Flood Risks for Locations Outside of SFHAs

Areas outside SFHAs may still be subject to flooding, so a facility may be vulnerable to flooding even when it is located outside of an SFHA. This is particularly true for facilities with below-grade floors. To assess flood risk, facility owners should:

- Examine the FIRM to determine if the facility is located in a shaded Zone X area. The area shown on a FIRM as shaded Zone X is bounded by areas at risk for inundation during a 1-percent- and the 0.2-percent-annual-chance flood event (100-year and 500-year event, respectively). If within a shaded Zone X, compare the critical equipment elevation with the 100-year and 500-year flood elevations.
- Investigate historic flooding. Records of actual flooding can augment studies that predict flooding, especially if historic events caused deep or widespread flooding. Information may be available from local planning, emergency management, and public works agencies; State agencies; the U.S. Army Corps of Engineers; or the U.S. Natural Resources Conservation Service. The most extreme flood, called the flood of record, is typically a lower probability event than the 100-year flood.
- Determine if the facility is located near a body of water (with or without a mapped flood hazard area). All bodies of water are subject to flooding, but not all have been designated as SFHA on FIRMs. It is important to note that FIRMs are only as accurate as the topography, bathymetry, and technical information used, and the technical analyses performed, to create them. While generally accurate when created, FIRMs become less accurate as physical conditions change.

Additional information can be obtained from the NFIP Floodsmart Web site at http://www.floodsmart.gov.

Code Requirements and FEMA Recommendations

New construction must adhere to adopted State and local code requirements; modification or repair to existing structures may also be required to adhere to code requirements as determined by local building officials. The building code requirements for new construction can be met by elevating equipment or installing dry floodproofing to protect equipment (refer to next section for discussion of mitigation measures).

Many of the flood provisions required by building codes are contained in American Society of Civil Engineers (ASCE) 24, *Flood Resistant Design and Construction*. ASCE 24 is referenced by the International Building Code (IBC) for construction in SFHAs and applies to all areas where the IBC has been adopted without local modifications. Table 1 lists the elevation and floodproofing protection requirements specified by ASCE 24 for Category Type IV Structures.

Table 1.
Required Elevation or Floodproofing Level for Utility Systems and Attendant Equipment for ASCE 24 Category Type IV Structures

Location	Required Elevation	Required Floodproofing
Zone A	BFE + 2 feet, or DFE, whichever is higher*	BFE + 2 feet, or DFE, whichever is higher*
Zone V and Coastal A Zone, where orientation is parallel to waves	BFE + 2 feet, or DFE, whichever is higher*	Floodproofing not allowed per ASCE 24-05 Section 6.2.1
Zone V and Coastal A Zone, where orientation is perpendicular to waves	BFE + 3 feet, or DFE, whichever is higher*	Floodproofing not allowed per ASCE 24-05 Section 6.2.1

Source: Adapted from ASCE 24-05 Tables 6-1 and 7-1

Note: ASCE 24 Structure Category Type IV Structures include hospitals, fire and police stations, and emergency operations centers

BFE = base flood elevation; DFE = design flood elevation

* In the upcoming edition of ASCE 24, it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater.

As a best practice, FEMA recommends protection that exceeds code minimums. For example, FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007) recommends protecting critical facilities to withstand at least a 0.2-percent-annual-chance flood event (often called the "500-year flood event"). Flood elevations for the 0.2-percent-annual-chance flood may be greater than the elevation specified by ASCE 24. If federal funding or other Federal action is involved, the requirements of Executive Order 11988 – *Floodplain Management* may necessitate protection of critical actions to the 500-year flood elevation (critical actions may include the construction and repair of critical facilities).

In existing facilities that have not been substantially damaged, it may not be possible to floodproof or elevate to provide protection from the 0.2-percent-annual-chance flood event. In those instances, floodproofing or elevating as high as practical is recommended.

Mitigation Measures to Help Protect Essential Utilities and Equipment

This Recovery Advisory describes two techniques for reducing flood damage to essential utility systems and equipment: elevating and dry floodproofing utility systems and equipment.

Elevating Equipment

The most effective mitigation method is to elevate all essential equipment above the highest anticipated flood elevation as shown in Table 1 or the elevation of the 0.2-percent-annual-chance flood recommended by FEMA, whichever is higher. When essential equipment is located below grade, elevating typically requires relocating the equipment to higher floors in the building. Unless space is already available, moving the equipment to a higher floor will displace other equipment, tenants, or functions. Building owners may need to evaluate all available space, including the attic and second floor, to determine whether a small elevated addition would be an acceptable solution. When elevating equipment is not practical, dry floodproofing may be an option.

Dry Floodproofing

Essential equipment can be protected with dry floodproofing methods. Dry floodproofing involves constructing flood barriers or shields around individual pieces of equipment or areas that contain essential equipment to prevent floodwaters from coming into contact with critical equipment. For dry floodproofing to be effective, the barrier must be high enough to protect equipment from floodwater, strong enough to resist flood forces, and sealed well enough to control leakage and infiltration. Dry floodproofing measures must also satisfy applicable codes and standards. For example, a dry floodproofed room created to protect a fuel tank will need mechanical ventilation to meet code requirements. Additional information is described in Hurricane Sandy Recovery Advisory No. 4, *Reducing Building Interruptions to Mid- and High-Rise Buildings During Floods* (2013).

Protection from floodwater. Dry floodproofing should meet ASCE 24 criteria in all locations, but in areas where ASCE 24 is adopted, dry floodproofing ***must*** meet them. To meet those requirements, any barrier installed to protect equipment must provide protection to the elevations shown in Table 1. FEMA 543 recommends protecting critical equipment to withstand at least the 0.2-percent-annual-chance flood elevation, which may exceed ASCE 24 requirements.

Protection from flood forces. Areas and equipment protected by dry floodproofing must be designed to resist hydrostatic forces that will exist when fully inundated with floodwater. Inundation creates both ***flood pressures*** and ***buoyant forces*** and successful dry floodproofing must be designed to resist both. Flood pressures can crush submerged equipment and must be resisted by making submerged equipment strong enough to prevent crushing. Crushing pressures depend on the depth of flooding—the deeper the flooding, the greater the pressure. Every foot of flood depth creates a crushing pressure of 62 psf (freshwater) or 64 psf (saltwater). Buoyant forces can dislodge submerged equipment and must be resisted by making the equipment heavy enough or anchored enough to resist the buoyancy force. Buoyant forces do not depend on flood depth but depend instead on the weight of the water displaced by the submerged equipment.

Crushing pressures and buoyant forces can be extreme. The two buildings shown in Figure 4 illustrate these effects. Building A has a fuel tank in a basement room located 10 feet, or one level, below grade. Building B has a fuel tank in a sub-basement room located 30 feet, or three levels, below grade. Both buildings are

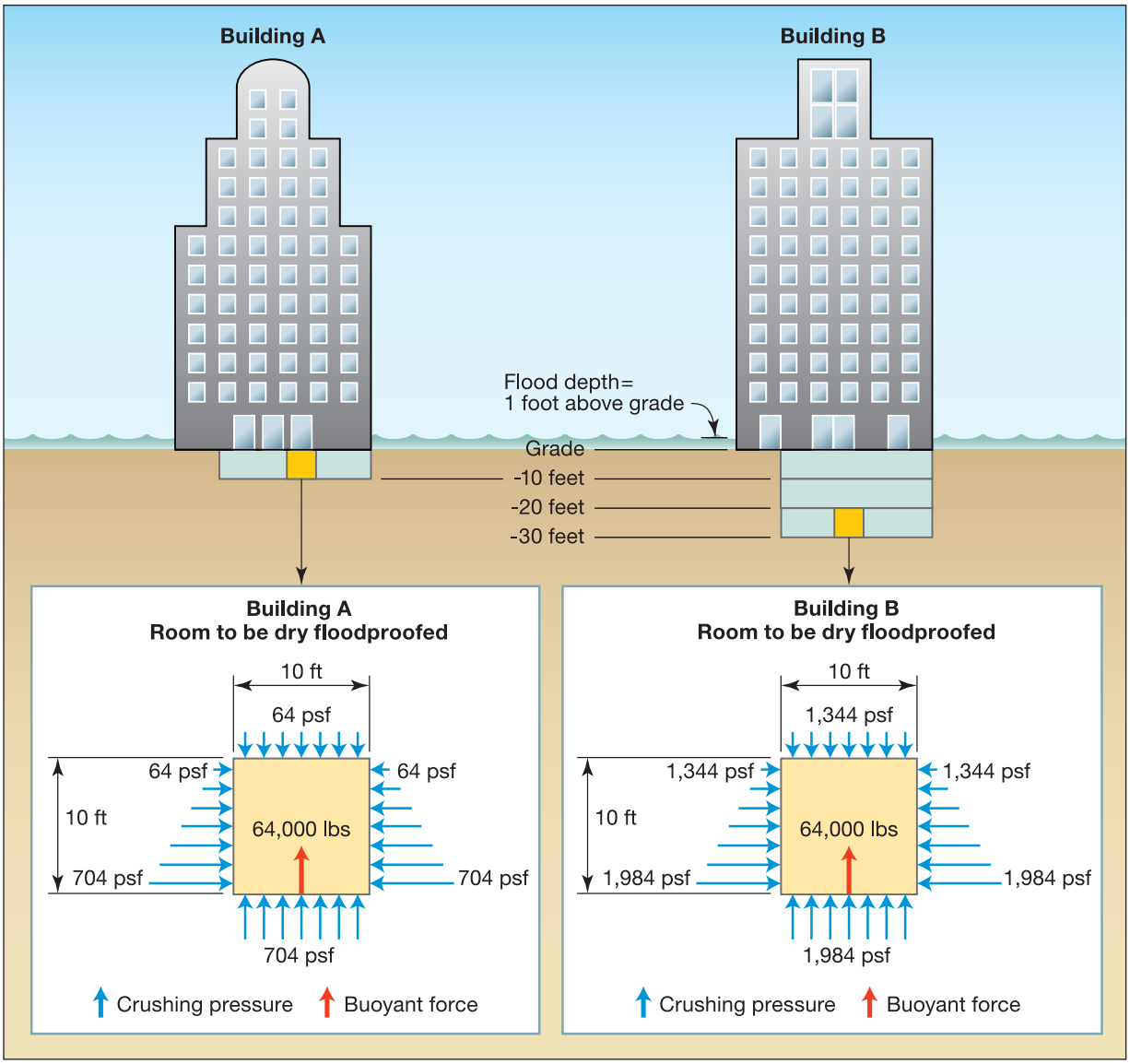

Figure 4. Crushing pressures and buoyancy forces that result when a 10 foot by 10 foot by 10 foot sub-grade dry floodproofed room is inundated with floodwater

located on sites inundated with 1 foot of floodwater, both buildings contain vents at grade level that allow floodwater to fill below-grade areas, and both have fuel tanks in rooms that have been sealed to prevent the entrance of floodwater. Crushing pressures can be calculated as follows:

- *Building A:* The top of the walls and the ceiling of the tank room would be exposed to 1 foot of flooding with a resulting crushing pressure of 64 psf. The base of the walls and floor of the tank room in Building A, however, would be exposed to 11 feet of floodwater with a resulting crushing pressure of 704 psf (11 feet times 64 psf/foot).
- *Building B:* The tank in Building B would be exposed to much deeper floodwaters and much greater crushing pressures than the room in Building A. The top of the walls and the tank room ceiling would be exposed to 21 feet of floodwater (two 10-foot levels plus 1 foot of flooding above grade) with a resulting crushing pressure of 1,344 psf. The base of the walls and the tank room floor would be exposed to 31 feet of floodwater with a resulting crushing pressure of nearly 2,000 psf (31 feet times 64 psf/foot).

The buoyant force experienced by the dry floodproofed room in both Building A and Building B would be the same since the force does not depend on flood depth but instead equals the weight of the displaced water. Both rooms would be subject to a buoyant force of 64,000 pounds (area of 10 cubic feet, subjected to saltwater weight of 64 pounds per cubic foot).

Protection from leakage and infiltration. Few dry floodproofing measures are completely watertight and some leakage and infiltration should be anticipated. Leakage can occur between joints and seams in flood barriers and infiltration can seep through penetrations in the barrier. Even small amounts of leakage or infiltration will eventually cause flooding in protected areas, so provisions to pump water out of dry floodproofed areas are mandatory. Since flooding often disrupts primary electrical power, emergency power should be provided for all pumping equipment serving dry floodproofed areas. To be effective, the entire emergency power system, including its fuel supply, must be protected from flooding.

Design Considerations for Protecting Essential Systems and Equipment

For effective mitigation, ***all*** essential equipment necessary for a critical facility to function should be protected. Mechanical and electrical systems are heavily interconnected, and damage of an individual component will often render the entire system inoperable unless the damaged component can be isolated from the remainder of the system and the system can function without the damaged component. Mitigation measures should be considered even in areas outside of the SFHA, as damaging flooding can still occur in these areas.

Electrical Service and Distribution Systems

Essential electrical systems should be located above flood levels or protected from floodwaters by dry floodproofing to prevent power interruptions during flooding events. Elements of the electrical service and distribution system that should be protected include primary supply lines of the utility company and the transformers they serve, the facility's main electrical service equipment, downstream feeders, and distribution panels. Where possible, the electrical service and distribution equipment should be located on elevated floors, and power should be distributed downward from an elevated floor to serve lower floors. If equipment must remain below the DFE, electrical power can still be supplied to vulnerable equipment provided that: 1) the equipment is fed from designated circuits or feeders that supply no essential equipment; 2) those circuits or feeders can be isolated from the main electrical system; and 3) the loss of the vulnerable equipment does not prevent the facility from functioning or performing its primary service.

Data Systems

The main servers, switches, and network hubs for telephone, data, and communication systems should be installed above flood levels to remain functional. Where communication and data wiring serves areas vulnerable to flooding, flood risks can be minimized by judicious routing of the wiring and placement of outlets. When routing and outlet placement still leave portions of the systems vulnerable to flooding, the vulnerable portions should be able to be readily isolated from the rest of the system. Similarly, power wiring supplying telephone, communication, and data equipment should be installed and routed above flood levels.

Heating, Ventilation, and Air Conditioning Systems

Essential components of HVAC systems should be located above flood levels. Components include boilers, chillers, cooling towers (when water-cooled chillers are used), pumps for circulating heating and chilled water, and associated system controls. Water piping may be routed through vulnerable areas, but the amount of piping exposed to floodwaters should be minimized to reduce cleaning and insulation replacement that will be required after a flood event. Air handling units that serve areas vulnerable to floodwaters should be separate from other portions of the HVAC system to prevent contaminated air from flood-damaged units from migrating to other portions of the building. Units should be installed to facilitate replacement after floodwaters recede.

Water/Wastewater Systems

Domestic water heaters, domestic water booster pumps, and hot water circulating pumps and system controls should be placed above anticipated flood levels. Pressurized piping can be installed in areas vulnerable to flooding, but the amount of piping exposed to floodwaters should be minimized to facilitate cleanup.

If components such as sump pumps, lift pumps, or macerator pumps that discharge effluent must be installed in areas vulnerable to flooding, the components and associated controls should be designed for submersible use.

Emergency Power Systems

Many of the recommendations provided for electrical service and distribution systems apply to emergency power systems. Care should be taken to evaluate each component to ensure the emergency power system will perform during a flood event. Generators, transfer switches (that send power to critical equipment from either the normal power system or the emergency system), pumps for fuel delivery from fuel tanks, electronic controls, and wiring should be located above flood levels whenever possible (Figures 5 and 6).

Flood risks should also be considered when selecting and placing fuel tanks and fuel pumping equipment. Where possible, all portions of the fuel delivery system should be placed above flood levels. If fuel system components (such as main fuel storage tanks and pumps) must remain in areas vulnerable to flooding, the components should be designed for submersible use. Fuel tanks should be designed to withstand the external forces from the weight of the water above and around the tank, anchored to prevent damage from buoyancy, and designed so the fuel tank vents extend above the anticipated flood levels. Designer calculations should assume the fuel tanks are empty. Fuel supply lines required to extend below DFE should be sealed to prevent infiltration of floodwater.

Most critical facilities cannot operate without utility power even for short periods of time. Model building codes are focused on protecting occupants against fire and require only enough emergency power to allow occupants to safely leave a building during a fire. Although the specific needs vary somewhat depending on occupancy and building height, emergency power is typically required to illuminate egress routes and energize exit signs and life safety equipment for 90 minutes after loss of normal power. Code-required emergency power can generally be supplied by stored energy devices such as batteries. For critical facilities that must remain functional during prolonged power outages, on-site power generation is needed.

Figure 5: Emergency generator in a ground-level mechanical room that was inundated by 18–20 inches of water during Hurricane Sandy flooding. The generator was able to continue functioning because it was elevated approximately 20 inches (Ship Bottom, NJ).

Figure 6: Emergency generator in a basement that was completely inundated during flooding from Hurricane Sandy (Long Beach, NY)

Elevators

Even when not part of the code-required egress routes, elevators are essential for many critical facilities to function. During Hurricane Sandy, many facilities were unable to function because of the loss of their elevators. Like many other critical systems, their vulnerability to flood damage can be reduced by elevating components above the flood level or by using flood-resistant materials for components that must be located in areas exposed to floodwaters. Also, adding controls that prevent elevator cabs from descending into floodwaters can significantly reduce flood damage and long-term loss of function. FEMA's Technical Bulletin TB-4, *Elevator Installation for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP* (November 2010), contains additional recommendations on elevators and their installation.

Vulnerability Assessments

Unless flood provisions were incorporated into their design, existing critical facilities may be vulnerable to flooding particularly if they are located within or near a SFHA. Flooding can result in damage ranging from minor inconvenience to complete closure of the facility. In some cases, facilities may be closed for several days or possibly weeks. To help facility operators plan for flood events, a vulnerability assessment can be conducted to identify equipment and systems vulnerable to flooding. The assessments are often conducted by a team of architects and engineers working closely with facility managers, operators, and maintenance staff. Findings from such an assessment can lay the groundwork for planning and budgeting capital improvements, identifying mitigation opportunities, and developing contingency plans that address flood risks.

As part of the planning process for new facilities, all possible natural hazards (flood, wind, seismic, and wildfire) should be considered. If the building design does not ensure continuity of operations, contingency plans that address facility disruption should be developed. FEMA's Risk Management Series provides guidance on conducting vulnerability assessments (see Resources and Useful Links).

Conclusions and Recommendations

Flood effects on essential systems and equipment can destroy a facility's ability to function and can prevent the facility from serving its community when it is needed most. Building professionals, building owners, building operators, and key decisionmakers should seek information for implementing a variety of mitigation measures to reduce the vulnerability to damage and disruption of operations during severe flood events. To improve building performance, vulnerability assessments that take a holistic view of critical equipment, critical systems, and critical functions should be completed to identify vulnerabilities and identify possible hazard mitigation measures. Those mitigation measures should be incorporated whenever damaged facilities are repaired or reconstructed. By building or creating robust critical facilities that remain operational during and after a major disaster, people's lives and the community's vitality can be better preserved and protected.

Resources and Useful Links

- American Society of Civil Engineers (ASCE). 2010. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-10.
- ASCE. 2005. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-05.

Risk Management Series: Publications listed below are available at http://www.fema.gov/mitigation/security-risk-management-series-publications.

- FEMA P-424. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*.
- FEMA 543. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*.
- FEMA 577. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds.*
- FEMA P-936. Unpublished. *Floodproofing Non-Residential Structures* (due to be published in 2013).

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

Building Science Publications and Resources: Publications listed below are available at http://www.fema.gov/building-science

- FEMA P-765. 2009. *Midwest Floods of 2008 in Iowa and Wisconsin*.
- Hurricane Sandy Recovery Advisories and Fact Sheets (2013):
  - RA1: *Improving Connections in Elevated Coastal Residential Buildings*
  - RA2: *Reducing Flood Effects in Critical Facilities*
  - RA3: *Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Buildings*
  - RA4: *Reducing Operational Interruptions to Mid- and High-Rise Buildings During Floods*
  - RA5: *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*
  - RA6: *Protecting Building Fuel Supplies from Flood Damage*
  - Fact Sheet 1: *Cleaning Flooded Buildings*
  - Fact Sheet 2: *Foundation Requirements and Recommendations for Elevated Homes*

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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Visit the Building Science Branch of the Risk Reduction Division at FEMA's Federal Insurance and Mitigation Administration at http://www.fema.gov/building-science.

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Restoring Mechanical, Electrical, and Plumbing Systems

In Non-Substantially Damaged Residential Buildings

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA3, April 2013*

Purpose and Intended Audience

The Federal Emergency Management Agency (FEMA) deployed a post-disaster assessment teams to observe building damage in New York and New Jersey after Hurricane Sandy. The Team noted numerous residential buildings where mechanical, electrical, and plumbing (MEP) systems (called "utility systems" in this Recovery Advisory) located on the ground or below-ground level were severely damaged by floodwaters (Figure 1). The damage was particularly severe for equipment located in basements, below-grade (ground) garages, crawlspaces, and at-grade storage areas near shorelines or areas subject to storm surge or riverine flooding. The purpose of this Recovery Advisory is to describe methods to restore utility systems in a manner that minimizes damage from future flood events and reduces the system restoration time following future storms. The intended audience for this Recovery Advisory is homeowners and the information is solely for residential buildings.

Figure 1: A water heater and furnace system damaged by Hurricane Sandy floodwaters (Beach Haven, NJ)

Many of the houses observed to have severely damaged utility systems may not have received Substantial Damage. This Recovery Advisory addresses houses that were not Substantially Damaged during Hurricane Sandy and are not undergoing Substantial Improvement. Repair and restoration work on these houses must be done in a manner that will not violate any floodplain management requirement in effect when originally built. Homeowners should always check with local building departments, as locally

Terminology

Substantial Damage: Defined by the National Flood Insurance Program (NFIP) as "damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred."

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010) for more information. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions.

enforced codes may differ from what is described in this Recovery Advisory. For example, some communities may require all utility system restoration or alteration work to comply with the applicable sections of the current code, even in houses that are not Substantially Damaged. When considering relocating or elevating systems, all applicable codes, regulations, and manufacturers' installation requirements should be followed.

Background information on the general requirements of the National Flood Insurance Program (NFIP) is provided so homeowners can understand what actions are allowed and which actions will help increase their home's flood-resistance. The remainder of this advisory describes how to protect utilities in homes, including the specific NFIP requirements related to utility systems.

Key Issues:

1. Utility systems in many houses are located in areas at or below grade.
2. Severe flood damage to those utility systems was observed.
3. Homeowners may have limited ability to relocate utility systems due to the proximity of surrounding houses and internal space restrictions.

This Recovery Advisory Addresses:

- General NFIP background
- General mitigation considerations for residential utility systems
- Considerations for specific equipment and systems
- NFIP requirements for utility systems
- Useful links and resources

Evaluation, repair work, and installation of utility systems should be done by qualified, licensed contractors to ensure they are installed safely and in compliance with codes.

Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SFHA and BFE are both shown on FIRMs.

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

General NFIP Background

NFIP requirements apply to buildings in regulatory floodplains, also called Special Flood Hazard Areas (SFHAs).[1] Although NFIP requirements only apply to buildings in an SFHA, the guidance in this Recovery Advisory is also applicable to buildings in areas outside of the SFHA where flooding is a concern. For houses in the SFHA, the NFIP regulations restrict the use of areas located below the base flood elevation (BFE). Allowable uses are vehicle parking, building access (e.g., foyers and stairwells), and storage. The following items are not allowed below the BFE because they may be damaged and their presence is inconsistent with allowable uses: appliances, heating and cooling equipment, and plumbing fixtures. Electrical equipment and wiring is permitted below the BFE only if needed to satisfy life safety and electric code requirements for the allowable uses as long as it meets the code requirements for wet locations.

Following large storm events, such as Hurricane Sandy, FEMA may perform an assessment to determine whether the 1-percent-annual-chance flood event, shown on the Effective Flood Insurance Rate Maps (FIRMs), adequately reflects the current flood hazard. The resulting Advisory Base Flood Elevations (ABFEs) are provided to communities as a tool to support recovery and future resiliency. Communities must use ABFEs when designing recovery or mitigation activities funded using FEMA grants (e.g., Public Assistance or Hazard Mitigation Grants).

1 Communities adopt and enforce flood provisions in order to participate in the National Flood Insurance Program (NFIP).

ABFEs and BFEs

FEMA recommends that communities apply the adopted ABFEs to new construction, buildings undergoing Substantial Improvements, and Substantially Damaged structures to ensure that construction is built stronger, safer, and less vulnerable to future flooding events.

Construction and repair of buildings in communities that have adopted ABFEs must use the revised elevation in place of the BFE shown on the Effective FIRM.

Post-Hurricane Sandy ABFE maps are available for parts of New York and New Jersey at http://www.region2coastal.com/sandy/abfe. FIRMs for all other participating communities are available at https://msc.fema.gov.

General Mitigation Considerations for Residential Utility Systems

Homeowners with damaged utility systems should consider elevating those systems while they are being repaired or replaced in order to minimize future flood damage. This subsection describes general mitigation considerations related to mitigating utility systems; specific considerations for different types of equipment (electrical panels, mechanical systems etc.) are described in the following subsection. When relocating or elevating utility systems, homeowners need to consider horizontal and vertical clearances; venting; and unions, fittings, and valves. The replacement of utility systems also presents an opportunity for homeowners to improve the energy efficiency of their houses by selecting high-efficiency equipment that may not have been available when the damaged equipment was installed.

FEMA recommends that all utility systems be elevated to the BFE or higher, though it may not be specifically required for houses that are not Substantially Damaged. Table 1 shows FEMA recommendations for elevating or relocating equipment based on the location of the home with respect to the SFHA. When elevating equipment to the recommended elevation is either not possible or cost-prohibitive, FEMA recommends protecting equipment by moving it to a location on or above the lowest living space floor.

Table 1. Recommended Equipment Elevations

Location of House	Recommended Elevation for Equipment
Inside SFHA, as mapped on Effective FIRM	Elevate to BFE or ABFE, whichever is higher
Outside SFHA, but inside Advisory Flood Zone A or V (defined on ABFE map)	Elevate to ABFE
Outside SFHA and outside Advisory Flood Zone A or V (defined on ABFE map)	Elevate to the nearest ABFE or lowest living area that was not flooded, whichever is higher

SFHA = Special Flood Hazard Area
BFE= base flood elevation
ABFE = Advisory Base Flood Elevation

Figure 2: Coastal house with a below-grade garage and storage area, which typically contain utility systems. These areas are subject to flooding (Manhattan Beach, Brooklyn, NY).

Relocating Equipment

If there is insufficient space on a higher floor, a homeowner may choose to build an elevated addition to the house to be used as a utility room. Moving equipment to a higher floor is particularly important for houses where the equipment is currently in basements and below-grade garages (Figure 2).

If equipment cannot be relocated to a higher floor or a utility room cannot be added, the equipment should be raised as high as possible in its current location. However, homeowners should understand that simply elevating equipment in basements and below-grade garages may have limited success in reducing flood

damage. Many houses with below-grade garages have sump pumps to remove rainwater that enters from the adjacent ground or down the driveway. For houses near the coast, however, the volume of floodwater from storm surge will likely exceed the capacity of any residential sump pump, causing deep flooding in any below-grade space. For houses located away from the coast and subject to flooding from rainwater only, sump pump systems are less likely to be overwhelmed; in these situations, placing equipment as high as practical on elevated platforms in walkout basements or sub-grade garages may be effective.

Elevated Platforms and Anchorage

A common method of improving flood resistance of heating and cooling equipment is to elevate equipment and components so the equipment is above flood levels. In such cases, indoor equipment is not moved to a different floor but simply raised above the floor using a solid pad (such as masonry or concrete) or a framed platform (wood or steel) (see Figure 3). Outdoor equipment can be elevated on a platform attached to the side of the house. The materials selected to construct elevated platforms should meet the requirements for being resistant to flood damage as described in FEMA Technical Bulletin 2 (2008), and should be non-combustible when required by the code. A pad should be properly anchored to the floor system or slab, and the equipment should be properly anchored to the pad. In regions subject to seismic requirements, additional bracing of the equipment may be required.

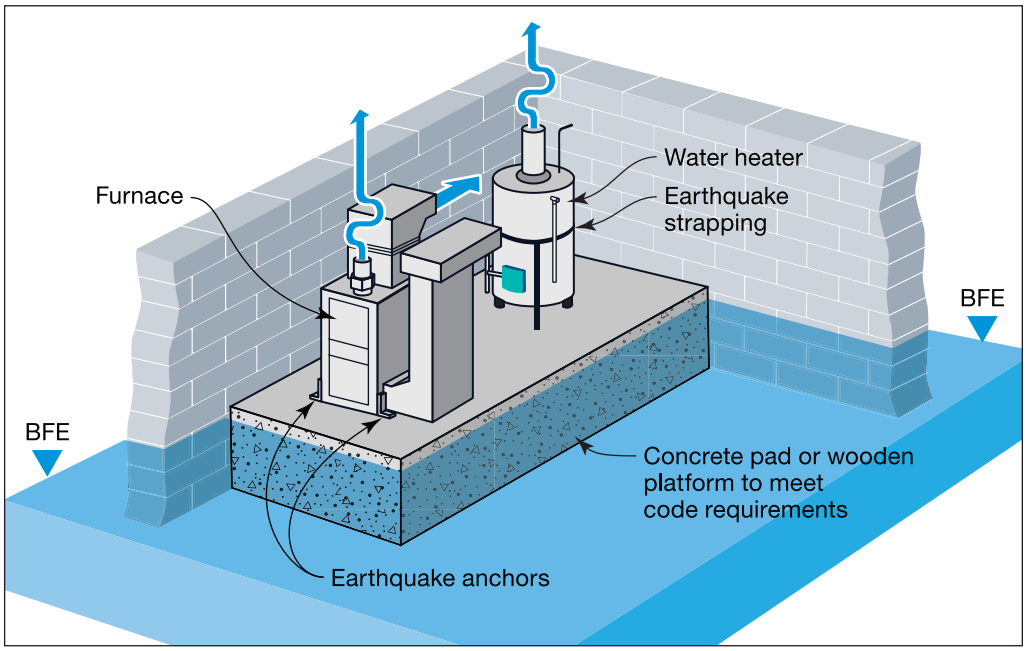

Figure 3: Elevation of mechanical equipment on an elevated platform in an area with the original slab below the BFE

Maintaining Horizontal and Vertical Clearances

When equipment is moved, either to another floor or elevated on a platform, it is important to maintain the recommended horizontal and vertical clearance around it as required by building codes and the National Electrical Code or as recommended by manufacturers. Minimum clearances required for equipment, conduits, piping, and duct work should be considered before relocating or elevating equipment. Designing for the minimum clearance is important to maintain air circulation, meet insurance or code requirements related to distance from combustible building materials, and provide space for maintenance. Most codes dictate that clearance requirements should follow those specified on the appliance label or installation instructions. Required clearance typically ranges from 6 to 36 inches, and can sometimes be reduced by installing heat shields if allowed by the building code. The use of a heat shield or other method to reduce clearance should be verified in codes and manufacturers' installation requirements. Failure to maintain proper clearance can result in safety issues including fire, and can void equipment warranties.

Venting Considerations

Oil- or gas-fueled boilers, furnaces, and water heaters require adequate combustion air and venting of exhaust gases. While some units may vent exhaust directly out of the unit through an exterior wall, other units may need to vent exhaust through a chimney. If elevating equipment, the type of venting system and the clearances necessary for the venting system may affect how high up the equipment can be elevated.

The venting system should be tested to ensure it draws adequate air and backdrafting[2] does not occur. If relocating equipment, homeowners (and their mechanical contractors) must consider the required venting system, as it may affect the final placement of the unit.

Unions, Fittings, and Valves

When it is not feasible to relocate or elevate equipment, it may be possible to replace unions, fittings, or valves to allow faster replacement of equipment when damaged, or to disconnect equipment prior to a flood event and relocate it to a higher floor. While this approach will not bring a non-conforming building into compliance with NFIP requirements, it may reduce potential flood damage to utility systems.

Considerations for Specific Equipment and Systems

Relocating and elevating equipment and systems can be a simple process, like elevating a water heater on a small platform, to a complex process involving relocating equipment to a higher floor or to a new addition built specifically as a utility room. Each type of system has specific vulnerabilities, characteristics, and restrictions on placement that can affect a homeowner's ability to relocate or elevate it.

Electrical Panels

Power outages after a flood event are often greatly extended if a house's electrical panel is located below the flood elevation. To reduce this problem, the electrical panel should ideally be relocated to an elevation above the lowest floor (into the living space). When moving electrical panels to an elevation above the lowest floor, additional components, such as a service disconnect, may need to be incorporated into the system in order to meet the requirements of the National Electrical Code. Also, when relocating electrical panels, code or local requirements may necessitate replacing significant portions of the house wiring. For additional information on relocating electrical systems, consult the Hurricane Isaac Recovery Advisory No. 2, *Minimizing Damage to Electrical Service Components* (2012).

Electrical Wiring

In many houses, some wiring is located below the BFE, especially where the utility service is routed underground. If wiring is located below the BFE and the wiring is not rated for wet locations, the wiring should be encased in a non-corrosive metal or plastic pipe (conduit) when allowed by code. The conduits should be installed vertically to promote thorough drainage when the floodwaters recede. It is easier to replace damaged wiring if it is installed in a conduit.

Mechanical Systems

Mechanical systems include the heating, ventilation, and air conditioning (HVAC) system, duct work, and the air handler that delivers the conditioned air throughout the house. Elements of the heating and cooling system below the BFE are subject to flooding. Ductwork beneath a house's floor system is susceptible to flooding and should be removed and replaced if it is inundated by floodwaters. Specifically, the ductwork connected to the furnace and air handler is often the most at risk of flood damage because the furnace is often located in the basement.

In many instances, it may not be possible to elevate mechanical systems above the BFE, but they should be elevated as high as possible. Relocating mechanical equipment may require replacing ductwork and moving electrical supply and refrigerant lines. Physical obstructions, such as walls or framing, may restrict the relocation of ductwork and the final location of the system components.

Condensing units. Protecting the condensing unit for an air conditioning system can often be achieved by elevating it on a platform or attaching a platform to the side of the house. A cantilevered platform is preferred over constructing a platform on posts because posts can obstruct flood-borne debris and are more vulnerable to damage and failure, such as through flood-borne debris impacts and being undermined by scour and erosion.

2 Backdrafting is a sudden explosion of hot gases due to oxygen re-entering an oxygen-starved environment.

Heating systems. ***Boiler systems*** heat water and either force hot water or steam through radiators or baseboards throughout the home and are typically oil- or gas-fired. A hot water boiler system consists of the main boiler, heat exchanger and burner, circulation pumps or control valves, and an expansion tank. Many components of a boiler system can be damaged by contact with floodwaters. Protecting a boiler system from flooding usually requires raising the system in its entirety to reduce flood vulnerability. Although most systems in residential use are hot water systems, the mitigation of a steam boiler is similar. Relocating a boiler heating system to an upper level is ideal, but can present some significant challenges. It may often be more practical to elevate the boiler as high as possible on its current floor. The main concerns when elevating a boiler are clearances, venting the exhaust, and protecting the supply tank from contamination. Systems using heating oil rely on either an above- or below-ground storage tank. The storage tank should be evaluated to make sure it is properly anchored and sufficiently sealed to prevent floodwater from contaminating the heating oil or allowing the oil to be released.

A ***furnace or forced air heating system*** uses oil or natural gas (and sometimes electricity) to heat air blown across heating coils in the system. It may be possible to relocate these systems to upper floors or attic areas. If elevating the furnace to an upper floor is not possible and elevating the furnace in its existing location below the living area is the only practical mitigation measure, homeowners will need to accommodate the required clearances and venting of the unit.

Water Heaters

Water heaters are powered from an electric coil or are oil or gas-fired. Conventional residential water heaters that use storage tanks typically range in capacity from 40 to 80 gallons. When exposed to floodwater, the internal components of the water heater can be damaged, which is not always apparent externally, necessitating replacement of the entire unit.

Electric water heaters. In some buildings, electric water heaters can be relocated to a higher floor or if no space exists on a higher floor, they can be placed in the attic. Relocating the unit will require plumbing and electrical work, as well as a method to drain the tank and prevent water damage from leakage. While relocating a water heater to the attic effectively protects it from flood damage, the heater needs to be equipped with a drain pan and drains to avoid costly water damage in the event of leakage. If a water heater is placed in an attic, it should be routinely maintained and inspected for leaks or other problems.

Oil or gas-fired water heaters. Oil- or gas-fired water heaters must be vented and may therefore be difficult to move into a main living space. If an appropriate location for the water heater on a higher floor is not available, it can potentially be elevated in its current location. Elevating the tank usually requires a small pad or platform, an appropriate location to vent the exhaust, and extending or shortening water supply lines and distribution lines.

Other water heaters. A homeowner may consider using a tankless water heater, which has little storage capacity and heats water instantaneously (see Figure 4). Although more expensive than conventional water heater systems, tankless systems require significantly less space and may present a flood mitigation opportunity due to their smaller size. Converting a conventional water heater unit fueled by natural gas to a tankless system requires minimal additional work. Electric tankless water heaters, by comparison, may not be practical because of the electrical system upgrades needed in some houses to provide the additional electrical power for the water heater.

Figure 4: Tankless water heater (Atlanta, GA)

Washer/Dryer Units

Many washing machines and clothes dryers are located in basements, where they are vulnerable to flooding. To protect these units from flooding, homeowners can relocate or elevate the units. Relocating the equipment to a higher floor may not be practical if space is limited in the living area. If it is not feasible to elevate these

units very much, even minimal elevation may prevent them from being damaged in low-level flooding situations. A permanent pad or platform should be constructed to elevate these units; stacked bricks or blocks should not be used because they can shift and result in injuries or damage to the equipment. Elevating washing machines and clothes dryers may require altering the water and drain piping, electrical connections, and gas connections.

NFIP Requirements for Utility Systems

NFIP requirements apply to buildings located in the SFHA, specifically new construction, buildings undergoing Substantial Improvement or buildings that received Substantial Damage and are undergoing repair. Installing features below the BFE that are not consistent with the allowable uses of building access, parking, and storage renders an enclosed area below the BFE non-compliant. Exceptions to the requirement to locate utility systems above the BFE may be permitted by a floodplain manager or a local code official, provided the element of the system is designed and/or located to prevent water from entering or accumulating within it during flooding conditions. Meeting the exception can be costly or difficult in many cases. Equipment manufacturers should be consulted before approving such an exception to verify that the equipment is designed to prevent damage from, or allow accumulation of, floodwaters.

All building materials below the BFE must be flood damage-resistant. Information on flood damage-resistant materials can be found in FEMA Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (2008). Additional requirements and recommendations apply to structures located in areas mapped as Zone V. Information on below-BFE building elements and free-of-obstruction requirements in Zone V can be found in FEMA Technical Bulletin 5, *Free-of-Obstruction Requirements* (2008).

Requirements for Houses with Substantial Damage

Houses that the local building official or floodplain manager determines to be Substantially Damaged must be brought into compliance with the flood provisions of current building codes, local floodplain ordinances, and NFIP regulations. Requirements include, but are not limited to, elevating utility systems above the flood elevation specified in the codes and regulations. Homeowners attempting to understand how high to properly elevate should consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*. It is important that homeowners verify with their local building department that they have all permits required to do the project. Relocating or elevating systems in conjunction with other projects may result in the local building department making a determination that the house is being Substantially Improved. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions of substantial improvement and substantial damage.

Flood Insurance Implications

Houses built after communities joined the NFIP were required to be elevated to minimize flood damage. These houses should already have elevated utility systems and components. However, if some equipment was not elevated (such as a furnace located in a crawlspace), owners may be paying much higher NFIP flood insurance premiums than necessary. Replacing damaged equipment on elevated platforms not only minimizes future damage, but may result in lowering the cost of flood insurance coverage. Owners should check with insurance agents to find out whether taking this action will affect their flood insurance premiums.

Resources and Useful Links

If a house is subject to flooding, homeowners should consult FEMA flood retrofitting publications to determine if other mitigation options or projects may be appropriate to consider during house renovations. The publications cover a variety of topics, including additional items related to utility system mitigation, such as installing backflow preventers to prevent damage to a system. The FEMA documents referenced can be downloaded from the FEMA Building Science Web site located at http://www.fema.gov/building-science-publications.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

- FEMA (Federal Emergency Management Agency) P-348. 1999. *Protecting Utilities from Flood Damage*. Washington, DC. Available at http://www.fema.gov/library/viewRecord.do?id=1750.
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- ICC (International Code Council). 2006/2009/2012. *International Building Code*. Country Club Hills, IL. The ICC offers a free viewer that shows the codes at http://www.iccsafe.org/content/pages/freeresources.aspx.
- ICC. 2006/2009/2012. *International Residential Code for One- and Two-Family Dwellings*. Country Club Hills, IL.
- National Electrical Code (2005/2008/2011). National Fire Protection Association (NFPA) 70. Quincy, MA.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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Reducing Interruptions to Mid- and High-Rise Buildings During Floods

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA4, March 2013*

Purpose and Intended Audience

During Hurricane Sandy, damage to critical building systems in mid- and high-rise buildings crippled building operations and affected thousands of occupants. Critical building systems (including, but not limited to, components such as the mechanical, electrical, plumbing, gas installations, communications, and fire suppression) are essential to the functionality of a building. Hurricane Sandy and other recent disasters demonstrate that buildings do not have to be severely damaged or collapse to be rendered inoperable. Lessons learned from the type of damage incurred can be used when repairing systems in existing buildings and designing them for new buildings to make mid- and high-rise buildings more resistant to disruption in future flood events.

The focus of this advisory is on design enhancement and techniques to reduce flood risk for mid- to high-rise buildings. Reduced flood risk decreases building service interruptions and lowers risks to tenants. This advisory incorporates observations from FEMA's Hurricane Sandy Mitigation Assessment Team (MAT) and describes best practices from successful local flood-resistant structures. The use of best practices is presented as a holistic approach to reduce flood risks in all structures. Mitigation measures include elevating critical building systems, floodproofing, and planning for power disruption. The recommendations in this advisory explain how to limit the interruption of building services caused by floods, but are not intended to enable buildings to remain occupied during an event or encourage sheltering in place. The audience for this Recovery Advisory includes building owners, operators, and managers; architects; engineers; building officials; and contractors.

Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SFHA and BFE are both shown on FIRMs.

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.

Key Issues:

1. Critical building systems are often placed on the lowest floors or subgrade (basement) levels in mid- and high-rise buildings due to building code requirements, policy mandates, costs, placement before consideration of flood hazards, or simply because the upper floors are more desirable for other uses.
2. Building systems located on lower floors are more vulnerable to flood damage. When critical building systems are damaged, building service is typically interrupted. Tenant risks significantly increase as a result of dark hallways, lack of elevator service, limited fire communication and suppression equipment, and lack of power to other systems.
3. To prevent flood damage and avoid interruption in building service, critical systems within the facility should be elevated above the base flood elevation (BFE) or protected from flood damage.

This Recovery Advisory Addresses:

- Protecting critical building systems by elevating and floodproofing
- Emergency power considerations
- Limiting building operation interruption

Protecting Critical Building Systems

The location of building systems is a critical factor in the continuing performance of mid- to high-rise buildings during a flood event. Even when flooding does not cause structural damage to a building, the inundation of lower floors can impair critical building systems, causing the building to be closed for weeks or months. The preferred method for protecting critical building systems is elevating them or relocating them to a floor with an elevation higher than the BFE or design flood elevation (DFE).

Elevating Critical Building Systems

Approaches for elevating utilities, controls, and equipment in existing and new facilities include:

- Installing platforms on the floor to elevate the equipment in place
- Relocating systems from below-grade or the first floor to a higher floor (or even the rooftop)
- Relocating systems to a higher elevation in a different building

When elevating equipment, both the appropriate elevation height and the codes and design restrictions that may affect their placement should be considered, as described in this section.

Determining how high to elevate equipment: Communities enforce floodplain management regulations and building codes that include requirements for buildings in mapped Special Flood Hazard Areas (SFHAs). The basic requirement in an SFHA is to protect buildings and systems to at least the BFE as determined from FEMA Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs). National Flood Insurance Program (NFIP) regulations require buildings to be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.

Following large storm events, such as Hurricane Sandy, FEMA may perform an assessment to determine whether the BFE, shown on the Effective FIRMs, adequately reflects the current flood hazard. The resulting Advisory Base Flood Elevations (ABFEs) are provided to communities as a tool to support recovery and future resiliency. Communities must use ABFEs when designing recovery or mitigation activities funded using FEMA grants (e.g., Public Assistance or Hazard Mitigation Grants).

A common misconception is that buildings located outside of the SFHA have little risk of flooding. During Hurricane Sandy, many of the buildings damaged were outside of the SFHA, and in some cases outside the area expected to be inundated during a 0.2-percent-annual-chance flood event (500-year flood event). Over 20 percent of NFIP claims received by FEMA—approximately one-third of requested disaster assistance for flooding—is for damage to buildings located outside of the SFHA.[1] Refer to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities*, for more information on assessing flood risks for locations outside of SFHAs.

When evaluating flood risk, it is important to remember that floodplain modeling was based on data available at the time. The models do not account for future conditions throughout the expected useful life of a building. Elevating existing systems can be difficult, so planning should include consideration of flood hazards that may change significantly over the life of the building due to urban development, flood protection projects, geologic processes

ABFEs and BFEs

FEMA recommends that communities apply the adopted ABFEs to new construction, buildings undergoing Substantial Improvements, and Substantially Damaged structures to ensure that construction is built stronger, safer, and less vulnerable to future flooding events.

Construction and repair of buildings in communities that have adopted ABFEs must use the revised elevation in place of the BFE shown on the Effective FIRM.

Post-Hurricane Sandy ABFE maps are available for parts of New York and New Jersey at http://www.region2coastal.com/sandy/abfe. FIRMs for all other participating communities are available at https://msc.fema.gov.

1 http://www.floodsmart.gov/floodsmart/pages/flood_facts.jsp

such as subsidence and erosion, climate change, or other future conditions. Elevating critical building systems above the 0.2-percent-annual-chance flood elevation is a best practice to make buildings less vulnerable during extraordinary future flood events. Refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*, for more information on SFHAs, BFEs, ABFEs, FIRMs, and Flood Insurance Studies.

Code requirements and design considerations: The building codes adopted by the States of New York and New Jersey are based on the International Building Code (IBC). The IBC references the standard ASCE 24, Flood Resistant Design and Construction, which is published by the American Society of Civil Engineers (ASCE). In new construction or existing buildings that are undergoing Substantial Improvements, critical building systems must be elevated to the height specified by ASCE 24-05 for that structure's category (Table 1). As a best practice to protect building systems from inundation, FEMA recommends using the ASCE 24-05 elevations shown in Table 1 whenever possible when retrofitting them in existing buildings.

It is important to consider the dead load on the building structure when elevating equipment to a higher floor (see Figure 1). The additional load may require structural reinforcement of the space where the equipment is being relocated. In some cases, special consideration should be given to the isolation of or resistance to vibration loads induced by mechanical equipment. It is also important to ensure the equipment will comply with code requirements when exposed to a different hazard. For instance, a generator moved to the rooftop to protect against flooding will need to be protected from seismic and wind loads.

Terminology

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

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010) for more information. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions.

Table 1. Minimum Elevations for Utilities and Associated Equipment

Structure Category *	Flood Hazard Areas (Zone A)	Coastal High Hazard Areas (Zone V) and Coastal A Zones	
		Orientation of LHSM Parallel** to Wave Approach	Orientation of LHSM Perpendicular** to Wave Approach
II. All buildings and other structures except those listed in Categories, I, III, and IV	BFE + 1 foot or DFE, whichever is greater	BFE + 1 foot or DFE, whichever is greater	BFE + 2 feet or DFE, whichever is greater
III. Buildings and other structures that represent a substantial hazard to human life in the event of failure (school with capacity greater than 250, power generation stations, etc.)	BFE + 1 foot or DFE, whichever is greater	BFE + 2 feet or DFE, whichever is greater	BFE + 3 feet or DFE, whichever is greater
IV. Buildings and other structures designated as essential facilities (hospital, fire and police stations, etc.)	BFE + 2 feet or DFE, whichever is greater***	BFE + 2 feet or DFE, whichever is greater***	BFE + 3 feet or DFE, whichever is greater***

BFE = Base flood elevation: The required minimum elevation for the lowest floor under the National Flood Insurance Program (NFIP) as delineated on FEMA Flood Insurance Rate Map (FIRM). If a building is located in a community that has adopted Advisory Base Flood Elevations (ABFEs), those elevations must be used instead of the BFEs shown on the FIRM.

DFE = Design flood elevation: BFE or higher depending on ASCE Structure Category and on State and local floodplain management requirements (i.e., some jurisdictions may require freeboard).

LHSM = Lowest Horizontal Structural Member

* Refer to ASCE 7 or ASCE 24 for complete definitions

** Parallel means ≤ +20 degrees from the direction of wave approach; perpendicular means > +20 degrees from the direction of wave approach

*** In the upcoming edition of ASCE 24, it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater.

Floodproofing

If elevating is not practical, critical equipment can be protected by floodproofing. Floodproofing is any combination of structural and non-structural additions, changes, or adjustments to a building that reduces flood damage. Floodproofing measures can reduce the length of time a building is unoccupied following a flood; however, they are ***not*** intended to help maintain building occupancy ***during*** a flood event. FEMA is currently developing a publication on floodproofing non-residential structures (FEMA P-936), which is scheduled for release later in 2013.

Dry floodproofing: Dry floodproofing entails making a building or an area within a building substantially impermeable, meaning that no more than 4 inches of water depth will accumulate during a 24-hour period (FEMA 1993). Dry floodproofing measures typically include strengthening the foundation, floors, and walls to resist hydrostatic loads and the application of waterproof coatings, impermeable membranes, backflow prevention valves, and flood shields over windows and doors. Some water may accumulate in the protected area, however, so an internal drainage collection system is required. The drainage system typically includes a sump pit, sump pump, emergency power to the pumps, and a discharge point above the DFE.

Dry floodproofing does not eliminate all potential for flood damage to a building, as flood levels can exceed the design of the floodproofing measures (Figure 2). Additionally, when incorporating a floodproofing measure, it is critical to evaluate the flood loads on the building structure to ensure the protective measure is not creating a structural hazard. For instance, if a door or shield is installed, all components, connections, and gaskets protecting a given dry floodproofed enclosure must be able to resist anticipated flood loads and be considered substantially impermeable as a system. Existing wood frame; spalled or cracked concrete; and unreinforced or inadequately reinforced masonry or concrete walls and floors are examples of especially vulnerable situations that should be flagged for further analysis before retrofitting an area into a dry floodproofed enclosure. Refer to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities*, for details on evaluating flood loads and additional information on dry floodproofing.

Terminology

Residual Risk: Remaining exposure to damage after other known risks have been countered, factored in, or eliminated. For example, a building elevated to the ABFE/BFE is still vulnerable to damage when the 1-percent-annual-chance flood is exceeded.

Figure 1: Temporary structural support system for electrical and mechanical room equipment being elevated from subgrade to a higher floor in a high-rise building in lower Manhattan. The temporary columns will eventually be replaced with a permanent support system.

Dry floodproofing involves:

- Conducting a detailed building evaluation to identify potential floodwater points of entry (such as pipe and conduit openings, doors, vents, and windows), collect flood hazard and load data, identify flood warning time, and consider residual risk.
- Designing the dry floodproofing system to prevent water from entering up to the DFE. Measures may include:
  - Installing or constructing substantially impermeable walls and floors
  - Sealing wall penetrations, such as pipe, conduit, vent, and other openings
  - Installing flood shields to close openings
  - Reinforcing the structure to resist lateral and uplift flood loads

- Installing backflow prevention valves
- Adding internal drainage systems along with a discharge point above the DFE
- Providing emergency power for critical system components (sump pumps)

- Developing an operations and maintenance plan

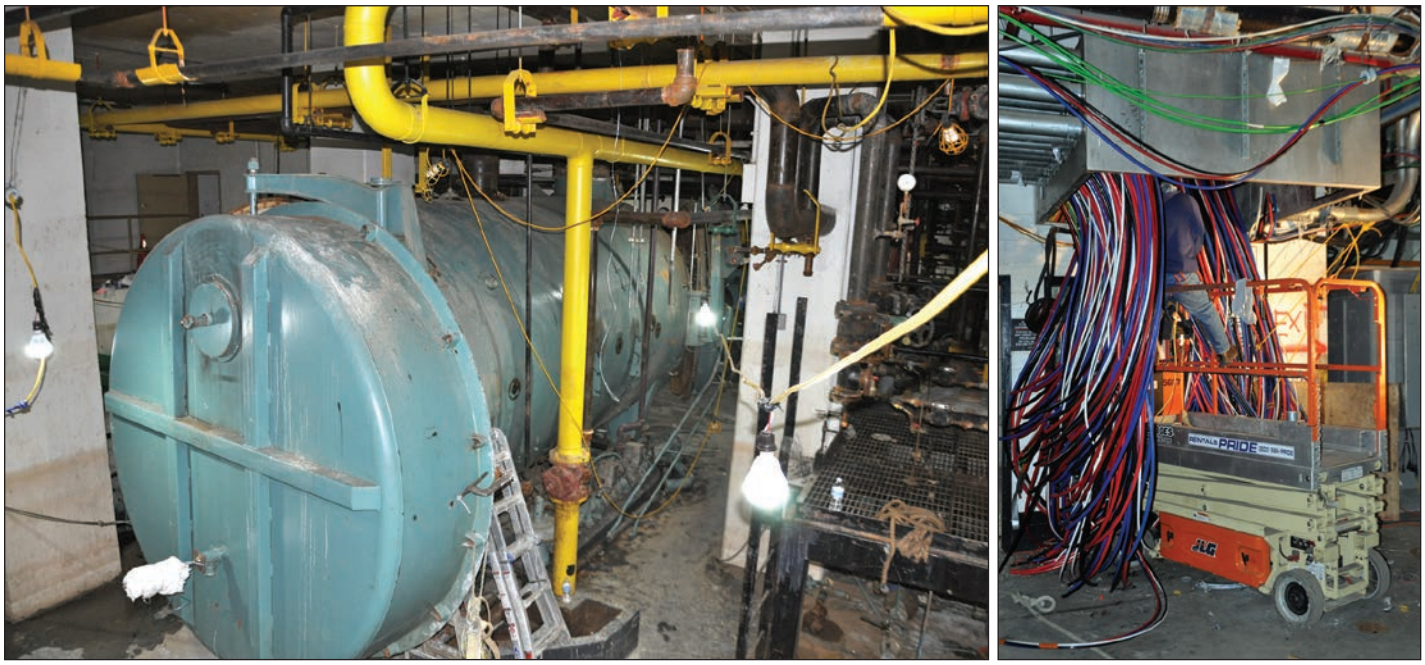

Figure 2: This mechanical room (left) in a recently built high-rise in lower Manhattan was inundated when dry floodproofing measures were overtopped by Hurricane Sandy floodwaters. This photograph shows electrical conduit (right) being replaced throughout the subgrade levels after being submerged in saltwater.

NFIP regulations prohibit dry floodproofing measures in new buildings, buildings determined to have Substantial Damage, or buildings undergoing Substantial Improvements in non-residential or multi-use buildings located within Zone V, also called the Coastal High Hazard Area (for more information, refer to 44 CFR Section 60.3(c)(3) and NFIP Technical Bulletin 3-93). ASCE 24 also prohibits dry floodproofing measures in High Risk Flood Hazard Areas, including the Coastal A Zone. To receive full credit for flood insurance rating, the NFIP requires that dry floodproofing measures protect the structure up to 1 foot above the BFE (or ABFE, if applicable) and be completely passive measures that do not require human intervention. ASCE 24-05 specifies limitations on flood velocity, human intervention, flood warning time, and other factors related to dry floodproofing (refer to Section 6.2 of ASCE 24 for a complete list of requirements). In addition, ASCE 24-05 requires minimum elevations when dry floodproofing, as shown in Table 2.

Identifying all potential **floodwater points of entry** can be complicated in mid- to high-rise buildings, especially in urban environments, where utilities may have multiple entry points and buildings may be interconnected below ground.

Table 2. ASCE 24-05 Minimum Elevations for Dry Floodproofing

Structure Category*	Minimum Elevation
II and III	BFE + 1 foot or DFE, whichever is greater
IV	BFE + 2 feet or DFE, whichever is greater**

BFE = Base flood elevation: The required minimum elevation for the lowest floor under the National Flood Insurance Program (NFIP) as delineated on FEMA Flood Insurance Rate Map (FIRM). If a building is located in a community that has adopted Advisory Base Flood Elevations (ABFEs), those elevations must be used instead of the BFEs shown on the FIRM.

DFE = Design flood elevation: BFE or higher depending on ASCE Structure Category and on State and local floodplain management requirements (i.e., some jurisdictions may require freeboard).

* Refer to ASCE 7 or ASCE 24 for complete definitions.

** In the upcoming edition of ASCE 24, it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater.

The model building codes and NFIP regulations provide an alternative that allows equipment to be located below the DFE. This alternative requires that such equipment be designed, constructed, and installed to prevent damage from floodwater. Protection can be provided by a floodproofed enclosure, for instance, that would prevent floodwater from entering or accumulating (see Figure 3). When such floodproofing measures are implemented, it is important to consider how the protected area would be adversely affected if flooding exceeds the design level of the enclosure.

Figure 3: Dry floodproofed fuel pump room adjacent to generator fuel tank vault in lower Manhattan

Wet floodproofing: Wet floodproofing prevents or provides resistance to damage from flooding while allowing floodwater to enter the structure or area. Application of wet floodproofing measures is generally limited to enclosures below elevated structures and must use flood-damage resistant materials. For more information, refer to NFIP Technical Bulletin 7-93, *Wet Floodproofing – Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (1993).

Application of wet floodproofing is typically limited to parking, building access, and storage areas below the DFE. Wet floodproofing measures include:

- Using flood damage-resistant materials below the DFE
- Elevating utilities, controls, equipment (including elevators), and important contents above the DFE
- Configuring electrical and mechanical systems to minimize disruptions and facilitate repairs
- Installing flood openings to allow automatic entry and exit of floodwater to equalize hydrostatic pressure
- Installing pumps to gradually remove floodwater from the building after a flood event

Integrated floodproofing measures: In some cases, dry and wet floodproofing measures are combined to reduce flood risk. For example, a building in lower Manhattan had floodproof enclosures for fuel pumps and tanks throughout its basement (Figure 3) along with wet floodproofed corridors and sump pumps throughout the basement. The basement experienced limited flooding, and the building had little to no functional downtime compared to an adjacent facility that was closed for 2 weeks. Integrating wet floodproofing measures within floodproof enclosures helps reduce recovery time if the dry floodproofing is overtopped during a flood event.

Emergency Power Considerations

Most buildings with emergency power use either battery-powered systems for emergency power and/or generators for longer duration outages. ***Battery-powered systems*** are typically used for emergency egress lighting, data servers, alarm systems, and other small equipment. ***Generators***, on the other hand, typically service a number of systems, including heating, ventilation equipment, fire pumps, elevators, and domestic water booster pumps.

Proper planning when designing and locating emergency power systems is essential for maintaining function during a major disaster. To protect emergency power systems, facility managers should first identify the emergency power needs and then decide how best to prevent the emergency power from failing during a flooding event.

Emergency power planning considerations: When planning the needed emergency power supply for a building, it is important to consider the following: (1) how long the building may be without utility power; (2) what equipment is critical to functionality and needs to be connected to the emergency power supply distribution; (3) whether

equipment will be damaged or lost during rapid, unexpected power loss or power restoration (surges, spikes); and (4) how quickly backup power is needed (seconds, minutes, hours, etc.).

Since it is difficult to predict the duration of a power outage before a major event, building operators and owners should consider factors such as the time needed to evacuate a building and the time needed to obtain additional temporary power. Using this information, owners and operators can establish the minimum length of time that emergency power will be required. For example, a continuity of operations plan for a high-rise data center may specify that emergency power will be required for 1 day to allow for the transfer of data to a back-up facility or 3 days to install a temporary generator on site.

It is important to consider the entire emergency power supply system as a whole or it may not function during an emergency. An effective plan should identify:

- Which building systems require emergency power
- What emergency power capacity is needed, how quickly it must be activated, and for how long
- Effective protection for the generator, such as locating it in an elevated and hardened position
- How distribution equipment, transfer switches, fuel pumps, and critical equipment supplied by the emergency power system will be protected
- A reliable and consistent fuel source for the generator (source should also be protected from flooding by being properly anchored, submersible, or elevated)

After identifying how long the building is likely to require emergency power, the next step is to identify what building equipment must be operated during the outage. Essential equipment may include life-safety equipment needed to evacuate the building; fire pumps; emergency lighting and outlets; heating and cooling elements such as boilers, pumps, chillers, and air handlers; domestic water booster pumps to provide water to upper stories; elevator controls; sump pumps; and any other equipment critical to operating the building (communications, alarm systems, food preservation, data centers/servers, medical, etc.).

Fuel source considerations: Selecting a fuel source for a generator is just as critical as estimating the power outage duration and deciding what equipment will need emergency power. The fuel source must be reliable to ensure it is available when the generator needs to operate. For example, natural gas companies often preemptively turn off the gas supply before a hazard event, making municipal gas an unreliable source during an event. Similarly, a below-grade fuel storage tank vent must be located well above the DFE to prevent fuel from contaminating floodwater and floodwater from entering the fuel tank. Additionally, fuel tanks must be protected from buoyancy and crushing forces when submerged in floodwater. Refer to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities*, for additional information. If possible, a redundant fuel source should be identified. A building may need multiple storage tanks or can install an emergency connection for temporary fuel in case the primary source is compromised.

Protect the entire emergency power system: The emergency power equipment and controls must be protected to ensure they will be available when needed. The generator contains controls that monitor output and adjust fuel based on the electrical power drain. A ***transfer switch*** regulates whether power is drawn from the electrical utility or the emergency source; this switch also prevents backfeeding generator power into utility lines. A ***fuel pump*** supplies the fuel to the generator. The ***distribution panel and electrical feeders*** supply the emergency power to the critical equipment. Protecting these components by properly locating or floodproofing them is just as critical as protecting the generator and fuel source, since failure of any element will cause the entire system to fail. The fuel pump in Figure 3 is an example of a protected emergency power system component.

Limiting Building Operational Interruption

In addition to elevating critical building systems or installing floodproofing measures, the following mitigation measures may reduce the loss of building services during flood events:

- ***Establish and maintain a connection point for temporary utilities.*** Several building managers interviewed after Hurricane Sandy stated they intend to establish or maintain a connection for at least temporary heat and power in the event of a future need. The building managers plan to prepare their buildings' infrastructure for quick transfer to a temporary power source, install a platform for the equipment, and establish an access point for emergency power.
- ***Establish and maintain redundancies.*** Establishing redundancies reduces the likelihood of losing service for the entire building. For example, one high-rise building visited after Hurricane Sandy had four electrical points

of service that all converged into one below-grade electrical switch gear room. The building manager plans to modify the system by distributing the services to four elevated switch gear rooms spread throughout the building, offering redundancy in case one is compromised. It is critical for these redundancies to be maintained throughout their life so they operate as intended when needed.

- ***Protect elevator service.*** Loss of elevator service in high-rise buildings hinders vertical building access and significantly affects building service and operations. Elevator and conveyance system components should be protected sufficiently to enable restoration of elevator service to the building as quickly as possible. When feasible, elevator equipment such as electrical controls and hydraulic pumps should be located above the DFE. If such equipment must be located below the DFE in the elevator pit, it should be protected using flood damage-resistant components.

Additional lessons learned include:

- ***Steam and gas heating systems are less prone to prolonged disruption than oil furnaces.*** Most of the buildings heated by steam and gas were online within a week or two after Hurricane Sandy, while those with oil furnaces were still reliant on an emergency heat source 2 months later. In addition, damaged oil tanks contaminated buildings, which complicated restoration and repairs.
- ***Use flood damage-resistant material.*** Use of such materials in lower floors reduced repair efforts in many of the buildings flooded during Hurricane Sandy. Repairing flooded buildings offers a good opportunity to improve flood-damage resistance.
- ***Limit use of lower floors.*** Buildings where lower levels were limited to parking, building access, and storage areas (e.g., fuel vaults) experienced less flood damage than those with multi-use lower levels.
- ***Elevate temporary equipment.*** Placing temporary equipment on scaffolding or platforms adjacent to facilities reduced the number of times temporary utility equipment had to be shut down and relocated (see Figure 4).

Figure 4: Temporary chillers elevated on scaffolding during repair of a high-rise building in lower Manhattan

Resources and Useful Links

American Society of Civil Engineers (ASCE). 2005. ASCE 24-05. *Flood Resistant Design and Construction*. Available at http://www.asce.org.

FEMA (Federal Emergency Management Agency). 1993. NFIP Technical Bulletin 3-93. *Non-Residential Floodproofing – Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. Available at http://www.fema.gov/library/viewRecord.do?id=1716.

FEMA. 1993. NFIP Technical Bulletin 7-93. *Wet Floodproofing — Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. Available at http://www.fema.gov/library/viewRecord.do?id=1720.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

FEMA P-348. 1999. *Protecting Building Utilities from Flood Damage*. Available at http://www.fema.gov/library/viewRecord.do?id=1750.

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FEMA. 2008. NFIP Technical Bulletin 2-08. *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*. Available at http://www.fema.gov/library/viewRecord.do?id=1580.

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FEMA. 2013. Hurricane Sandy Recovery Advisory No. 5. *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*. Available at http://www.fema.gov/library/viewRecord.do?id=6994.

FEMA P-936. 2013. *Floodproofing Non-Residential Buildings*. Available at http://www.fema.gov/media-library/assets/documents/34270.

International Code Council (ICC). *International Building Code*. 2006/2009/2012. Available at http://www.iccsafe.org.

National Fire Protection Association (NFPA). 2011. *National Electrical Code*. NFPA 70, 2011 Edition. Available at http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=70&cookie%5Ftest=1.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

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Designing for Flood Levels Above the BFE After Hurricane Sandy

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA5, April 2013*

Purpose and Intended Audience

Flooding in New York and New Jersey extended far beyond mapped Special Flood Hazard Areas (SFHA) and exceeded base flood elevations (BFEs) by several feet in some areas. Lessons learned from Hurricane Sandy can be used to guide repair and reconstruction efforts and design of new buildings to reduce susceptibility to future flood damage.

This Recovery Advisory reviews how coastal Flood Insurance Rate Maps (FIRMs) and BFEs are established and provides guidance on elevating buildings to minimize flood damage in cases where flood levels exceed the BFE. The intended audience for this advisory is primarily homeowners and designers, but it may be helpful to anyone involved in selecting lowest floor elevations for new construction and reconstruction of buildings in areas affected by Sandy.

Key Issues:

1. Elevating to the BFE does not provide complete protection against flooding. Storms more severe than the base flood can and do occur.
2. FIRMs are only as accurate as the topography, bathymetry, and technical information used, and the technical analyses performed, to create them. FIRMs are a snapshot in time and may become outdated as physical conditions, climate, and engineering methods change.
3. Once flood levels exceed the lowest floor of a building, the extent of damage increases dramatically, especially in areas subject to coastal waves (Figure 1).
4. Design and construction practices can minimize damage to buildings, particularly by elevating the building higher than the minimum required elevation.

This Recovery Advisory Addresses:

- FIRMs, FISs, and flood risk
- Building damage when flood levels rise above the lowest floor
- How high above the BFE a building should be elevated
- Effect of building elevation on flood insurance premiums
- Additional design considerations for mitigating flood damage, inside and outside mapped flood hazard zones

Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SHFA and BFE are both shown on FIRMs.

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Figure 1: Back wall failure due to flood level above the lowest floor of a house in Ortley Beach, NJ

FIRMs, FISs, and Flood Risk

Constructing a building to the minimum National Flood Insurance Program (NFIP) requirements—or constructing a building outside the SFHA—is no guarantee the building will be undamaged by flooding. In order to make informed decisions during repair and reconstruction, owners, designers, and communities should understand the following:

- FIRMs are based on modeling of the best available topographic, hydraulic, and climate conditions data at the time of the Flood Insurance Study (FIS). However, there are inherent uncertainties in the modeling and analysis of BFEs and flood hazard zones. Some FIRMs, particularly older FIRMs, may no longer accurately reflect the shoreline location, land characteristics, and actual risk during a base flood event.
- The BFE is the flood level with a 1-percent-annual chance of occurrence. In coastal areas, the BFE is based on model studies of both historical and hypothetical storms.
- Floods can and do exceed the BFE and extend beyond the SFHA. In some recent storms (Katrina [2005], Ike [2008], and Sandy [2012]), flood levels exceeded the BFE by several feet in some areas and extended far beyond the SFHA shown on the FIRM. Figure 2 shows a comparison of the mapped SFHA at the time of Sandy (yellow hatched area) and the area actually flooded by Sandy (blue shaded area) for a portion of Coney Island, NY.

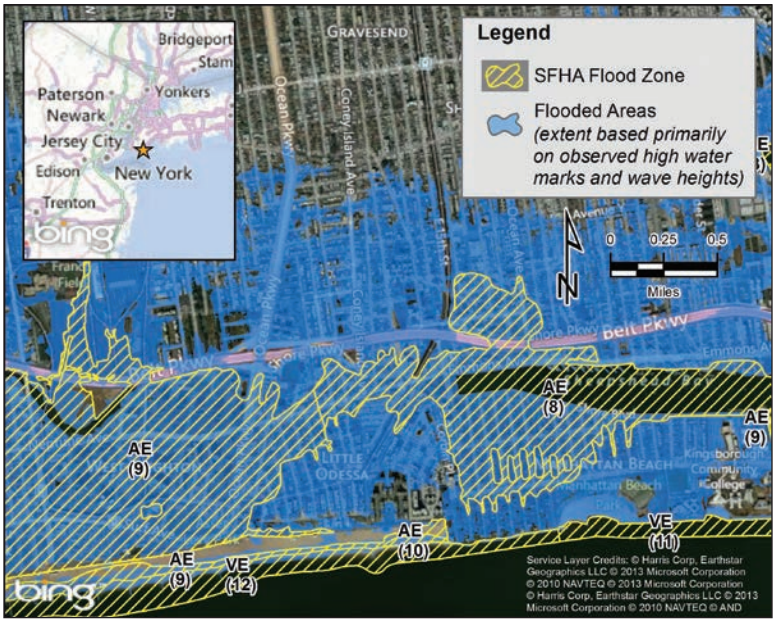


Figure 2: Comparison of SFHA and extent of inundation from Hurricane Sandy, Coney Island, NY

Sources of Flood Hazard Information

FIRMs and FISs.[1] FIRMs delineate flood hazard zones (e.g., Zone VE, Zone AE), which reflect the nature of the flood conditions expected during the base flood. FIRMs also show Zone X areas that are outside the SFHA but which are subject to flooding with a 0.2-percent-annual chance of occurrence (500-year flood).[2] FIRMs show BFEs associated with a flood that has a 1-percent-annual chance of occurrence (Figure 3). BFEs in coastal areas include wave effects and are higher than storm surge stillwater levels.

FIRMs are issued after an FIS is completed, and are then adopted by communities that regulate floodplain development. FISs are prepared using the specified models and the physical, hydraulic, and climate conditions in effect at the time of the FIS. The resulting FIRMs are drawn using the FIS data. FIRMs and FISs are thus a "snapshot" of flood risk at a certain time, and can become outdated as topographic or hydraulic or climate conditions change, or as engineering methods and models improve.

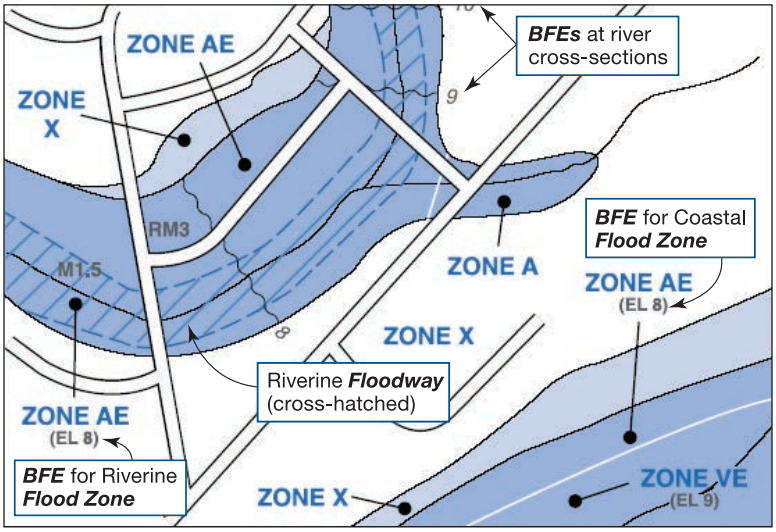


Figure 3: Sample FIRM showing flood hazard zones and BFEs

1 FIRM and FIS tutorials are available through FEMA (FEMA 2000a, FEMA 2000b)
2 FIRMs may also show areas where flood risks have not been studied or determined (Zone D).

Most FIRMs produced after approximately 2005 are based on FEMA's current computer models and engineering procedures. BFEs and flood hazard zones on FIRMs that are dated many years before this may understate actual flood risk. In such cases, elevating buildings above the BFE and extending flood-resistant construction practices outside the mapped SFHA is recommended. The date of the technical studies should be verified for any referenced FIRM by reviewing the associated FIS. Some recent FIRMs, even those published since 2005, are not based on new technical studies (e.g., FIRMs for New York City dated 2007 were based on storm surge models and statistical analyses from the 1980s).

It is critical for building owners, operators, designers, and others to understand that FIRMs do not account for future impacts related to:

- Shoreline erosion, dune loss, land subsidence, and sea level rise
- Multiple severe storms occurring over a short period of time
- Topographic and bathymetric changes, upland development, and addition of impervious surfaces that affect drainage and/or flooding
- Degradation or settlement of seawalls, levees, and floodwalls
- Changes in storm climatology (frequency and severity)

These future conditions can be addressed through building siting decisions in concert with design considerations and mitigation actions described in subsequent sections of this advisory. More information on coastal FIRMs and BFEs can be obtained in FEMA publications, specifically: Section 3.6 of FEMA P-55, *Coastal Construction Manual* (2011 edition) and Fact Sheet No. 3 in *Home Builder's Guide to Coastal Construction* (FEMA 2010a). Section 3.7.1 of FEMA P-55 also provides guidance on evaluating a FIRM to determine whether it still reasonably depicts base flood conditions.

Advisory Base Flood Elevation (ABFE) maps. After severe coastal storms FEMA may issue ABFE maps for areas where the existing FIRMs no longer adequately represent the actual base flood risk. ABFE maps are based on ***in-progress*** or ***approximate*** studies. Figure 4 shows an example ABFE map. They are intended to offer guidance on elevating new and reconstructed buildings. ABFE maps provide interim information for reconstruction efforts and can be used until the new FISs and FIRMs become effective.

Use of ABFE maps is mandatory only when a State or community adopts them. ABFE maps for portions of New Jersey and New York are available at http://www.region2coastal.com/sandy/abfe.

- ***New Jersey:*** ABFE maps were released for 10 New Jersey counties (Atlantic, Bergen, Burlington, Cape May, Essex, Hudson, Middlesex, Monmouth, Ocean, and Union) on December 14, 2012. New Jersey adopted the ABFE maps for reconstruction on January 24, 2013.[3]

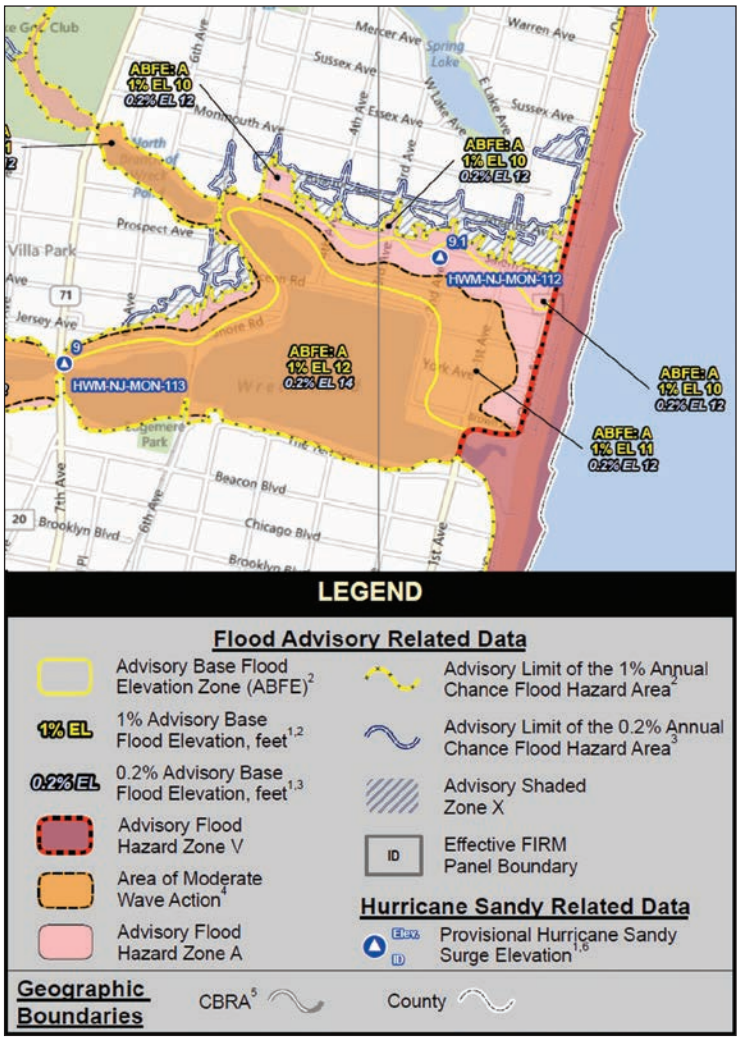


Figure 4: Example ABFE map (Monmouth County, NJ)

3 For more information, see "Local Flood Damage Prevention Ordinance – Adoption of Advisory Base Flood Elevation maps" (State of New Jersey 2013)

- ***New York:*** ABFE maps were released for six New York Counties (Bronx, Kings, New York, Richmond, Queens, and Westchester). ABFE maps were released for Westchester County and for portions of New York City on January 28, 2013. The remaining New York City ABFE maps were released on February 25, 2013. No ABFE maps will be released for Nassau and Suffolk Counties because their FIRMs are up-to-date and are based on current models and technical studies. As of January 31, 2013, New York City requires reconstruction to add freeboard above the effective BFE, but allows zoning relief for some reconstruction if owners build to the ABFE (if the ABFE is higher than the effective BFE plus freeboard).[4]

Probability of Flood Level Exceeding the BFE

FIRMs depict the regulatory limits of flooding, flood elevations, and flood hazard zones for the 1-percent-annual chance (100-year) flood event. Buildings constructed to the elevations shown on a FIRM offer protection only to the BFE. Some coastal storms result in flood levels that exceed the BFE. The blue line in Figure 5 shows the probability of a flood event that will result in floodwaters above the 100-year flood level. As shown on the figure, there is an 18 percent chance the 100-year flood level will be exceeded in a 20-year period, a 26 percent chance it will be exceeded in a 30-year period, and a 51 percent chance it will be exceeded in a 70-year period (typical useful life of a home). Therefore, a building elevated to the BFE has a significant chance of being flooded during its useful life and elevating above the BFE reduces this chance and can also reduce flood insurance premiums for the building. Likewise, buildings sited just outside the SFHA (beyond the 100-year flood hazard area, but especially those within the 500-year flood hazard area) still have a significant chance of being flooded over their useful life.

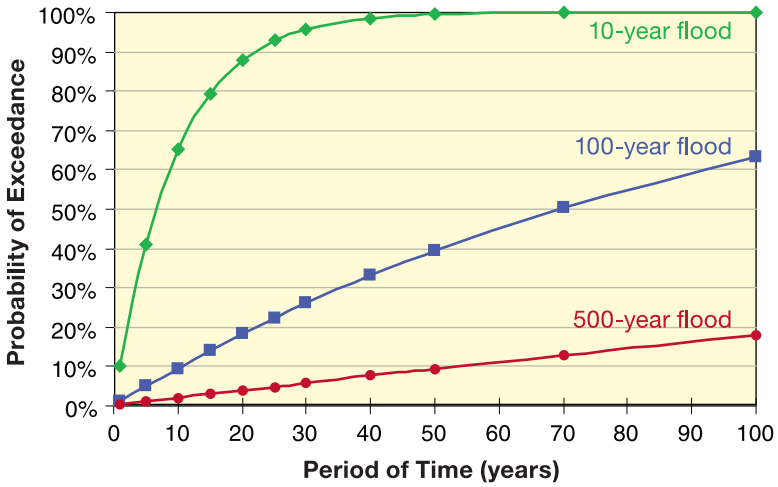


Figure 5: Probability of a flood exceeding the 10-year (10-percent-annual chance), 100-year (1-percent-annual chance), and 500-year (0.2-percent-annual chance) flood level during a given period of time (assuming no sea level rise)

Building Damage When Flood Levels Rise above the Lowest Floor

Buildings are designed to resist most environmental hazards (wind, seismic, snow, etc.), but are generally designed to avoid flooding by elevating the building above the anticipated flood elevation. The reason for this difference in design approach is because of the sudden onset of damage when a flood exceeds the lowest floor elevation of a building—building elements and contents get wet, and moving water imparts large structural loads on the building.[5]

Areas Subject to Wave Action

Severe flood damage is likely in areas where waves accompany coastal flooding. In Zone V areas, waves are capable of causing Substantial Damage (refer to text

Terminology

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

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010b) for more information. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions.

4 For more information, see "Rebuilding After Sandy" webpage (New York City Department of Buildings 2013)
5 Refer to the flood damage calculator at http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp

box) to some buildings when the tops of the waves reach approximately 1 to 2 feet above the top of the floor. In contrast, inundation flooding (without waves) in Zone A areas may submerge the structure without causing Substantial Damage. This difference in building damage is a result of the energy of coastal waves striking and undermining buildings. This difference was obvious in the variation in flood damage caused by Hurricane Sandy (Figures 6 and 7).

Figure 6: Wave, storm surge, and erosion damage to oceanfront house at Rockaway, NY

Figure 7: Area subjected to shallow inundation, but not subject to waves or erosion at Long Beach, NY

Areas Protected by Barriers

When buildings are situated behind barriers such as dunes, seawalls, or levees, a failure of the barrier can result in rapid flooding and introduction of waves into the formerly protected area. Moreover, buildings close to barriers that fail are more likely to be physically damaged by water moving at high velocities than are buildings farther from the barrier. Buildings farther away are more likely to suffer inundation damage. Even when barriers remain intact, buildings close to them can be struck by waves that overtop the barrier.

How High Above the BFE a Building Should be Elevated

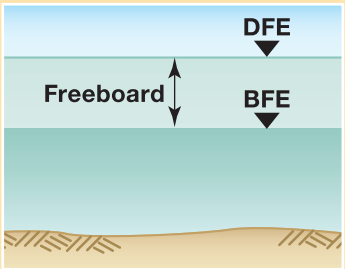
New buildings, buildings with Substantial Damage undergoing reconstruction, and buildings undergoing Substantial Improvements must be elevated so that their lowest floor[6] is at or above the BFE. Some States and communities require elevation above the BFE; this is known as adding freeboard. Adding freeboard or regulating to a flood more severe than the base flood results in a higher minimum building elevation. This is often known as the design flood elevation (DFE).

The amount of freeboard to be added depends on a number of factors. Before selecting a freeboard value, building owners and designers should decide whether a freeboard mandated by a State or community is sufficient to protect a particular building or if additional freeboard is needed.

Terminology

Freeboard: The vertical difference between the lowest floor[6] of a building and the BFE, usually expressed in feet. It can be thought of as a factor of safety to compensate for the fact that flood levels can reach higher than the BFE.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.



6 In Zone A, lowest floor means the top of the lowest floor; in Zone V, lowest floor means the bottom of the lowest horizontal structural member of the lowest floor

Required Design Considerations

The selection of appropriate freeboard amounts must include consideration of locally adopted requirements, as well as the importance of the building to the community during and after a hazard event.

> Building owners and designers should consult with building officials and floodplain managers regarding appropriate freeboard levels above the BFE.

Building codes and floodplain management regulations. Building codes may contain freeboard requirements or reference other documents with freeboard requirements. The International Building Code (IBC), which serves as the basis for the New York State, New York City, and New Jersey State building codes, requires buildings to be designed and constructed in accordance with the American Society of Civil Engineers' *Standard for Flood Resistant Design and Construction* (ASCE 24). ASCE 24 requires between 0 and 3 feet of freeboard above the BFE, depending on the flood hazard zone and the importance of the building.[7]New York State adopted freeboard in its residential building code, and some communities in both New York and New Jersey have adopted freeboard in their floodplain management regulations. Buildings must be elevated as high as the freeboard requirement in the building code or reference standard or floodplain management regulation. Owners may choose to build even higher.

Building height restrictions. Some communities may limit (through zoning or building regulations or restrictive covenants) the number of building stories or may specify a maximum height above the ground that a building floor level or roof cannot exceed. Such height restrictions may limit the vertical height of a building and preclude the amount of freeboard that some owners may desire. Owners and designers should check with communities to see if height restrictions exist and work with communities to relax those restrictions to achieve improved flood damage resistance.

Importance of the building to the community. Certain buildings and facilities (e.g., police, fire, emergency operations centers, and hospitals) are deemed critical or essential to a community and must remain partly or fully operational during and after severe flood events. In some cases, the community may determine that other buildings and facilities (such as schools, community centers, transportation, and utilities) are critical or essential for their community and should be capable of carrying out operations immediately after a severe storm. The recommendations in this advisory can also be applied to those buildings and facilities. To maintain needed functionality, these essential buildings and facilities should be elevated or protected to a higher elevation than most commercial and residential buildings. Building codes and ASCE 24 acknowledge this need and require additional freeboard. FEMA recommends that essential facilities be elevated or protected to the higher of: the code-mandated elevation, the community-mandated elevation, or the 500-year flood elevation. Communities may wish to use the flood of record[8] as the elevation/protection level for essential facilities.

> For more information on category classification requirements, see Occupancy Category Table 1-1 ASCE 7-05 and Risk Category Table 1.5-1 in ASCE 7-10, as well as the guidance in FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*, January 2007. Note: ASCE 7-05 and ASCE 7-10 use different category classifications; also, check for any modifications made by your State or local jurisdictions.

> **ABFEs and BFEs**
>
> FEMA recommends that communities apply the adopted ABFEs to new construction, buildings undergoing Substantial Improvements, and Substantially Damaged structures to ensure that construction is built stronger, safer, and less vulnerable to future flooding events.
>
> Construction and repair of buildings in communities that have adopted ABFEs must use the revised elevation in place of the BFE shown on the Effective FIRM.
>
> Post-Hurricane Sandy ABFE maps are available for parts of New York and New Jersey at http://www.region2coastal.com/sandy/abfe. FIRMs for all other participating communities are available at https://msc.fema.gov/.

7 Use of the 1998 edition of ASCE 24 is required by the 2003 edition of the IBC. Use of the 2005 edition of ASCE 24 is required by the 2006, 2009, and 2012 editions of the IBC. The 2009 and 2012 IRC permit, but do not require, use of ASCE 24-05.

8 Refers to the highest recorded flood elevation for a given location.

Grant requirements. Hazard Mitigation Assistance and other Federal or State grants for elevating or reconstructing buildings often require projects to use ABFEs or other freeboard requirements.

Recommended Considerations

In addition to required design considerations, FEMA recommends review of available FIRMs, FISs, and ABFE information; evaluation of possible future conditions; and consideration of building owner risk tolerance when determining appropriate freeboard amounts.

Building owner tolerance for damage, displacement, and downtime. Many building owners never want to go through the disruption and damage sustained during Hurricane Sandy again. Reducing the probability of this occurring again will necessitate using either large freeboard amounts when repairing and rebuilding buildings and equipment or construction of tall flood barriers (where permitted). Freeboard and other flood-resistant design and construction practices should be incorporated to the maximum extent feasible.

Age of the Effective Flood Analysis. See subsection on FIRMs and FISs.

Availability of Preliminary FIRMs. When FISs are completed, the FIRMs are first issued as "Preliminary" maps to allow the public to submit comments and appeals. Once the comment period is over and appeals, if any, have been resolved, the final maps are issued. Preliminary FIRMs represent the best available data prior to final FIRMs being adopted and becoming effective. If preliminary BFEs are higher than effective BFEs,[9] buildings should be elevated above the BFEs shown on Preliminary FIRMs, with the amount of freeboard depending on the other factors described in this Recovery Advisory.

Availability of ABFEs. FIRMs for many of the New Jersey and New York counties affected by Hurricane Sandy were based on flood studies that are more than 25 year old. FEMA had initiated new FISs prior to Hurricane Sandy, but those studies were not complete and Preliminary FIRMs had not been issued when Sandy struck. As described in the FIRMs and Flood Risk subsection of this advisory, FEMA produced ABFE maps after Hurricane Sandy using data from the restudies in progress and other information. Buildings should be elevated at least as high as the ABFEs unless more detailed studies show the ABFEs are overly conservative.

Future conditions. Because FIRMs reflect conditions at the time of the FIS, owners, designers, and communities may wish to consider future conditions (such as sea level rise, subsidence, shoreline erosion, increased storm frequency/intensity, and levee settlement and failure) when deciding how high to elevate a building.

Rising sea levels have been well documented at National Oceanic and Atmospheric Administration (NOAA) tide gages in New Jersey, New York, and Long Island Sound.[10] Figure 8 shows an example of a sea level records between 1856 and 2006 in New York. Taken as a whole, sea level in the area affected by Hurricane Sandy has been rising at a rate of 2.4 to 4.1 millimeters/year (0.8 to 1.3 feet/century), averaging 3.0 millimeters/year (1.0 foot/century). If this rate of sea level rise continues into the future, the frequency of coastal flooding will increase. Today's base flood will be more likely to occur in the future, and future BFEs will increase above today's level. If the rate of sea level rise accelerates beyond the historical trend, as many scientists predict (New York City Panel on Climate Change 2009), sea levels could rise several feet in the next century, significantly increasing the risk of flooding to buildings inside and outside the SFHA.

Most buildings are expected to have a functional life span of many decades, so it is important to consider future conditions when designing new buildings or performing significant retrofits on existing ones. Although not incorporated into the BFE or ABFE, FEMA recommends that sea level rise be considered when selecting lowest floor elevations for new and reconstructed buildings. At a minimum, 1 foot of freeboard above the code-required freeboard is recommended to account for a continuation of the historical rate of sea level rise. Owners, designers, and communities should add additional freeboard if they want to plan for sea level rise above the historical trend. Section 3.3.4.1 of FEMA P-55, *Coastal Construction Manual* (CCM) (FEMA 2011), provides information on sea level rise statistics. Section 8.5.2 of P-55 illustrates simple procedures to estimate future effects of coastal erosion and sea level rise. State Coastal Zone Management (CZM) agencies should be consulted for erosion rate and other future conditions information that can be used with the CCM procedures.

9 If effective BFEs are higher than preliminary BFEs, local regulations will require use of the effective BFEs until such time as new maps are adopted and become effective.

10 Refer to NOAA Web site at http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml.

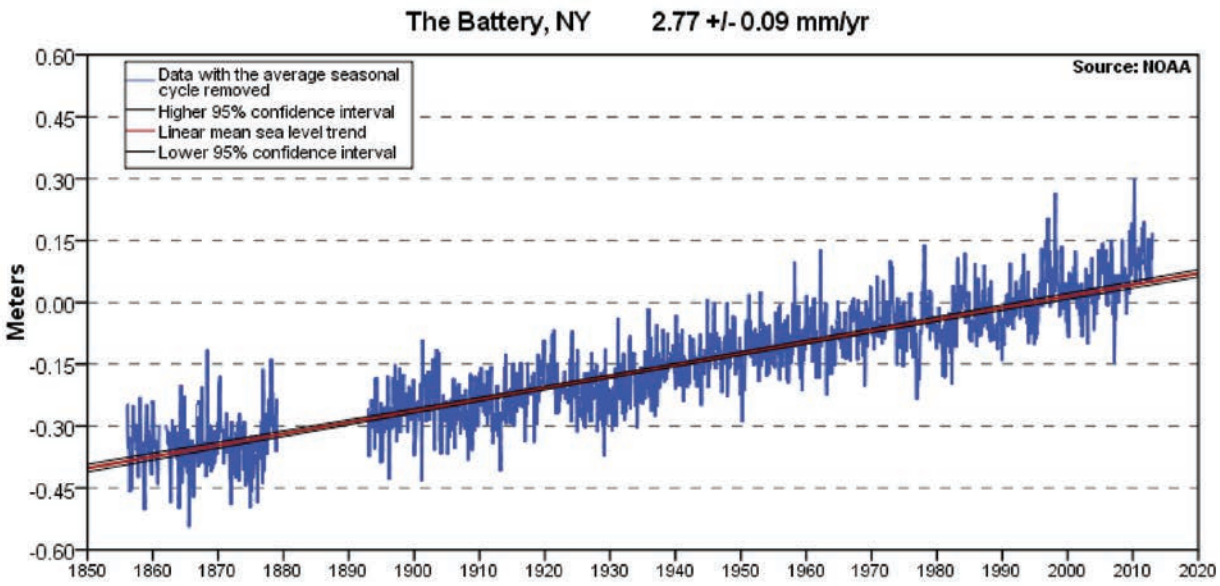


Figure 8: Sea level rise at The Battery, NY, 1856–2006 (Source: NOAA Web site)

Effect of Building Elevation on NFIP Flood Insurance Premiums

NFIP flood insurance premiums are affected by the elevation of the building in relationship to the BFE. As part of design considerations, building owners should be aware of two things:

- Flood insurance premiums drop significantly as freeboard increases, provided equipment is not located below the BFE and any enclosed space is compliant with NFIP requirements (e.g., flood openings in Zone AE, free of obstructions in Zone VE, etc.).
- The 2012 NFIP reauthorization legislation (called the Biggert-Waters Flood Insurance Reform Act of 2012) eliminates flood insurance premium subsidies and "grandfathering" for many existing buildings that are—or may be in the future—below the BFE (for more detail, see the text box on page 9 titled "Biggert-Waters impact on flood insurance premiums").

Flood Premiums and Freeboard

According to the flood insurance premium rate tables in FEMA's *Flood Insurance Manual*, premium savings can be substantial when freeboard is added to building design (FEMA 2013a). These savings can be enough to repay the added cost of elevating higher in just a few years' time (AIR 2006, FEMA 2008).

- Adding 1 foot of freeboard above the BFE can save an owner approximately 25 to 40 percent in annual flood insurance premiums, depending on the flood hazard zone and building characteristics.
- Adding 4 feet of freeboard can save approximately 50 to 65 percent in annual flood insurance premiums in some flood zones.

Biggert-Waters Flood Insurance Reform Act of 2012

On July 6, 2012, a new law (hereafter called "Biggert-Waters") took effect, significantly changing the NFIP and how flood insurance premium rates will be determined in the future (FEMA 2012). Changes affect how buildings are rated to reflect actual flood risk and eliminate grandfathering and flood insurance premium subsidies for many buildings.

Of importance to property owners, some buildings constructed in compliance with today's BFEs and flood hazard zones may be subject to significantly higher flood insurance premiums in the future if revised FIRMs show higher BFEs and increased flood risk. For more information, please see FEMA's *Flood Insurance Reform Act of 2012: Impact of changes to the NFIP* (FEMA 2013b).

Additional Design Considerations for Mitigating Flood Damage Inside and Outside Mapped Flood Hazard Zones

In addition to the design considerations described in other sections of this advisory, the following recommendations can help building owners minimize damage in the event that coastal flood levels rise above the BFE.

Design for Hazardous Wave Conditions

In addition to adding freeboard, buildings should be designed to withstand more hazardous wave conditions than the FIRM indicates (see Figure 10). Anticipate future conditions, including:

- Zone V conditions extending inland into the Coastal A Zone.
- Coastal A Zone (1.5- to 3-foot wave heights during the base flood) extending into the mapped Zone A.
- Zone A flood conditions extending landward of the SFHA boundary into Zone X (extend the freeboard elevation landward until the ground rises to this elevation). See Figure 10, A-2.[11]
- In other words, if a building is situated in one flood zone but is close to a more hazardous zone, property owners should consider designing, elevating, and using construction methods as if the building were located in the more hazardous zone.

Elevate Bottom of Lowest Horizontal Structural Member to BFE

In all areas where flooding is anticipated, inside and outside the mapped SFHA, elevate the lowest floor so that the bottom of the lowest horizontal structural member is above the BFE (see Figures 11 and 12).

Even though the NFIP and some building codes allow the top of the lowest floor to be set equal to the BFE in Zone A, the top of the floor should be set above the BFE. Otherwise, the floor systems, floor coverings, floor insulation, lower walls, and utilities contained therein will incur flood damage during the base flood. In addition to structural damage, inundation may lead to costly repairs from mold or floodwater contamination.

Design Loads

In Zones V and A, design loads and conditions (hydrostatic loads, hydrodynamic loads, wave loads, floating debris loads, and erosion and scour) should be calculated using 100-year flood conditions. Loads can be based on freeboard levels if desired, but freeboard is usually used as a factor of safety against getting wet, not for design load calculations.[12]

Effect of Biggert-Waters on Flood Insurance Premiums

According to *Changes in the Flood Insurance Program: Preliminary Considerations for Rebuilding* (FEMA 2012):

> *Under the new law, flood insurance premium rates on many properties in special flood hazard areas will increase. The new rates will reflect the full flood risk of an insured building and some insurance subsidies and discounts will be phased out and eventually eliminated.*
>
> *Rates on almost all buildings that are,* **or will be***, in special flood hazard areas will be revised over time to reflect full flood risks. Based on various conditions set forth in the law, subsidies and grandfathered rates will be eliminated for most properties in the future.*
>
> *Subsidies will be phased out for the following types of properties: non-primary residences, severe repetitive loss properties, business properties, and properties that have incurred flood-related damages where claims payments exceed the fair market value of the property.*
>
> *Policy rates will also increase based on one or all of the following circumstances:*
>
> - *After a change of ownership;*
> - *After there is a lapse in insurance coverage;*
> - *When a new or revised flood insurance rate map is issued; or*
> - *If there is substantial damage or improvement to a building.*

11 If in Zone X, completing an Elevation Certificate may help implement this recommendation.
12 If the design flood is defined as a higher flood return period (e.g., 500-year flood), the design loads should be based on the higher flood level.

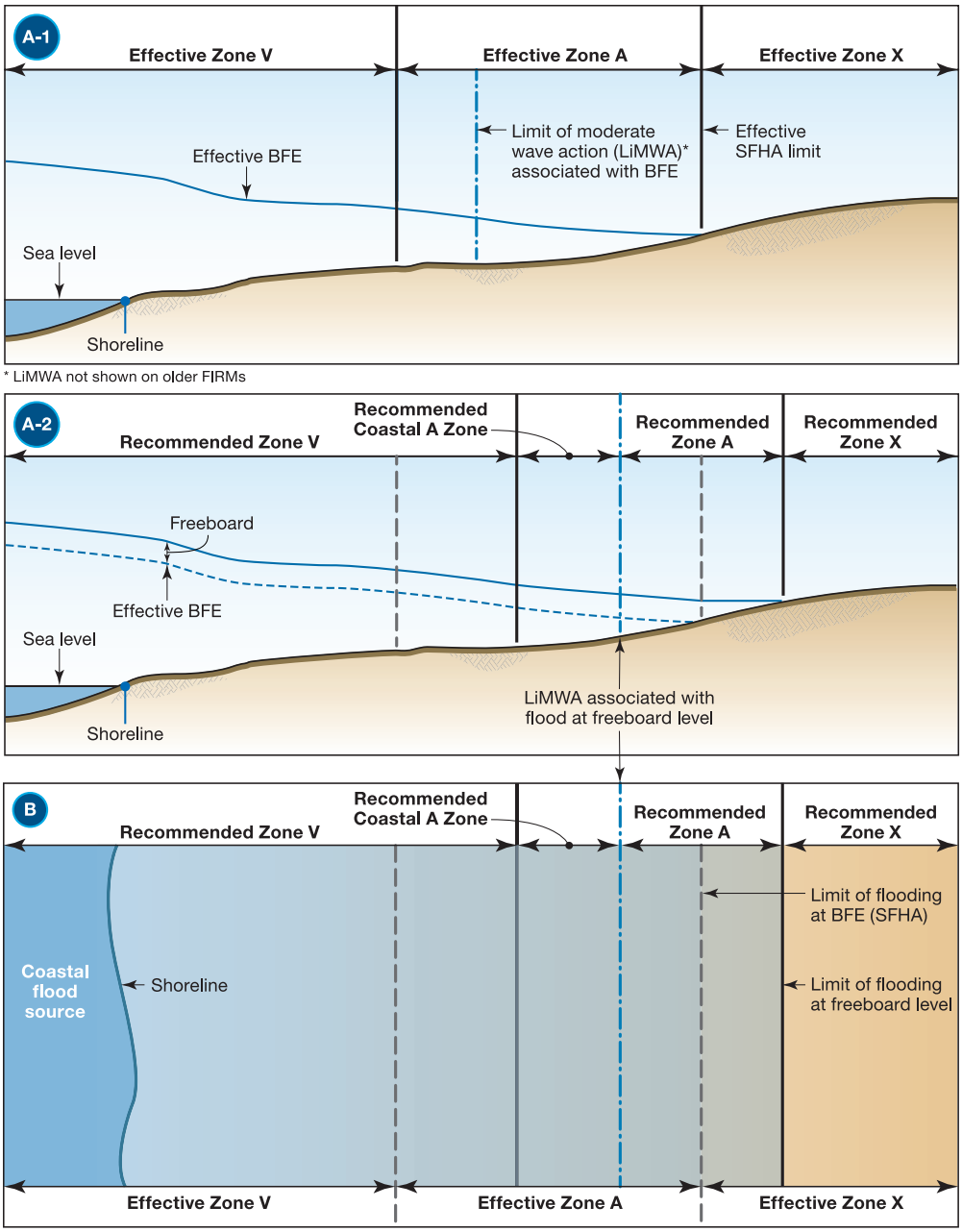


Figure 10.
Higher flood levels shift flood zones landward. Figure A-1 shows a cross-section of existing coastal flood hazards. Figure A-2 shows how recommended flood hazard zones shift as higher flood levels occur or higher freeboard is considered. Figure B is a map view comparing the existing and recommended flood hazard zones.

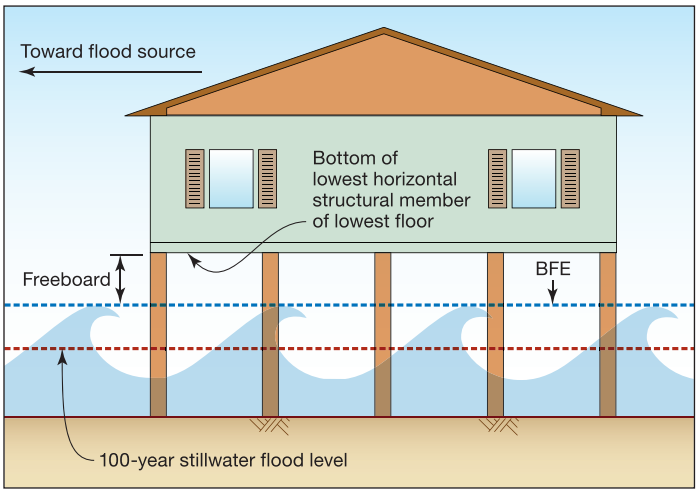


Figure 11: Recommended construction in anticipated Zone V and Coastal A Zones

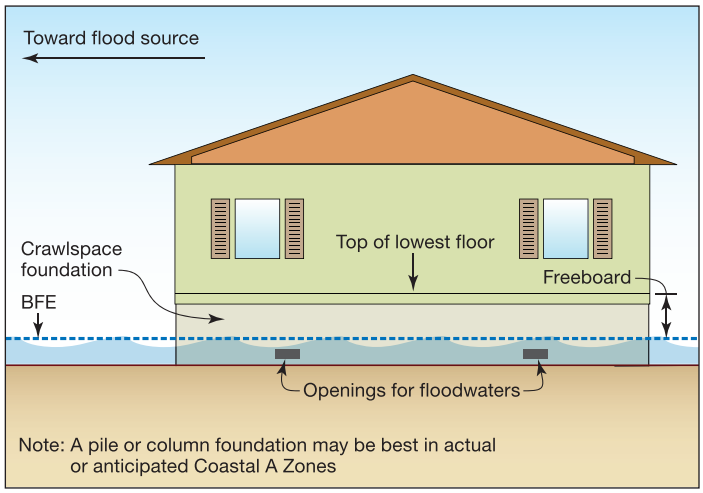


Figure 12: Recommended elevation in landward portion of Zone A. Applies also in Zone X where flooding is anticipated or likely; in Zone X, substitute freeboard elevation for BFE.

Property owners sometimes ask if elevating a home will result in higher wind loads on the building. Calculations indicate that wind pressures on elevated buildings are nominally higher than for non-elevated buildings, and therefore this is not generally a concern (FEMA 2009). Although the incremental wind load is generally small, the increased wind loads should be considered in foundation design and in the attachments of the elevated house to the foundation.

Use Strong Connections

Use strong connections between the foundations and the elevated building to prevent the building from floating or washing off the foundation if flood levels rise above the lowest floor. Refer also to Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings* (2013).

Use Flood Damage-Resistant Materials

Flood damage-resistant building materials and methods should be used not only below the lowest floor, but also for wall construction and floor finishes sitting directly on the lowest floor. For example, consider using drainable, dryable interior wall assemblies similar to those illustrated in Figure 13. This allows interior walls to be opened up and dried after a flood that rises above the lowest floor. Walls should be designed and constructed to accommodate flooding without damage (LSU 2012). To prevent wicking and limit flood damage, building owners can use the following flood damage-resistant methods and materials:

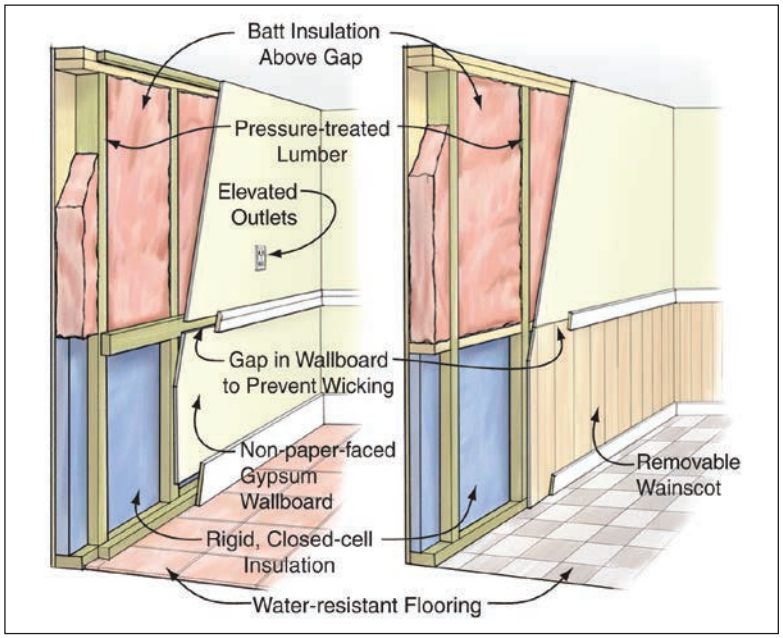


Figure 13: Wet floodproofing techniques for interior wall construction; details may vary depending on wall construction (Source: LSU, 2012)

- Construct walls with pressure-treated wood framing and with horizontal gaps in the wallboard (a chair rail can be used to conceal the gap)
- Elevate electrical outlets, wiring, and circuit panels to a location above the horizontal gap
- Install rigid or closed-cell insulation in lower portions of walls
- Below the horizontal gaps, use non-paper-faced gypsum wallboard, concrete board, or a removable wainscot; use a water-resistant drywall primer and finish with latex paint
- Use water-resistant flooring with waterproof, marine-grade adhesive

Resources and Useful Links

- AIR (American Institutes for Research). 2006. *Evaluation of the National Flood Insurance Program's Building Standards.* Available at http://www.fema.gov/library/viewRecord.do?id=2592.
- ASCE (American Society of Civil Engineers). 2005. *Standard for Flood Resistant Design and Construction*. ASCE 24-05.
- FEMA (Federal Emergency Management Agency). 2000a. *How to Read a Flood Insurance Rate Map – Tutorial*. Available at http://www.fema.gov/library/viewRecord.do?id=2324.
- FEMA. 2000b. *How to Read a Flood Insurance Study – Tutorial*. Available at http://www.fema.gov/library/viewRecord.do?id=2325.
- FEMA 543. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*. Available at http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=2441.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

- FEMA. 2008. *2008 Supplement to the 2006 Evaluation of the National Flood Insurance Program's Building Standards*. Washington D.C.
- FEMA P-762. 2009. Local Officials Guide for Coastal Construction. Available at http://www.fema.gov/media-library/assets/documents/16036.
- FEMA P-499. 2010a. *Home Builder's Guide to Coastal Construction Technical Fact Sheet Series.* Available at http://www.fema.gov/technology-transfer/home-builders-guide-coastal-construction-technical-fact-sheet-series-fema-p-499.
- FEMA P-758. 2010b. *Substantial Improvement/Substantial Damage Desk Reference*. Available at http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=4160.
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- FEMA. 2012. *Changes in the Flood Insurance Program: Preliminary Considerations for Rebuilding.* Available at http://www.seasideparknj.org/wp-content/uploads/2012/12/NFIP-Fact-Sheet.pdf.
- FEMA. 2013a. *Flood Insurance Manual,* January 1, 2013 edition. Available at http://www.fema.gov/flood-insurance-manual.
- FEMA. 2013b. Biggert Waters *Flood Insurance Reform Act of 2012, Impact of National Flood Insurance Program (NFIP) Changes*. Available at http://www.fema.gov/library/viewRecord.do?id=7187. Accessed April 4, 2013.
- Louisiana State University Agricultural Center. 2012. "Wet Floodproofing." Web page available at http://www.lsuagcenter.com/en/family_home/home/design_construction/Design/Remodeling+Renovation/Preventing+Flood+Damage/Wet+Floodproofing.htm. Accessed March 3, 2013.
- New York City Department of Buildings. 2013. "Rebuilding After Sandy." Webpage available at http://www.nyc.gov/html/dob/html/rebuilding_after_sandy/storm_update.shtml. Accessed April 2, 2013.
- New York City Panel on Climate Change. 2009. *Climate Risk Information*. Available at http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf.
- NOAA (National Oceanic and Atmospheric Administration). 2013. *Sea Levels Online*. Available at http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml. Accessed March 11, 2013.
- State of New Jersey. 2013. "Local Flood Damage Prevention Ordinance – Adoption of Advisory Base Flood Elevation Maps." Letter published February 4, 2013. Available at http://www.nj.gov/dep/floodcontrol/docs/20130204community-abfe-letter.pdf.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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Protecting Building Fuel Systems from Flood Damage

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA6, April 2013*

Purpose and Intended Audience

Hurricane Sandy impacted several highly developed metropolitan areas including New York City and surrounding cities in New York and New Jersey. Some of the most significant impacts resulted from the failure of fuel tanks that supplied buildings with heat, hot water, and fuel for emergency power systems. Many buildings that experienced damage to their fuel systems during Hurricane Sandy were constructed before codes requiring flood protection were adopted.

This Recovery Advisory provides building owners, operators, facility managers, and designers with information on mitigation actions that can help protect fuel supplies from flood damage, enabling basic functionality to be restored at facilities shortly after floodwaters recede.

Mitigation actions can be taken to reduce the potential for flood damage to fuel systems. These actions are recommended for facilities damaged during Hurricane Sandy as well as facilities that were not damaged but have fuel tanks and fuel supply equipment that is vulnerable to future flood damage.

Key Issues:

1. All components of a fuel system (the main fuel tank, all pumps, power supplies, and all controls) should be protected from floodwater. Protecting system components is especially important for fuel tanks that supply emergency power systems.
2. FEMA's Hurricane Sandy Mitigation Assessment Team (MAT) observed fuel tanks on the lowest floor (in basements) in New York City and other jurisdictions in the impacted area. The New York City building code requires that main fuel tanks be placed on the lowest floor of buildings (including the basement) in order to reduce the fire risk associated with large volumes of flammable liquids. This location, while ideal for reducing the risk of fire, is usually the most vulnerable to flooding.
3. Current codes that reference American Society of Civil Engineers (ASCE) standard ASCE 24, *Flood*

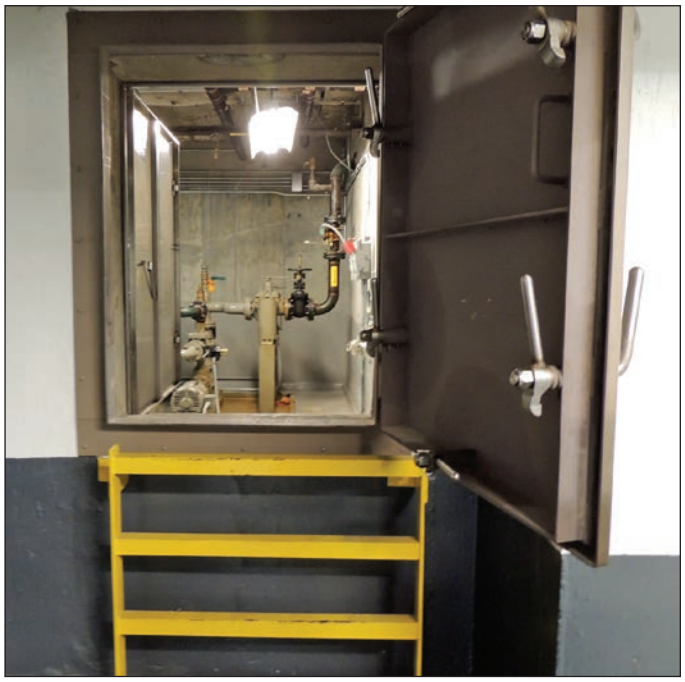

Figure 1: Fuel pump protected by watertight enclosure and "submarine doors" in Manhattan high-rise (top); 13,350-gallon fuel tank in a Manhattan high-rise protected by a similar method (bottom)

Resistant Design and Construction, require equipment and utilities to either be elevated to a specified height or protected by dry floodproofing when placed in buildings located in areas with identified flood risk. However, fuel systems in older buildings constructed before ASCE 24 provisions were adopted or buildings whose flood risk has increased since construction may be vulnerable, particularly when they have floors that extend below grade.

This Recovery Advisory Addresses:

- Codes and standards governing fuel systems
- Retrofit of fuel systems in existing buildings
- Preparing for a flood event in unmitigated buildings
- Links and useful resources

Codes and Standards Governing Fuel Systems

Several different codes and standards regulate the installation of new fuel tanks and fuel systems. The following section discusses some of the more pertinent regulations that apply to new construction and *may* apply to the repair or replacement of fuel systems in existing buildings. Local building departments should be contacted to identify all applicable requirements. In existing buildings, codes and standards that contain flood provisions should be met when fuel systems are repaired or replaced, even when not required, in order to protect these fuel systems from future flood events.

International Building Code

Section 1612.4 of the International Building Code (IBC) requires that buildings located in flood hazard areas be designed in accordance with ASCE 24. Section 7.0 of ASCE 24 contains general requirements for utilities and Section 7.4 contains specific requirements for mechanical and HVAC systems.

ASCE 24 requires that utilities and attendant equipment be elevated or protected from flooding. The amount of elevation or protection required depends on the type of facility (e.g., critical facilities, such as fire or police stations, and hospitals) and its flood risk identified on FIRMs (i.e., Coastal A Zone, Zone V, etc.). Utilities and attendant equipment (fuel pumps, control systems, motors, etc.) are required to be elevated from 1 to 3 feet above the base flood elevation (BFE) or elevated above the design flood elevation (DFE), whichever is greater. The elevation requirements are listed in Table 7-1 of ASCE 24. In the upcoming edition of ASCE 24 (ASCE 24-13), it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater. In terms of required elevation, both Advisory Base Flood Elevations (ABFEs) and any applicable local requirements (such as freeboard) should be considered. Refer to text box for ABFE information, and refer to Hurricane Sandy Recovery Advisory No. 5 for a description of freeboard.

Terminology

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.

Design Flood: ASCE 24 defines the design flood as the "greater of the following two flood events: (1) the *base flood*, affecting those areas identified as *special flood hazard areas* on the community's FIRM; or (2) the flood corresponding to the area designated as a *flood hazard area* on a community's *flood hazard map* or otherwise legally designated."

Advisory Base Flood Elevation (ABFE): After severe coastal storms, FEMA may issue ABFE maps for areas where the existing FIRMs no longer adequately represent the actual base flood risk. ABFE maps are based on *in-progress* or *approximate* studies. They are intended to offer guidance on elevating new and reconstructed buildings. ABFE maps provide interim information for reconstruction efforts. Use of ABFE maps is mandatory only when a State or community adopts them. ABFE maps for portions of New Jersey and New York are available at http://www.region2coastal.com/sandy/abfe.

For more information, refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy* (FEMA 2013).

Appendix G of the IBC, *Flood Resistant Construction*, covers tank requirements in section G701.

Section G701.1: Specifies that underground tanks must be designed and constructed to prevent flotation, collapse, or lateral movement from hydrostatic loads (including the effects of buoyancy) during design flood conditions.

Section G701.2: Specifies that aboveground tanks must be located above the DFE specified in ASCE 24, or designed, constructed, and anchored to prevent flotation, collapse, or lateral movement from hydrostatic and hydrodynamic loads.

Section G701.3: Specifies that all tank inlets and vents extend above the DFE specified in ASCE 24 or be fitted with covers designed to prevent the inflow of floodwater and the outflow of tank contents. The inlets and vents must also be properly anchored to prevent lateral movement from hydrostatic and hydrodynamic loads, including the effects of buoyancy.

International Mechanical Code

The International Mechanical Code, Section 1305.2.1, specifies that all fuel oil pipe, equipment, and appliances located in flood hazard areas must be either located above the flood elevation required by ASCE 24 or be capable of resisting all flood forces associated with the design flood.

International Fire Code

The International Fire Code (IFC) specifies that the design, fabrication, and construction of fuel tanks must comply with National Fire Protection Association (NFPA) 30, *Flammable and Combustible Liquids Code*. The IFC also includes requirements limiting the size and location of tanks to protect against the risk of fire. If the local building codes have requirements that conflict with the IFC, the building official is responsible for making the determination on which code governs.

Section 603.3.2.5. Requires that tanks in basements be located not more than two stories below grade.

Section 5704.2.7.8. Specifies that uplift protection be provided in accordance with NFPA 30 Sections 22.14 or 23.14 in locations subject to flooding. Section 22.14 applies to above ground tanks; Section 23.14 applies to underground tanks.

New York City Building Codes

The New York City codes have more specific requirements for fuel oil systems than the IBC, likely because of the large number of high-rise buildings in the city. These buildings often require large fuel oil tanks to provide heat and hot water to tenants, and often the fuel tanks must be stored within the building itself. The New York City Mechanical Code specifies that fuel-oil storage and piping systems must comply with the requirements of Chapter 13 and, to the extent not otherwise provided for in the code, with the requirements of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*. The pertinent requirements from the New York City Mechanical and Building Codes are:

Section 1305.11.1 (Mechanical Code). The New York City Mechanical Code specifies that no more than 100,000 gallons of fuel may be stored inside any building.

– Belowground tanks: The maximum tank capacity for tanks installed below ground is 35,000 gallons.

– Aboveground tanks on lowest floor: For tanks installed above ground on the lowest floor, the maximum tank size is 660 gallons, and no more than 1,375 gallons stored in the same 2-hour fire area (the 2-hour fire area is defined in the New York City Fire Code). Tanks larger than 660 gallons are allowed for some construction types when the tanks are located in dedicated rooms or enclosures that are separated from the rest of the building by fire-rated construction. For example, in a building of Type I, II, IIIA, IV, and VA construction with a maximum total allowed quantity of 15,000 gallons, a 15,000-gallon tank is allowed if it is separated from the rest of the building by 3-hour fire-rated construction.

Section 1305.12 (Mechanical Code). Both aboveground and belowground tanks must be in compliance with appropriate design standards.

Section 1305.2.1 (Mechanical Code). To protect against flood hazards, tanks must be in compliance with Appendix G of the New York City Building Code. If a tank or tank vault located in a Zone A area is to be dry floodproofed, it must be designed and installed in accordance with ASCE 24-05.

Section 1704.16 (Building Code). Fuel-oil storage equipment shall be inspected in accordance with the approved construction documents, and testing shall be in accordance with Section 1308.1 of the New York City Mechanical Code.

Appendix G of the New York City Building Code. Most pertinent flood provisions in Appendix G of this code are consistent with those described for Appendix G of the IBC, but are numbered differently. The appropriate sections in the New York City Building Code are Sections G307.1 (corresponds with IBC G701.1), G307.2 (corresponds with IBC G701.2), and G307.3 (corresponds with IBC G701.3). Section G102.1 of the New York City Building Code differs from the IBC.

– *Section G102.1:* Item 9 applies to pre-FIRM buildings and actions that increase the degree of non-compliance. Any changes that would increase the degree of non-compliance, such as relocating equipment, are prohibited.

Requirements for Buildings with Substantial Damage or Undergoing Substantial Improvement

If a building is determined by the local building official or floodplain administrator to have been substantially damaged or will be substantially improved, it must be brought into compliance with the flood resistant construction requirements for new construction, including requirements for fuel tanks.

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

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure (or smaller percentage if established by the community) before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010) for more information. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions.

Retrofit of Fuel Systems in Existing Buildings

Existing buildings may lack the hazard-resistant design features required by current codes. In addition, the flood hazard at the building location may have changed since construction—the building location may be more vulnerable to flooding or may be subject to a higher base flood elevation. As a result, existing buildings may be more vulnerable to floods. Common flood-related failures of fuel systems in existing buildings include:

- Inadequately anchored fuel tanks can become displaced from their foundations when inundated by floodwater. Once displaced, the tanks or the fill, vent, and fuel lines that connect to them, are often damaged, allowing the discharge of fuel that can contaminate the building and surrounding area.
- Partially filled fuel tanks can implode when submerged by floodwaters and cause fuel to be released.
- Fuel tanks with vents that do not extend above the design flood depth or fuel tanks with non-watertight fill lines can either become contaminated with floodwater when submerged, or allow fuel to be released when displaced by floodwaters.
- Fuel pumps—used to move fuel oil from main storage tanks to tanks or equipment on elevated floors—that are not designed for submersible operation can fail when inundated by floodwaters. When fuel pumps fail, the equipment they serve can only operate for a limited time before the equipment exhausts the fuel stored on the upper floors.

To ensure fuel systems remain operational during and after a flood event, all components and equipment should either be elevated above the BFE or DFE as defined by ASCE 24, whichever is higher, or protected from inundation to that height. Because codes may require placing portions of the fuel system at risk of flooding, elevating all components of a fuel system may not be possible, so protecting system components from inundation may be necessary. The following mitigation measures describe floodproofing techniques for the major elements of a fuel oil system.

Fuel Tanks

For situations where fuel oil tanks cannot be elevated, it may be feasible to provide flood protection by replacing the tank with one that can resist floods and flood forces or by placing the tank in a dry floodproofed area.

Tank replacement. Replacing the tank with one that can resist flood forces provides flood protection by ensuring that the fuel tank can resist the hydrostatic pressures and buoyancy (uplift) forces for the design flood event. This may include ensuring that the tank's application is within the boundary conditions stated in testing performed on it, standards it complies with, or manufacturer's guidance provided.

- *Hydrostatic pressures* can cause tanks to implode. For example, a tank that extends 10 feet below the flood level needs to resist pressures as high as 640 pounds per square foot. Even tanks listed for underground applications may not be designed to resist hydrostatic pressures if they are placed at greater depths than those specified by the manufacturer.
- *Buoyant force* on a tank may cause it to separate from its foundation or, in the case of a buried tank, may force it out of the ground. For example, an empty 25,000-gallon fuel oil tank will be subject to over 200,000 pounds of buoyant force when submerged. Using this example, if concrete ballast were used to anchor the tank and the ballast was inundated with floodwaters, nearly 2,400 cubic feet of concrete (approximately 14 feet square by 14 feet high) would be needed to counteract the buoyant force. The weight of material stored in a tank offsets the buoyant force and reduces uplift. Because the level of fuel in a tank can vary, however, the weight of the material within the tank should not be relied upon to resist buoyant forces. When possible, tanks should be anchored sufficiently to prevent flotation when the tank is completely empty. If the required amount of anchorage is not possible, anchorage should be sufficient to prevent flotation of the tank when it contains the least amount of fuel oil that it would normally store. Anchorage points should be distributed across the tank to prevent unequal uplift forces on the tank.

NFPA 30 Tank Requirements

For **aboveground tanks**, NFPA 30 requires that at least 30 percent of a vertical tank's volume extend above the "maximum flood stage" (the phrase "maximum flood stage" is not defined in that code). It requires that anchorage be provided to resist buoyancy when more than 70 percent of a horizontal tank's capacity will be submerged at the "established flood stage" (the phrase "established flood stage" is also not defined). The amount of anchorage only needs to resist uplift for a full tank.

For **underground tanks**, NFPA 30 requires that tanks be anchored to resist buoyancy when empty and fully submerged.

Dry floodproof. Providing protection by dry floodproofing involves placing the tank in a water-tight space. Tanks that cannot resist hydrostatic pressures or cannot be anchored to resist buoyancy may be placed in reinforced rooms designed to resist hydrostatic pressures and anchored to prevent flotation. The rooms, often called vaults, are typically constructed of reinforced concrete because its mass helps counteract buoyancy, and with proper reinforcement, concrete can resist hydrostatic pressures. Steel vaults, which are typically lighter than concrete, can also be used but generally require additional mass or anchorage to resist buoyant forces. Because rooms containing tanks require access and ventilation to prevent explosive concentration of fumes from collecting, they should be equipped with specially designed, watertight submarine doors and ventilation equipment that vents above the design flood level. Also, although dry floodproofing entails making a building or an area within a building "substantially impermeable," meaning that no more than 4 inches of water depth will accumulate during a 24-hour period, some water may accumulate so an internal drainage collection system is required. Sump pumps supported by emergency power sources are recommended. Due to space limitations in many buildings, dry floodproofing may require constructing vaults around existing tanks. Refer also to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities* (2013), and NFIP Technical Bulletin 3, *Non-Residential Floodproofing – Requirements and Certification* (1993).

Fuel Pumps

Fuel pumps and their controls should also be protected from floodwaters. There are two general types of pumps: submersible pumps and external pumps. Submersible pumps, which are installed within the fuel tank, are typically used in underground tanks and sometimes in aboveground tanks within buildings. External fuel pumps are generally not resistant to floodwaters and should only be used when located in dry floodproofed

areas. The pump controls and power for both types of pumps should be elevated, dry floodproofed, or designed for submerged operation.

Fill Lines and Tank Vents

All fill lines, pipes, and connections should include appropriate components (i.e., valves) to prevent floodwaters from contaminating fuel tanks and to prevent fuels from escaping during a flood. Also, tank vents should either extend above flood levels or be provided with check valves that prevent floodwaters from entering the vents when submerged. Because failure of a check valve can result in contaminated fuel, extending vent lines above the DFE is preferred. These recommendations are consistent with NFPA 30 requirements.

Preparing for a Flood Event in Unmitigated Buildings

In the days and hours before a large storm, facility owners can make temporary adjustments to limit damage to fuel tanks in their buildings. These actions are especially critical for instances where no long-term solutions have been implemented to protect tanks and associated equipment. Although these temporary adjustments may reduce the potential for damage to the fuel system and reduce clean-up costs, planning and executing more robust measures as described in this advisory are recommended as they will provide more complete flood protection.

Before the Flood

- **Shut off all fuel-burning equipment**. An example of such equipment is a boiler. If emergency generators are supplied from the main fuel tank or if the amount of fuel stored in day tanks is not sufficient to provide power long enough for code-required life safety protection, the building will need to be evacuated.
- **Fill the fuel tank to minimize buoyant forces and mitigate against structural failure**. If possible, the tank should be completely filled with fuel oil. While completely filling a tank increases the amount of fuel that could be discharged if the tank fails, the potential for tank failure is greatly reduced by filling a tank.

  As a stop-gap measure, water can be used to fill a tank. NFPA 30 describes this approach as water loading. Since freshwater is approximately 12 percent denser than fuel oil, filling a fuel tank with water will increase stresses in the tank and, in extreme cases, could lead to tank failure. The risk of tank failure from water loading is greatest if the tank is empty before it is filled with water; topping off a nearly full fuel tank with water only slightly increases stresses. Water loading should only be done after it can be confirmed that the tank can withstand water loading.
- **Provide shut-off valves at the tank for all lines the tank supplies**. Install the valves as close to the tank as possible. Close the valves if flooding is anticipated.

After the Flood

- **Inspect equipment**. Inspect all portions of the fuel system for damages. Repair or replace all flood damaged equipment.
- **Clean tank**. If water was used to fill the tank, remove water from the tank and properly dispose of the water or fuel oil/water mix. Flush lines and restart the equipment.

Resources and Useful Links

Referenced Codes and Standards

ASCE and ICC

- ASCE (American Society of Civil Engineers). 2005. ASCE 24-05: *Flood Resistant Design and Construction.* FEMA prepared "Highlights of ASCE 24" online at http://www.fema.gov/library/viewRecord.do?id=3515.
- ICC (International Code Council). 2012. *International Building Code/International Residential Code*. Country Club Hills, IL. The ICC offers a free viewer that shows the codes at http://www.iccsafe.org/content/pages/freeresources.aspx.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

– ICC. 2012. *International Fuel Gas Code*. Country Club Hills, IL.
– ICC. 2012. *International Mechanical Code.* Country Club Hills, IL.

NFPA

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For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

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Reducing Flood Risk and Flood Insurance Premiums for Existing Residential Buildings in Zone A

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA7, November 2013*

Purpose and Intended Audience

The Federal Emergency Management Agency (FEMA) Mitigation Assessment Team (MAT) observed inundation damage to residential buildings in New Jersey and New York whose lowest floors were below Hurricane Sandy flood levels. Based on these observations, FEMA offers the information in this advisory to residential property owners interested in reducing their flood risk and National Flood Insurance Program (NFIP) flood insurance premium for existing residential buildings located in Zone A. As property owners rebuild, it is important for them to not only consider mitigation measures that can reduce their risk for flood damage from a future flood event, but also understand how these mitigation measures affect their flood insurance premiums (see Figure 1).

The mitigation measures described in this advisory are intended to be applied to buildings that did not incur Substantial Damage during Hurricane Sandy and are not undergoing Substantial Improvement, though the information may also be useful for owners of homes that incurred Substantial Damage or are undergoing Substantial Improvements. Implementing the mitigation measures described in this advisory may qualify a home for reduced flood insurance rates. Homes that have incurred Substantial Damage or that are undergoing Substantial Improvement are required to be brought into compliance with local floodplain management regulations and building codes.

In addition to describing mitigation measures such as elevation and filling in a basement, this advisory specifically includes guidance on modifying or strengthening existing ground floor walls of a single-family home or row house/townhouse into either an open foundation or solid foundation walls, while also converting the ground floor living area to an enclosure and moving the living area so it is at or above the BFE.

The intended audiences for this Recovery Advisory are homeowners and local floodplain management and building officials, but it may also be useful for planners, contractors, and design professionals advising homeowners.

NFIP Floodplain Management Terminology

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

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

Refer to FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010) for more information. Homeowners should consult a local building official or floodplain administrator to determine whether their local codes and regulations have more restrictive definitions.

Figure 1: The house on the left is in the final stages of being elevated, which will result in reduced flood risk and lower flood insurance rates compared to the house on the right (Highlands, NJ)

Key Issues:

1. Repairing homes damaged during Hurricane Sandy gives building owners the opportunity to implement mitigation measures that will improve flood resistance and lower NFIP flood insurance premiums.
2. Before undertaking a mitigation project, it is critical for building owners to understand the requirements of the NFIP and building codes, including the requirements related to enclosed areas below elevated buildings.
3. Homeowners should work with a registered design professional to develop feasible and effective mitigation solutions.

This Recovery Advisory Addresses:

- Key NFIP requirements for buildings in Zone A
- Moving a building's lowest floor to or above the base flood elevation (BFE) by converting the ground floor and filling below-grade areas and basements or elevating the building
- NFIP requirements for enclosures below elevated buildings
- Elevating mechanical, electrical, and plumbing systems to appropriate levels
- Useful links and resources

Flood Hazard Identification Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SFHA and BFE are both shown on FIRMs.

Special Flood Hazard Areas (SFHAs): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C, on older FIRMs.

Base flood elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Key NFIP Requirements for Buildings in Zone A

Communities that participate in the NFIP are required to adopt and enforce local regulations that apply to new construction and buildings undergoing Substantial Improvement or that have incurred Substantial Damage in areas mapped as Special Flood Hazard Areas (SFHAs). The NFIP establishes minimum criteria and design requirements specifying how structures are to be constructed to minimize the potential for flood damage. A primary requirement is that buildings must be elevated to or above the BFE (see text box for definition). Building owners can determine whether their location is in an SFHA by talking to a local floodplain administrator or building official or by reviewing the applicable Flood Insurance Rate Map (FIRM) and Flood Insurance Study (FIS) report, which show the extent of the SFHAs and the BFEs. For more information on NFIP maps, refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (2013).

After large storm events such as Hurricane Sandy, FEMA may publish Advisory Base Flood Elevations (ABFEs) and associated ABFE Maps to support recovery and improve future resilience. FEMA has also released Preliminary Work Maps (an interim product created as part of the process of developing new FIRMs). Communities must use the latest available flood hazard information when designing recovery or mitigation activities funded using FEMA grants (e.g., Public Assistance or Hazard Mitigation Grants). Recipients of the U.S. Department of Housing and Urban Development (HUD) Community Development Block Grants must use the latest available flood elevation plus 1 foot.

Guidance for Communities Using Post-Hurricane Sandy Flood Hazard Information

FEMA recommends that communities use BFEs obtained from Advisory BFEs (ABFEs), Preliminary Work Maps, or Preliminary FIRMs and Flood Insurance Studies (FISs), if those BFEs are higher than the BFEs in the current Effective FIS report and on current Effective FIRMs. This will help ensure that all recovery construction is built stronger, safer, and less vulnerable to future flooding events. Some communities may require the addition of freeboard (additional elevation) to the ABFE or the Effective BFE.

Guidance for using post-Hurricane Sandy flood hazard information can be found in FEMA Floodplain Management Bulletin 1-98, *Use of Flood Insurance Study (FIS) Data as Available Data* (1998) which provides information on the use of ABFEs, Preliminary Work Maps, or Preliminary FIRMs and FIS reports as "available data" for regulating floodplain development. Post-Hurricane Sandy ABFE maps are available for parts of New Jersey and New York at http://www.region2coastal.com/sandy/bestdata. FIRMs for all other areas are available at https://msc.fema.gov/.

Before beginning any construction, it is important that building owners verify with their local building department that they have all the State and local permits required to do the project. Mitigation projects such as those described in this advisory may result in the local building department making a determination that the home is undergoing Substantial Improvement. Buildings determined by a building official or floodplain administrator to have incurred Substantial Damage or to be undergoing Substantial Improvement are treated as new construction and must be brought into full compliance with the flood provisions of current building codes and local floodplain ordinances that meet or exceed the floodplain management requirements of the NFIP regulations (see text box on Substantial Damage/Substantial Improvement).

NFIP Minimum Criteria and Performance Requirements

NFIP requirements specify how new buildings should be constructed to minimize the risk of flood damage. Building codes include similar requirements. Table 1 summarizes some of the key NFIP requirements for new construction in Zone A, which includes all zones shown on FIRMs as Zones A, AE, A1-A30, AR, AO, and AH. The information in Table 1 is discussed in more detail in other sections of this Recovery Advisory.

When considering mitigation measures, it is important to remember that the house must resist multiple hazards. Buildings must be able to resist the effects of wind and water loads acting simultaneously (where applicable, seismic loads must also be addressed).

Table 1: Key NFIP Building Design Requirements for Buildings Located in Zone A

Provision	Requirement
Design and Construction 44 CFR 60.3(a)(3)(i)	Building and foundation must be designed, constructed, and adequately anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.
Lowest Floor Elevation 44 CFR 60.3(c)(2)	Top of lowest floor (including basement) must be elevated to or above the BFE.
Flood Damage-Resistant Materials 44 CFR 60.3(a)(3)(ii)	Structural and nonstructural building materials below the BFE must be flood damage-resistant.
Enclosures 44 CFR 60.3(c)(5)	Enclosures must be used only for parking of vehicles, building access, and storage. Each enclosure must have a minimum of two flood openings on different walls to allow passage of floodwaters and the bottom of all openings must be no higher than 1 foot above grade.
Utilities 44 CFR 60.3(a)(3)(iv)	Utilities and equipment must be located (elevated) at or above the BFE or designed to prevent floodwaters from entering and accumulating in components during the base flood.

When determining the appropriate building design requirements, homeowners in Zone A should consider that if the area is remapped as Zone V in the future, they may be subject to higher flood insurance premiums. In addition, FEMA recommends applying Zone V requirements to buildings in the Coastal A Zone. For information on Zone V requirements and mitigation options, refer to Hurricane Sandy Recovery Fact Sheet No. 2, *Foundation Requirements and Recommendations for Elevated Homes* (2013).

Terminology

Coastal A Zone: The area of Zone A that is subject to coastal waves during the base flood, delineated by the Limit of Moderate Wave Action (LiMWA), also called the Area of Moderate Wave Action (MoWA) on maps and in some publications. Although the MoWA designation does not currently affect flood insurance premiums, FEMA recommends that communities apply more stringent requirements in this area, such as applying Zone V requirements, to reduce flood damage caused by wave action.

Even when not required by the community, FEMA recommends that homeowners with property in the Coastal A Zone mitigate wave action by conforming to Zone V requirements.

Additional Considerations Related to Flood Insurance Premiums

NFIP flood insurance premiums are based on a number of factors, including the flood risk zone, elevation of the lowest floor above or below the BFE, the type of building and foundation, the number of floors, and whether there is a basement or enclosure below the elevated building. One of the major factors in determining an NFIP flood insurance premium is the designation of the “lowest floor” and how high it is compared to the BFE.

NFIP flood insurance policies have limits on coverage of contents in basements and enclosures below elevated buildings. Upon

completion of any mitigation work related to elevating a building, it is important to have a surveyor complete a new Elevation Certificate[1] to document the elevation of the new lowest floor so that insurance companies can rate the building for flood insurance.

Communities may adopt minimum elevations for buildings in SFHAs that are higher than the Effective BFE, ABFE, or other available data if higher than the Effective BFE. The addition of height above the BFE expressed in feet is referred to as a freeboard requirement. While the addition of freeboard is not an NFIP minimum requirement, it does result in significantly lower flood insurance rates due to reduced flood risk. FEMA recommends the addition of at least 1 or 2 feet of freeboard to account for uncertainties, future development, and floods higher than the base flood.

Designers, contractors, and owners should contact a qualified insurance agent or the NFIP for more information about policy coverage, coverage limits, and costs.

FIRMs are a "snapshot" of conditions at the time the maps were developed. Future conditions may result in higher flood elevations and may change zone designations. Refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy*, for more information on this and on how the recently passed Biggert-Waters Flood Insurance Reauthorization Act of 2012 may affect a property.

NFIP Floodplain Management Terminology

Basement: "Any area of the building having its floor subgrade (below ground level) on all sides."

Lowest floor: "The lowest floor of the lowest enclosed area (including a basement). An unfinished or flood-resistant enclosure, usable solely for parking of vehicles, building access, or storage in an area other than a basement area, is not considered a building's lowest floor provided that such enclosure is not built so as to render the structure in violation of the applicable non-elevation design requirements of §60.3" [the NFIP].

Source: Code of Federal Regulations, Title 44, Part 59.1

Moving a Building's Lowest Floor To or Above the BFE

As shown in Table 1, the lowest floor of a building must be elevated to or above the BFE to minimize flood damage and reduce flood insurance premiums. There are several ways to modify an existing home to elevate or locate the lowest floor to or above the BFE. Table 2 provides a broad overview of the mitigation measures described in the following sections and allows a comparison by building type (detached or attached), relative cost, and the level of difficulty associated with undertaking the project. Refer to FEMA P-312, *Homeowner's Guide to Retrofitting* (2009), for additional mitigation measures.

Table 2: Mitigation Measures for Elevating the Lowest Floor of a Building in Zone A

Feature of Existing Home	Building Type		Cost*	Project Difficulty
	Detached (Free-Standing)	Attached		
Mitigation Measure: Convert ground floor and fill basement (to create NFIP-compliant open foundation or compliant enclosure)				
Concrete/masonry foundation walls	Y	Y	$ – $$	Easy – Moderate
Wood-framed walls	Y	Y	$ – $$	Easy – Moderate
Basement or below grade areas	Y	Y	$	Easy
Mitigation Measure: Elevate the building or elevate floors within the building				
Existing slab-on-grade foundation	Y	**	$$$	Moderate
Existing crawlspace foundation	Y	**	$$	Moderate
Floors of row house/townhouse	Not applicable	Y	$$$$	Hard

Note: Consider using an open foundation consistent with Zone V requirements for buildings in Coastal A Zone.

Y = mitigation measure is possible.

* One dollar sign indicates a less expensive option and four dollar signs indicate the most expensive option.

** Options for attached homes such as duplexes and townhomes are complicated unless all owners elect to undertake mitigation actions together.

1 Elevation Certificate and instructions are available at https://www.fema.gov/media-library/assets/documents/160.

Some of the measures described in this advisory may be difficult to accomplish: for instance, it may not be possible to modify or strengthen the home's existing foundation if the foundation is functionally deficient, or the necessary work may be cost prohibitive to achieve the desired outcome. If it is not possible to modify or strengthen the existing foundation as described in this advisory, a registered design professional should consider other solutions outlined in FEMA's Hurricane Sandy Recovery Fact Sheet No. 2, *Foundation Requirements and Recommendations for Elevated Homes* (May 2013).

WARNING: Property owners should check that the design professional (engineer or architect) is registered or licensed in the State in which the work is being performed.

Regardless of the type of building construction, the NFIP enclosure requirements for the area below the lowest elevated floor (described on page 11 in the subsection titled "NFIP Requirements for Enclosed Areas below the BFE in Zone A") must be followed for the elevated building to be eligible for lower flood insurance premiums.

It may also not be possible to undertake some of the measures described in this advisory if homes are on small lots or too close to adjacent buildings. Therefore, the building and building site must be evaluated carefully when selecting the preferred mitigation measure. Projects that require a large space for equipment access or temporary relocation of a building may not be feasible on some sites; pursuing such a project on a small or constrained lot may result in a project that is complicated and expensive. If elevation is the preferred mitigation measure and the lot size and equipment access would make an individual elevation project too difficult and expensive, one solution may be to elevate multiple homes at the same time.

Converting the Ground Floor and Filling Below-Grade Areas and Basements

If the next highest floor above the ground floor is above the BFE, one way to reduce future damage and reduce flood insurance premiums may be to convert the ground floor to an open foundation or foundation walls with an enclosure. Another option is to fill the basement area if a higher floor is already at or above the BFE, in which case the higher floor can be designated as the lowest floor. How the conversion is done and whether it qualifies for lower flood insurance premiums depends on several factors, described below.

Converting a ground floor or filling in a basement requires moving all the living space and necessary electrical, heating, plumbing, and air conditioning equipment above the BFE (Figure 2). While the amount of living space is reduced, the reduction in NFIP insurance premiums may offset the inconvenience and any loss of building value. To compensate for the lost living space, it may be possible to construct an elevated lateral addition if the lot has enough space. Other options are to remove the existing roof and construct another story above the existing building or finish an unfinished attic area. Homeowners should consult with the community's floodplain manager or building official to see if this is permitted, and also consult with an engineer or architect to help develop options and determine feasible, cost-effective solutions.

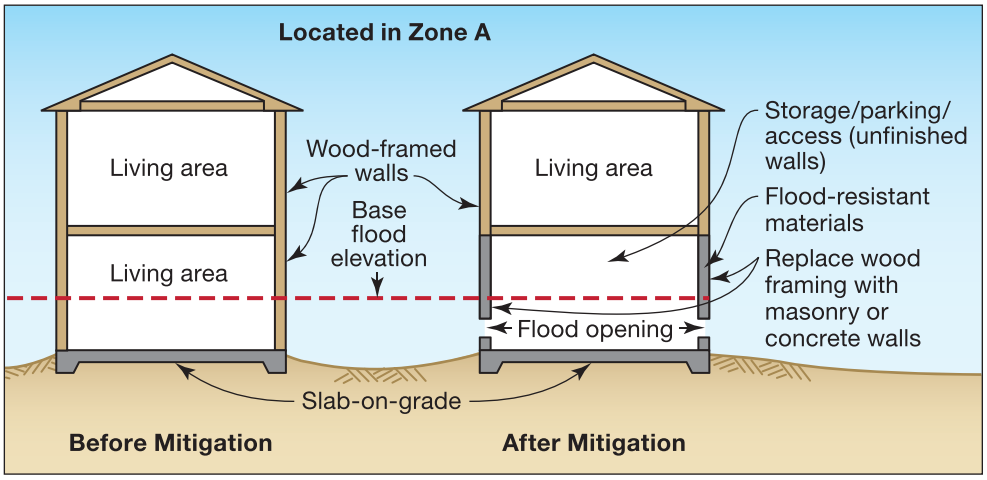


Figure 2: In Zone A, the floor below the BFE (left) can be modified to be compliant with NFIP criteria (right)

Evaluating buildings for converting ground floors. Converting a ground floor living space to an NFIP-compliant open foundation or foundation walls with a compliant enclosure, or filling in a basement, may appear to be simple solutions for some homes. However, even if only minimal remodeling of the ground floor is necessary, a registered design professional should verify that it is an appropriate mitigation measure and that the foundation walls for the ground floor are properly designed and have adequate anchoring to resist anticipated conditions (flooding, wind,

seismic, etc.). A registered design professional should evaluate the building and certify that the design and methods of construction specified for retrofitting the foundation walls are in accordance with accepted standards of practice for meeting the following provisions:

- The foundation and building attached to the foundation must be anchored to resist flotation, collapse, and lateral movement resulting from the effects of base flood water loads acting on building components below the BFE and wind, seismic, or other loads imposed on the structure.
- The potential for scour and erosion at the foundation must be anticipated for conditions associated with the base flood, including wave action.
- Enclosures below the BFE must be designed only for parking of vehicles, building access, and storage.
- Walls below the BFE and supporting the structure must be constructed using flood damage-resistant materials.
- Walls of an enclosure below the BFE must contain flood openings that will allow the automatic entry and exit of floodwater such that they comply with NFIP criteria. See FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).
- To be rated for flood insurance as an elevated building, the building must have no basement, and its lowest elevated floor must be raised above ground level by foundation walls, shear walls, posts, piers, pilings, or columns.

Figure 3 is an example of a foundation wall design certification statement that can be signed by a registered design professional to certify that the design and methods of construction meet the above provisions.

Concrete or masonry foundation walls and shear walls. Homes that have foundation walls made of concrete or masonry are the easiest to convert so that the ground floor becomes an NFIP-compliant open foundation or foundation walls with an enclosure. The work required primarily entails removing any interior finishes; making sure any mechanical, electrical, and plumbing equipment are elevated so that they are at or above the BFE; and adding flood openings in the walls to automatically equalize hydrostatic flood forces on exterior walls. Refer to FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008), to determine the number, size, and location of flood openings the building will need.

Foundation Wall Design Certification Statement

I certify that: (1) I have developed or reviewed the structural design, plans, and specifications for modification of _____(building address) and (2) that the design and methods of construction specified are in accordance with accepted standards of practice for meeting the following provisions:

- The foundation and structure attached thereto are anchored to resist flotation, collapse, and lateral movement due to the effects of base floodwater loads acting on building components below the Base Flood Elevation and wind, seismic, or other loads imposed on the structure.
- The potential for scour and erosion at the foundation has been anticipated for conditions associated with the base flood, including wave action.
- The enclosure below the Base Flood Elevation is designed only for parking of vehicles, building access, and storage.
- The walls below the Base Flood Elevation and supporting the structure are constructed using flood damage-resistant materials.
- The walls of the enclosed space below the Base Flood Elevation contain flood openings that will allow the automatic entry and exit of floodwater.
- The building has no basement and its lowest elevated floor is raised above ground level by foundation walls, shear walls, posts, piers, pilings, or columns.
- The foundation **does / does not** employ wood-frame shear walls (circle one).

Certification and Seal

This certification is to be signed and sealed by a registered professional engineer or architect authorized by law to certify structural designs. I certify the Foundation Wall Design Certification Statement.

Certifier's Name_____ License Number_____
Title_____ Company Name_____
Address_____
City_____ State_____ Zip Code_____
Signature_____ Date_____ Telephone_____

Figure 3: Sample foundation wall design certification statement

A registered design professional should evaluate the building by examining both the footing system and the foundation walls. The footing system should be checked to verify that it can resist erosion and scour and that it will not fail when floodwater rises around the house. The walls should be evaluated to make sure they tie into the footing properly and can resist forces exerted on them during flooding. Most concrete walls have reinforcing steel inside the concrete. Masonry walls should be investigated to verify the presence of reinforcing steel. If it is determined that there is no reinforcing steel or not enough reinforcement given the anticipated flood conditions, the registered design

professional should determine whether it is feasible to reinforce the walls to provide sufficient resistance.

Wood-framed walls. Homes with the lowest floor below the BFE that are built on concrete slabs with wood-framed walls do not meet the minimum floodplain management requirements of the NFIP and building codes. This advisory provides guidance for modifying or strengthening the walls of such homes so that the wood-framed walls function as shear wall foundations. However, homes modified or strengthened in this way may not be eligible for lower flood insurance premiums unless the work is considered a Substantial Improvement. To qualify for lower flood insurance, the conditions shown in the text box must be met. Both conditions are described below.

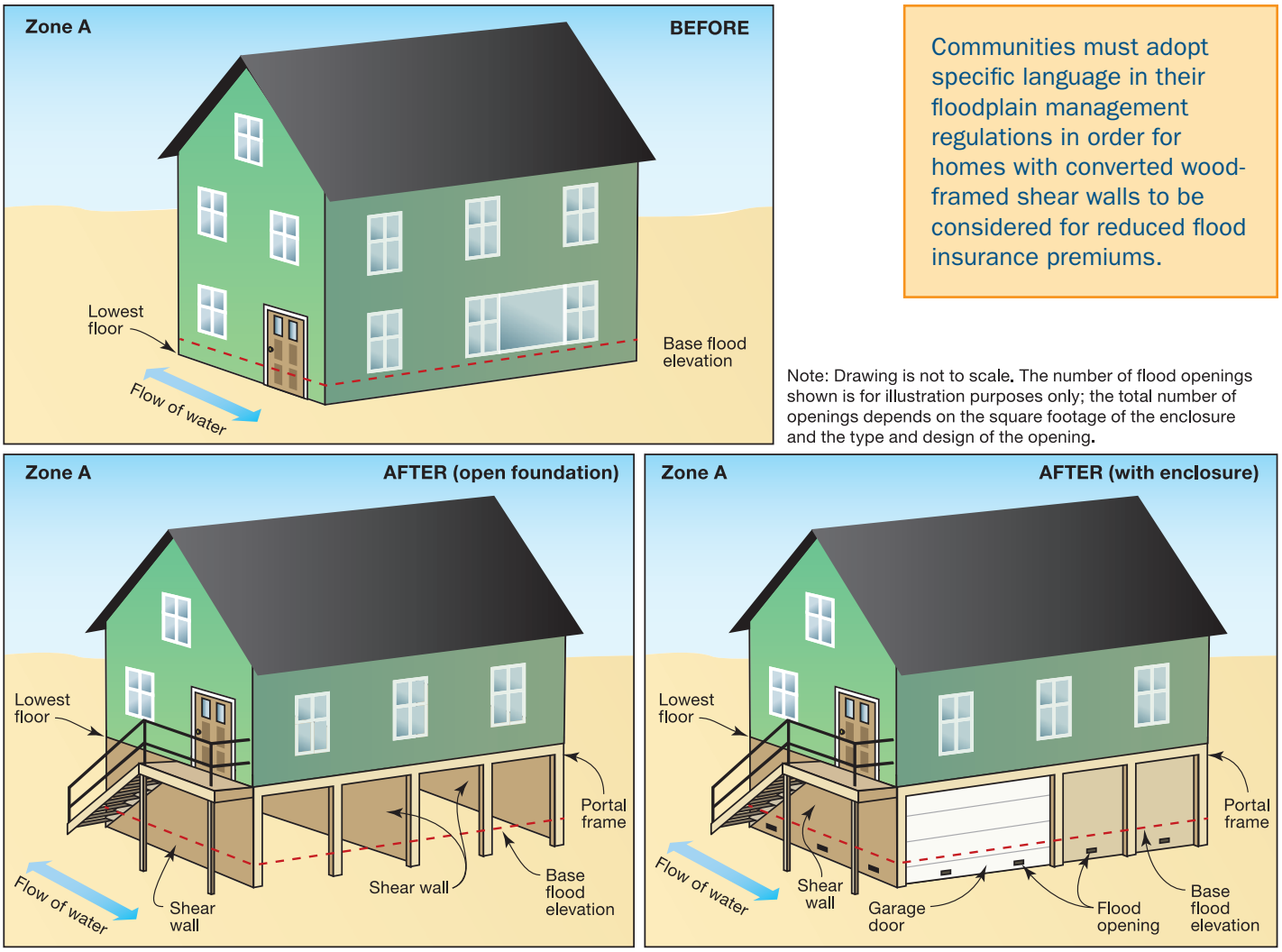
> **WARNING:** Simply strengthening wood-framed walls that are below the BFE will not result in reduced flood insurance premiums.
>
> **To qualify for lower flood insurance premiums when wood-framed walls are converted to shear walls, the following conditions need to be met:**
>
> a. The **structure must meet or exceed minimum floodplain management requirements of the NFIP and building codes**, with wood-framed shear walls designed with a continuous load path to resist all applicable flood loads and wind, seismic, or other loads imposed on the structure; and
>
> b. The **community must adopt an expanded definition of Substantial Improvement** in its floodplain management regulations to include converting ground floors built with wood-framed walls by modifying or replacing the wood-framed walls, regardless of the cost of the work (sample ordinance language is provided on page 9).

(a) Replace or modify wood-framed walls: A registered design professional with experience in evaluating homes in Zone A should determine whether modifying the wood-framed walls is feasible or if it would be more beneficial to replace the wood-framed walls with masonry or concrete foundation walls, piers, or columns. Replacing the walls requires installing temporary cribbing or shoring so the old walls can be removed and new foundation walls can be constructed. New foundation walls should be designed by an architect or engineer, who should pay particular attention to properly anchoring the walls to the footing or existing slab. For more information on maintaining a continuous load path, refer to Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Buildings* (2013) and FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010) Fact Sheets 4.1, 4.2, and 4.3.

In Zone A, a possible alternative to replacing wood-framed walls with concrete or masonry is to modify the walls by using a combination of wood shear walls and a series of portal frames, moment frames, or other methods to create an open foundation or foundation shear walls with a compliant enclosure. Shear walls are walls that are designed to resist the lateral (side-to-side) forces imposed by floodwater, wind, and earthquakes. Shear walls should be oriented parallel to the direction of floodwater movement. The existing wood-framed walls may need to be modified so they can resist all lateral and vertical loads (due to gravity or uplift from the wind), and a registered design professional must evaluate whether the load capacity of the wall needs to be increased by adding additional structural sheathing (e.g., plywood sheathing), additional studs, wood blocking, anchors, fasteners, or structural connectors. If shear walls are used and the area below the lowest floor is enclosed, the walls connecting the shear walls should not be structurally connected, and should be designed to fail under base flood conditions. An example of such a wall is described in FEMA Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings* (2008). If the shear walls are completely enclosed, the walls must have flood openings that automatically equalize hydrostatic flood forces on exterior walls.

Building codes may also require that fire protection measures, such as use of gypsum board (drywall), be incorporated into the design. Walls below the BFE with gypsum board would have to be constructed using paperless gypsum board. The registered design professional should also inspect the concrete slab and footings to verify that they are capable of withstanding the loads that the shear walls will transfer to them.

Figure 4 illustrates an example of a two-and-a-half-story house where the ground-level wood-framed walls are converted to a series of shear walls and portal frames. All the wall sections and open foundation elements below the BFE must be constructed of flood damage-resistant materials, and any enclosed area below the BFE must meet all NFIP requirements for enclosures. Homeowners should keep documentation of modifications to the wood-framed wall systems, including design certifications described above and shown in Figure 3, and should notify future owners that subsequent modification of the foundation walls and enclosures below elevated buildings may violate the terms of permits. The best way to accomplish this is for communities to require non-conversion agreements (described in the section titled "NFIP Requirements for Enclosed Areas Below the BFE in Zone A" on page 11).



Communities must adopt specific language in their floodplain management regulations in order for homes with converted wood-framed shear walls to be considered for reduced flood insurance premiums.

Note: Drawing is not to scale. The number of flood openings shown is for illustration purposes only; the total number of openings depends on the square footage of the enclosure and the type and design of the opening.

Figure 4: Before (2.5-story house at-grade) and after (1.5-story house with NFIP-compliant open foundation or compliant enclosure below the BFE) of a house in Zone A with the lower floor converted using a shear wall and portal frame foundation system

(b) Adopt optional definition of "Substantial Improvement" to qualify homes with modified wood-framed walls for reduced flood insurance premiums. The optional Substantial Improvement definition (shown in text box on page 9) would explicitly include the work to modify ground-floor wood-framed walls to become an NFIP-compliant open shear wall foundation or foundation shear walls with a compliant enclosure, regardless of the cost of the work. This would allow the building to be rated by the NFIP as an elevated building with lower flood insurance rates. However, any subsequent changes to the building inconsistent with the community's floodplain management regulations would be deemed a violation of the permit and could result in a rerating of the policy. For example, an owner who changes the use of an enclosure (e.g., by adding a bathroom or turning it into a bedroom) or who blocks the flood openings would have violated the conditions of the permit.

Information on filling a basement. Buildings with basements are susceptible to structural damage if floodwater enters the basement. Insurance premiums can be significantly reduced by filling the basement using gravel and soil, and modifying the remaining space above the fill to meet NFIP requirements for enclosures below the BFE. The fill should be placed at least up to the adjacent grade (ground) level. Also, although filling a basement will likely result in lower insurance premiums, other retrofits may be necessary to maximize premium reductions. Note that if it is likely the house will be elevated in the future, it is much better to elevate at the same time the basement is filled to avoid complications.

It is important to plan for proper drainage when filling a basement. If fill is placed on top of the original basement slab, any water that enters the area may be trapped in the original basement and have no way to drain. To provide drainage, the basement slab can be broken up, or drain holes or trenches can be cut through the slab. A registered design professional may recommend a system of underdrains be installed to improve drainage.

Optional Local Ordinance Provision for Conversion of Wood-Framed Ground Floors
(underlined text must be added to the NFIP definition)

Substantial improvement means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures which have incurred "substantial damage", regardless of the actual repair work performed. Substantial improvement also means a structure in which a ground floor with wood-framed walls is converted to an open wood-framed shear wall foundation or a wood-framed shear wall foundation with enclosed areas in accordance with ***[community inserts applicable provisions of its floodplain management regulations and building codes]***, regardless of the cost of the work determined to meet or exceed those requirements before the "start of construction". The term does not, however, include either:

(1) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions or

(2) Any alteration of a "historic structure", provided that the alteration will not preclude the structure's continued designation as a "historic structure".

It can be difficult for a contractor to properly compact fill placed in an existing basement because mobilizing and using compaction machinery can be difficult in a confined space. Therefore, some settlement of fill should be expected after initial placement. Additional fill may be needed to maintain the required fill level in the basement after the initial fill has settled.

Row house/townhouse: Row houses have been constructed in New Jersey and New York since the late nineteenth century. Many of these buildings consist of two to three stories of upper floors and a lower level or walk-out basement that is not below grade on all sides. Walk-out basements that are not below grade on all sides are not classified as a basement per NFIP criteria if the ground is sloped so that water drains freely away from the building.

To achieve lower flood insurance premiums, it may be necessary to convert the ground floor to NFIP-compliant open foundation or compliant enclosure and modify the upper floors. If the floor above the lowest floor is also below the BFE, it will need to be raised and reconstructed to a higher elevation to or above the BFE (Figure 5). For row houses with higher ceilings typical of older construction, it may be possible to raise the floor while retaining the original floor space of the upper levels, but with lower ceiling heights (Figure 6). In such situations, walls at the front and rear of the building can often be modified to raise windows as needed. In more modern townhomes, it may be

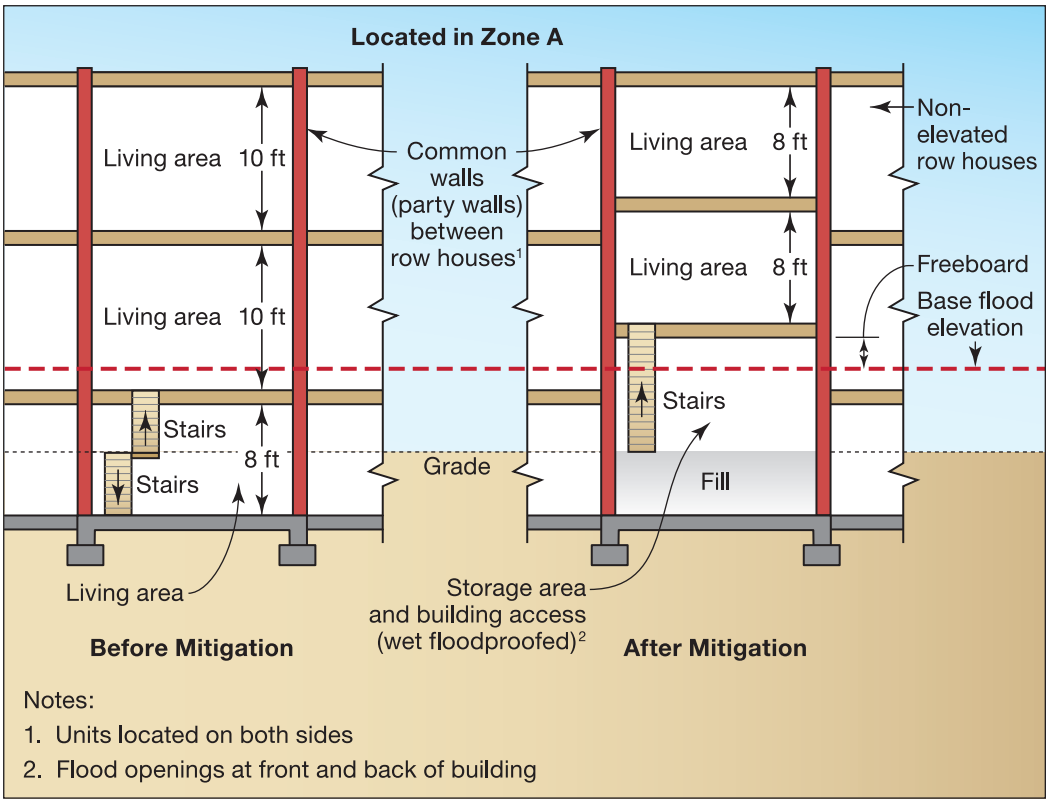


Figure 5: A row house with the floor levels being elevated to maximize living area above the BFE in Zone A

possible to convert the ground floor to an NFIP-compliant open foundation or compliant enclosure and make adjustments to the upper floors, such as moving utilities and mechanical equipment to higher floors. Uses appropriate for areas below the BFE are described in the subsection "Use of Enclosed Areas" on page 11.

Elevating Buildings

Elevating a home involves raising it so that the lowest floor is at or above the BFE or the elevation required by the community. Elevation projects typically involve separating the building from its foundation, constructing a new, higher foundation, and reattaching the building to the new foundation. For more information on the elevation process, refer to FEMA P-312, *Homeowner's Guide to Retrofitting* (2009).

The type of new foundation that can be constructed is dictated by a number of factors, including the flood zone in which the building is located, soil conditions at the site, and the design and construction of the house. The new foundation should be designed to create a continuous load path to resist all applicable flood loads and any wind, seismic, or other loads imposed on the structure. For information on how high to elevate buildings, refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013).

Figure 6: Elevation of a floor system in a row house. The old floor joist system (outlined in red) was removed and the gaps left by the joists filled. The new floor joist system (red arrow), designed by an engineer, was installed at a higher elevation (Brooklyn, NY).

Slab-on-grade houses.
Although slab-on-grade houses may be difficult to raise, a number of options exist with regard to raising the structure with the slab or without the slab (in which case a new floor system must be provided).

There are two common options for elevating a house in Zone A where the first floor of the living space is on a slab: (1) cut the walls away from the slab, raise the house, construct foundation walls and/or foundation piers, and construct a new wooden floor system (Figure 7); or (2) elevate the whole house including the concrete slab and then construct the new foundation under the slab. Because there are unknown design variables associated with elevating a house with the slab attached, the first option of raising the house above the existing foundation and constructing

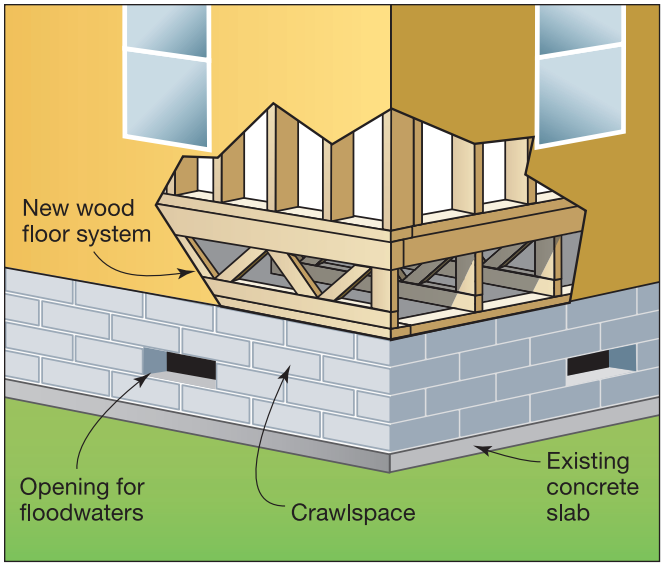


Figure 7: Mitigating a slab-on-grade house by elevating an existing wood-framed house without the slab and installing a new wood truss floor system (adapted from FEMA P-259 Figure 5E-19)

Figure 8: This house in Zone A was detached from its slab foundation (which remains) and elevated on masonry piers. The floor system is supported by new wood joists (Mandeville, LA).

a new floor system is generally preferred. Figure 8, illustrating option 1, shows a completed slab-on-grade elevation project with the walls separated from the poured slab (which remains on the ground) and a new wood-framed floor system added. If the elevation results in an enclosure below the lowest floor, flood openings are required.

Houses with crawlspaces or open foundations. Houses on crawlspaces or open foundations are generally the easiest and least expensive houses to elevate. They are usually one- or two-story houses built on masonry or concrete crawlspace walls, piers, or columns. The crawlspace or open space underneath the house allows access to place the steel beams under the house for lifting and raising the house with a series of jacks (Figure 9). Outside equipment such as air conditioning compressors should be elevated, and duct work in the crawlspace often needs to be replaced during the process.

Figure 9: A house in the final process of being elevated in Zone A. The columns have been poured and the cribbing and steel lifting beams (red arrows) will be ready to be removed soon (Highlands, NJ).

When elevating a house on a crawlspace, to achieve the necessary height, the foundation walls that form crawlspaces can be replaced or extended. A new foundation of either a continuous masonry or poured concrete walls is constructed along with higher interior piers. Although the minimum Zone A requirement is that the top of the lowest floor must be at the BFE, additional elevation high enough that the under-floor ductwork is above the BFE is usually less expensive and easier than retrofitting under-floor ductwork to prevent floodwater infiltration or separately relocating utility equipment.

NFIP Requirements for Enclosed Areas Below the BFE in Zone A

While the main portions of elevated buildings are above the BFE, the foundation and any enclosed areas below the BFE are exposed to flood forces. An overview of NFIP design requirements for buildings in Zone A is provided in Table 1. The following is a more detailed explanation of some of the key requirements and some information on reducing risk and obtaining the lowest flood insurance premium.

Use of Enclosed Areas

The NFIP insurance and building design regulations specify that enclosed areas below the BFE can only be used for:

- Parking of vehicles (attached garages or parking areas below elevated buildings)
- Building access (stairwells, foyers, elevators)
- Storage (low-value items recommended only)

Installing utility stub-outs (i.e., purposely placed utility access points for future connections) is inconsistent with the allowable uses of an unfinished enclosed area.

It is important to understand how an otherwise compliant area below the BFE can be rendered non-compliant by installing features that are inconsistent with the limitations on use. Changing the use—for instance, if a bathroom is installed or the area is converted to a bedroom—may result in significantly higher flood insurance premiums.

To verify that the use of an enclosure below the BFE is consistent with NFIP criteria, some communities use a "non-conversion agreement," which is a deed restriction stating that the property owner will not convert or modify the enclosed area below the elevated building, and will maintain it in accordance with the conditions of the permit for the life of the property. Non-conversion agreements are usually binding to future owners, heirs, successors, personal representatives, and assignees, and many communities require recordation on property deeds. When such agreements are used, property owners who fail to maintain compliance may be subject to enforcement action by the community, a possible rerating of their flood insurance policy, or a denial of flood insurance coverage by FEMA if the property is declared by a State or local authority to be in violation of State or local floodplain management regulations.

Flood Damage-Resistant Materials

Careful attention to compliance with the NFIP regulations for flood damage-resistant materials is important during design, plan review, construction, and inspection. Compliance influences the building's vulnerability to flood damage, the cost of flood insurance, and the building's ability to recover after a flood event.

Flood damage-resistant materials. In all flood zones, every part of a building that is below the BFE is susceptible to flooding during the base flood. The NFIP regulations require the use of flood damage-resistant building materials (refer to text box). For more information, see FEMA Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas* (2008) and FEMA Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (1996). As defined in Table 1 of FEMA Technical Bulletin 2, only Class 4 materials (resistant to floodwater damage from wetting and drying, but less durable when exposed to moving water) and Class 5 materials (highly resistant to floodwater damage, including damage caused by moving water) are acceptable for use below the BFE.

Terminology

As defined in FEMA Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas* (2008):

Flood damage-resistant material: Any building product [material, component or system] capable of withstanding direct and *prolonged contact* with floodwaters without sustaining *significant damage*.

Prolonged contact: At least 72 hours.

Significant damage: Damage requiring more than *cosmetic repair*.

Cosmetic repair: Cleaning, sanitizing, and resurfacing (e.g., sanding, repair of joints, repainting) of the material. The cost of cosmetic repair should also be less than the cost of replacement of affected materials and systems.

Finished interiors. Finishing the interior of enclosures with drywall or other finish materials is not permitted unless necessary to comply with life-safety and fire code requirements. NFIP flood insurance will not pay a claim for finish materials in basements or in enclosed areas below elevated buildings, even if those materials are rated as flood damage-resistant.

Flood Openings

NFIP requirements related to flood openings apply only to buildings in Zone A that have enclosed areas below the elevated building. If enclosure walls are not equipped with flood openings to relieve the pressure of standing or slow-moving water against them, the walls can be damaged or fail during a flood. Figure 10 illustrates the placement of flood openings in a typical above-grade crawlspace foundation wall.

FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008), explains the NFIP requirements for flood openings and provides guidance for prescriptive (non-engineered) openings and engineered openings. Non-engineered openings are required to have 1 square inch of net open area for every square foot of enclosed area. As an alternative, engineered openings without those specifications may be used, provided they are designed and certified by a registered design professional as meeting certain performance characteristics described in Technical Bulletin 1.

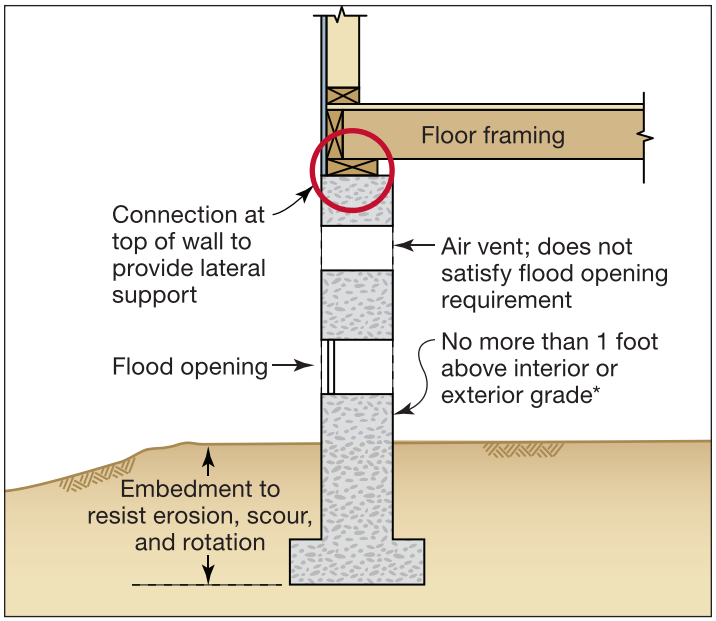


Figure 10: Flood opening in typical crawlspace foundation (adapted from FEMA P-259 Figure 5E-13)

Walls Below the BFE in Zone A

Elevated buildings in Zone A should have the lowest floor raised above ground level on foundation walls, shear walls, posts, piers, pilings, or columns. Although new homes may be elevated on earthen fill, use of fill as a mitigation measure to elevate existing homes in coastal areas is rare and discouraged because of the potential for undermining by erosion and scour. To be

recognized by NFIP flood insurance as an elevated building, foundation walls (with some exceptions for shear walls) should be constructed of masonry or concrete. The NFIP uses the following definitions when determining "lowest floor elevation" for flood insurance purposes:

- *Foundation Walls:* Masonry walls, poured concrete walls, or precast concrete walls, regardless of height, that extend above grade and support the weight of a building.
- *Solid Perimeter Foundation Walls:* Walls that are used as a means of elevating a building in Zone A areas and that must contain sufficient openings to allow for the unimpeded flow of floodwater more than 1 foot deep.
- *Shear Walls*: Walls used for structural support but not structurally joined or enclosed at the ends (except by breakaway walls). Shear walls should be parallel, or nearly parallel, to the flow of the water and can be used in any flood zone. (Note that this definition is different from that typically used by structural engineers and other design professionals.)

Homes that have foundation walls that are different from the NFIP Flood Insurance Manual definitions shown here may incur higher flood insurance premiums.

Buildings in Zone A that are elevated on foundation walls should have a distinct footing underneath the foundation wall. Before considering a building retrofit, both the footing and the foundation wall should be evaluated by a registered design professional who can verify that the foundation system is capable of resisting all necessary loads (see subsection "Concrete or masonry foundation walls and shear walls" on page 6). Which mitigation option is selected may depend on the results of the foundation system evaluation and the retrofits required to resist applicable loads and bring the foundation into compliance.

Elevating Mechanical, Electrical, and Plumbing Systems to Appropriate Levels

As shown in Table 1, utilities and equipment must be elevated to or above the BFE or designed to prevent floodwater from entering and accumulating in components during the base flood. The NFIP requires utility systems to be protected from flood damage in buildings that have incurred Substantial Damage or that are undergoing Substantial Improvement, using the same criteria as new construction.

Mechanical, electrical, and plumbing systems in existing buildings can often be effectively protected from flood damage by elevating them on platforms. The easiest and most practical time to undertake this effort is during construction, renovations, or repairs. Additional information on elevating equipment can be found in the Hurricane Sandy Recovery Advisory No. 3, *Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Buildings* (February 2013) and in FEMA P-348, *Protecting Utilities from Flood Damage* (1999).

Resources and Useful Links

The following resources describe numerous mitigation options with sufficient detail to complete an elevation mitigation project.

- FEMA NFIP Technical Bulletins. Available from http://www.fema.gov/national-flood-insurance-program-2/nfip-technical-bulletins.
  - Technical Bulletin 1: *Openings in Foundation Walls and Walls of Enclosures* (2008).
  - Technical Bulletin 2: *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas* (2008).
  - Technical Bulletin 5: *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas in accordance with the National Flood Insurance Program* (2008).
  - Technical Bulletin 8: *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (1996).
  - Technical Bulletin 9. *Design and Construction Guidance for Breakaway Walls Below Coastal Buildings* (2008).
- FEMA Hurricane Sandy Recovery Advisories. 2013. Available from http://www.fema.gov/media-library/assets/documents/30966.
  - Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings.*

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities including available FEMA assistance and recovery initiatives. Please refer to www.region2coastal.com.

– Hurricane Sandy Recovery Advisory No. 3, *Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Buildings*.

– Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy*.

- FEMA Hurricane Sandy Fact Sheet No. 2, *Foundation Requirements and Recommendations for Elevated Homes.* Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/32506.
- FEMA Floodplain Management Bulletin 1-98. 1998. *Use of Flood Insurance Study (FIS) Data as Available Data.* Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/7401.
- FEMA P-348. 1999. *Protecting Utilities from Flood Damage*. Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/3729.
- FEMA P-312. 2009. *Homeowner's Guide to Retrofitting*. Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/480.
- FEMA P-757. 2009. *Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report.* Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/15498.
- FEMA P-499. 2010. *Home Builder's Guide to Coastal Construction*. Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/6131.
- FEMA P-55. 2011. *Coastal Construction Manual.* Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/3293.
- FEMA P-259. 2012. *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*. Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/3001.
- FEMA 086-0-33. 2012. *National Flood Insurance Program Elevation Certificate and Instructions*. Washington, DC. Available at http://www.fema.gov/media-library/assets/documents/160.
- FEMA. 2013. *National Flood Insurance Program Flood Insurance Manual*. Washington, DC. Available at http://www.fema.gov/flood-insurance-manual.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

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Cleaning Flooded Buildings

Hurricane Sandy Recovery Fact Sheet No. 1 **May 2013**

FEMA

www.FEMA.gov

The impact of Hurricane Sandy extended far beyond the structures destroyed by the storm surge. Although the water has receded and most structures have been pumped out, the large number of properties that need repair means that restoration will go on for months.

Therefore, this Fact Sheet was developed to help building owners, operators, contractors, and volunteer assistance groups deal with the challenges of working in structures that were not fully cleaned and dried shortly after the flooding. Remember that when first returning to a flood-damaged building, responders should follow the initial precautions and restoration steps detailed in the FEMA Recovery Advisory, *The ABC's of Returning to Flooded Buildings* (Appendix E of FEMA 549, 2005).

When a flooded home has not been cleaned and dried within a few weeks of the flood event, mold contamination should be expected, and specific steps are needed to clean and restore the home. Basic cleaning and drying information is presented in the FEMA Recovery Advisory *Initial Restoration for Flooded Buildings* (FEMA 549, 2005), which specifies five steps for post-flood building restoration, including (1) air out, (2) move out, (3) tear out, (4) clean out, and (5) dry out. This Fact Sheet builds on the last two of these steps and assumes that the majority of the muck-out and gutting process has been completed and the home is ready for cleaning and drying.

Key Issues

- Floodwaters carry a variety of contaminants such as bacteria, oil, heavy metals, and pesticides. While first responders' initial evaluations of Hurricane Sandy floodwaters indicated that exposure to such items are below current limits for safe occupancy, proper cleaning and preparation for rebuilding is critical to protect workers and occupants from both short-term hazards and long-term risk.
- Other hazards are present in addition to the substances brought in with the floodwaters, especially in homes that were not dried out within a week of the flooding. Safety issues related to wet mechanical and electrical systems, exposure to lead and asbestos released from building materials, and mold growth need to be addressed.
- Mold is a serious health hazard if the home is reoccupied without proper cleaning. Although a variety of products and techniques can reduce and control mold, the cleaning and drying process described in this Fact Sheet also helps to remove other floodwater contaminants.

Personal Safety

Flooded buildings can pose a number of health and safety risks, for both individuals who wish to maintain occupancy and those who work to repair them. Eliminating hazards is the best way to protect occupants and workers; however, until conditions can be returned to normal, anyone working in a flooded building should use appropriate personal safety equipment and take appropriate safety precautions. The Occupational Safety and Health Administration (OSHA) Fact Sheet, *Hurricane Sandy Cleanup PPE Matrix,* provides information on personal protective equipment (OSHA-FS-3612, 2012).

Protection from electrical shock: Because of the danger of shocks and fire, electrical receptacles that were flooded should not be used to operate cleaning or drying equipment. An electrician should evaluate the condition of flooded components prior to use. As a rule, all flooded receptacles should be removed and replaced after the appropriate circuit breakers or fuses are deactivated and the interruption of power to the receptacle confirmed.

Protection from mold contamination: Anyone entering a house with visible mold growth should wear a disposable suit to prevent contamination of their clothes and vehicle, rubber gloves or other hand protection, and respiratory protection. A disposable respirator marked with an N-95 rating (when used in accordance with the manufacturer's instructions) offers the minimum lung protection that should be used when in the presence of mold. A full-face respirator is recommended for mold cleaning to protect both the eyes and the respiratory system. If a full-face respirator is not used during cleaning, goggles or a face shield should be worn with the disposable respirator. The OSHA Fact Sheet, *Mold Hazards During Hurricane Sandy Cleanup,* provides information on mold (OSHA-FS-3619, 2012).

Figure 1: Mold (on wood) and asbestos (yellow arrows) hazard in flooded house

Protection from asbestos and lead paint: Asbestos in floor tile, pipe and boiler insulation, and electrical wiring is common in many homes built before 1980 (Figure 1). Breathing asbestos fibers released from building products can increase the risk of cancer and cause a number of serious lung diseases. Similarly, paint in homes constructed prior to 1978 may contain lead. If lead paint is aerosolized during muck-out or gutting activities it can damage a person's health and is especially dangerous to child occupants if not cleaned up properly. If asbestos or lead paint is suspected, obtain the services of a specialist to perform material testing, and do not disturb the material until testing has been completed. If testing confirms the presence of lead, remediation should be conducted by a licensed professional. If materials containing asbestos are present, remediation must be performed in accordance with applicable State and Federal regulations.

Cleaning Flood-Damaged Homes

If not already installed as part of the muck-out and gutting process, plastic barriers should be set up between affected and unaffected areas of the premises (typically between the first and second floors at the base of the stairs). The barriers will reduce the potential of mold spores spreading to unaffected areas.

Because of the wide range of contaminants that can be present in floodwaters and grow on wet surfaces, all objects that came into contact with the floodwaters should be cleaned and sanitized. Generally, water-damaged porous materials are difficult to properly clean and should be discarded.

Selecting a Cleaner or Sanitizer

There is a wide variety of products that help eliminate mold and bacteria growth. The Environmental Protection Agency (EPA) registers products that are approved as a disinfectant and sanitizer for water damage restoration. It is critical to choose products registered with the EPA, as they have been proven to be effective for such biological contaminants. For information related to registration of chemicals as antimicrobials suitable for work with mold, access the EPA's pesticide product label system (PPLS).[1] EPA's Web site allows searches by chemical name,

1 EPA Web site: http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1

manufacturer, or EPA registration number. Regardless of the chemical selected, it must be used in accordance with the label directions.

Moldy surfaces should be cleaned first and then disinfected; some products do both in a single step. In all cases, mold spores should be removed as completely as possible since killing them does not eliminate their toxicity or allergenic properties.

Application of Cleaners

Cleaners are most efficiently applied using a combination of foam cleaning processes and brush cleaning, followed by pressure washing.

Foam cleaning: Foam cleaning processes have many advantages over spraying or wiping because foaming allows the product to stay on the surface (dwell) long enough for the chemicals to kill the mold or bacteria. Foam cleaning also reduces the amount of liquid used, making drying easier. Pump-up, air operated, and motorized foam generators are commercially available (Figure 2). Brushes improve decontamination of wooden studs and other surfaces by scrubbing the foam into affected surfaces. The combination of foam and scrubbing also helps to remove waterborne contaminants other than mold that get absorbed into wooden materials. The foam should sit on the surface for 3 to 5 minutes before scrubbing (refer to the label of the EPA-registered product for minimum dwell time).

Water-damaged porous materials should be removed. Non-flooded gypsum board and plaster walls that remain after gutting that are dirty or harboring mold growth can be cleaned using the foam solution. Care should be taken to inspect both the front and back side of the non-flooded gypsum board and plaster walls for remaining dirt and mold to ensure all affected areas are cleaned. These semi-porous surfaces should not be scrubbed, but should instead be wiped off with disposable towels.

Pressure washing: Residual foam on wall studs, floor joists, and other surfaces can be rinsed off with clear water. The fastest and most efficient rinse method that minimizes the amount of water used is a residential-type pressure washer set at low pressure so that the spray is a light mist (Figure 3). Squeegees can be used to control or direct remaining liquid. High-Efficiency Particulate Air (HEPA) vacuums designed for wet use can be used to collect the residue.

Drawbacks of Bleach

While bleach is convenient as a cleaner and stain remover for hard, non-porous items, it has distinct drawbacks when cleaning flood-impacted buildings. Many types of bleach are not EPA-registered as a disinfectant. Further, its effectiveness in killing bacteria and mold is significantly reduced when it comes in contact with residual dirt, which is often present in flooded homes. Also, if bleach water comes into contact with electrical components and other metal parts of mechanical systems it can cause corrosion. Bleach water can also compromise the effectiveness of termite treatments in the soil surrounding the building.

Figure 2. Pump-up or motorized foam generators can apply a wide range of cleaning chemicals

Figure 3. Using a pressure washer to rinse surfaces cleaned with a foam solution

Cleaning in Weather Extremes

Although cold weather poses challenges for restoring flooded buildings, it also has some advantages. In particular, cooler weather slows down the spread of mold. However, buildings need to be warmed to 50° to 75°F to provide for worker comfort, improve the effectiveness of cleaning and sanitizing agents, and allow commercial drying equipment to operate efficiently.

Hot and humid weather conditions also pose challenges. Mold and bacteria spread more quickly under such conditions, and natural drying of building materials slows significantly. In such circumstances, the use of drying equipment or air conditioning is critical to lower the moisture content of structural materials prior to any rebuilding activities.

Cleaning Crawlspaces

Crawlspaces must be accessed to complete the decontamination of a home. Removing the flooring is the simplest way to enter these areas. Once access is obtained, solid contamination should be removed from under the building, along with any remaining water. Application of cleaning foam followed by agitation should be conducted on all exposed sides of floor joists, foundation walls, and remaining structural elements. After cleaning and eliminating standing water any exposed ground in the crawlspace not already covered with intact plastic sheeting (vapor retarder) should be covered with plastic sheeting and held in place with landscape fabric pins to minimize potential mold growth and future moisture migration into the house.

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

Proper Drying Prior to Rebuilding

After the cleaning process has been completed, the building and any salvageable contents need to dry. The decision to allow the building and contents to dry naturally or to accelerate the drying by using equipment (Figure 4) often depends on whether power is available, whether the home's heating and ventilation systems have been restored, and the moisture content of the affected materials.

Once the electrical and HVAC systems have been restored and sanitized, the moisture content of wetted salvageable building materials should be checked to determine whether drying equipment will be necessary (see Figure 5 and Table 1). Drying equipment includes fans, dehumidifiers, air conditioners, and auxiliary electric heaters. Moisture content should be checked using an intrusive/penetrating (pin-type) moisture meter (Figure 5) because moisture content is difficult to assess accurately using only touch or sight. The materials must be rechecked after drying before doing any rebuilding. Wetted materials are presumed to be dry when their moisture content is less than or equal to 15 percent (Table 1).

Figure 4: Drying equipment

Figure 5: Use of a penetrating (pin-type) moisture meter to verify that wood frame has a water content of less than 15 percent

Natural drying can be sped up by opening windows and doors. If structural materials are allowed to dry naturally, the moisture content must be checked before doing any rebuilding. Natural drying can take a long time, especially in cold weather. Verifying that materials are sufficiently dry before rebuilding is the key to minimizing future problems such as fungal growth.

Resources and Useful Links

Centers for Disease Control and Prevention. "Storm, Flood, and Hurricane Response: Guidance on Personal Protective Equipment and Clothing for Flood Cleanup Workers." Web site: http://www.cdc.gov/niosh/topics/emres/ppe-flood.html. Accessed February 12, 2013

FEMA. 2006. *Initial Restoration for Flooded Buildings.* FEMA Recovery Advisory, initially published in November 2005 and also included in Appendix E of FEMA 549, *Mitigation Assessment Team Report: Hurricane Katrina in the Gulf Coast.* July 2006, Washington, DC. Available at http://www.fema.gov/library/viewRecord.do?id=2633

FEMA. 2006. *The ABC's of Returning to Flooded Buildings.* FEMA Recovery Advisory, initially published in November 2005 and also included in Appendix E of FEMA 549, *Mitigation Assessment Team Report: Hurricane Katrina in the Gulf Coast.* July 2006, Washington, DC. Available at http://www.fema.gov/library/viewRecord.do?id=6711

Occupational Safety and Health Administration (OSHA). 2012. *Hurricane Sandy Cleanup PPE Matrix.* OSHA Fact Sheet OSHA-FS-3612. December 2012, Washington, DC. Available at http://www.osha.gov/Publications/OSHA-FS-3612.pdf

OSHA. 2012. *Mold Hazards During Hurricane Sandy Cleanup.* OSHA Fact Sheet OSHA-FS-3619. December 2012, Washington, DC. Available at http://www.osha.gov/Publications/OSHA-FS-3619.pdf

U.S. Department of Housing and Urban Development. 2008. *Rehabbing Flooded Houses: A Guide for Builders and Contractors.* Bilingual guide. Washington, D.C. Available at http://www.huduser.org/Publications/pdf/Rehab_FloodedHouses.pdf

U.S. Environmental Protection Agency. 2012. *Flood Cleanup: Avoiding Indoor Air Quality Problems.* Fact Sheet, revised November 2012. Washington, DC. Available at http://www.epa.gov/iaq/pdfs/floods.pdf

Table 1. Level of Drying Required Before Rebuilding

Summary of Moisture Reading Results for Wood Framing Materials	
Moisture Reading	**Results**
> 20%	Wet, no good
15–20%	Partially dry, caution
< 15%	Dry, ok

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

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Foundation Requirements and Recommendations for Elevated Homes

Hurricane Sandy Recovery Fact Sheet No. 2 **May 2013**

FEMA

www.FEMA.gov

Many homes in New York and New Jersey damaged during Hurricane Sandy experienced flood levels that exceeded the base flood elevation (BFE).

Terminology

Flood Insurance Rate Map (FIRM): A map produced by FEMA to show flood hazard areas and risk premium zones. The SFHA and BFE are both shown on FIRMs.

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as "base flood" and "100-year flood"). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Figure 1: Homes on small, tightly spaced lots, typical throughout coastal New York and New Jersey, present access and construction challenges when being transitioned to a raised pile foundation (Rockaway, NY)

The Federal Emergency Management Agency's (FEMA) Mitigation Assessment Teams (MATs) observed several construction and foundation types in the disaster area. The assessment teams also observed narrow building lots and lots with constrained access that will pose construction challenges if those homes are required to be elevated or if owners elect to elevate them to reduce exposure to future flooding (Figure 1).

This fact sheet is intended to assist architects, builders, code officials, planners, and engineers with reconstruction and new construction to create elevated flood-resistant homes. The concepts in this fact sheet will help qualified, registered design professionals (licensed engineers or architects) determine proper site-specific foundation design recommendations when working on narrow lots and lots with constrained access. This fact sheet assumes the reader is familiar with National Flood Insurance Program (NFIP) Special Flood Hazard Area (SFHA) zone designations, including Coastal A Zones. For more information about the coastal SFHA zone designations, visit http://www.region2coastal.com/coastal-mapping-basics.

Of critical importance is how high a home must be elevated to reduce the risk of flooding. The minimum required elevation is based on the base flood elevation(BFE) shown on Flood Insurance Rate Maps (FIRMs), which are now being updated in many areas impacted by Hurricane Sandy to reflect changes to the physical, climatological, and scientific baseline that have occurred since the last maps were published. Shortly after Hurricane Sandy, FEMA issued Advisory BFEs (ABFEs) to help communities and homeowners make informed decisions as they rebuild. Additional elevation above the ABFE or Effective BFE, otherwise known as freeboard, may be required by a community.

This fact sheet includes:

- A description of basic NFIP criteria as they relate to flood insurance rates. It is financially advantageous for homeowners to renovate their homes in accordance with NFIP criteria. The first three pages of the Fact Sheet summarize some of the basic concepts about the NFIP.
- Design guidance for restoration projects involving existing elevated homes damaged by Hurricane Sandy. Many of these homes present renovation challenges because of their location on constrained building lots or the need to elevate a closed-foundation home on an open foundation. Design guidance begins on page four of this Fact Sheet.

National Flood Insurance Program Requirements

Communities that participate in the NFIP are required to adopt and enforce local regulations that apply to structures and all development located in areas mapped as SFHAs. The NFIP establishes minimum criteria and design performance requirements. These criteria specify how new structures and structures that have sustained Substantial Damage or are undergoing Substantial Improvement are to be constructed to minimize or eliminate the potential for flood damage.

Flood Insurance Rate Reform

On July 6, 2012, President Obama approved the Biggert-Waters Flood Insurance Reform Act of 2012 (BW12) which significantly changes the NFIP rating structure used to write flood insurance policies. Flood insurance premium rates are determined based on actual flood risk. "Grandfathering" and Federal flood insurance premium subsidies for many older structures will be eliminated over time. For more information about BW12, consult FEMA's *Flood Insurance Reform Act of 2012: Impact of changes to the NFIP* (2013), available at http://www.fema.gov/library/viewRecord.do?id=7187.

Substantial Improvement / Substantial Damage

The NFIP requires that homes within mapped flood hazard areas, if determined by a community to have sustained Substantial Damage or be undergoing Substantial Improvement, be brought into full compliance with the flood provisions of current building code and local floodplain ordinances that

Terminology

Designers, builders, and homeowners should consult with local building officials to determine whether local codes and regulations have more restrictive definitions and requirements, such as freeboard.

Basement: Any area of the building, including any sunken room or sunken portion of a room, having its floor below ground level (subgrade) on all sides.

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

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010) for more information at http://www.fema.gov/library/viewRecord.do?id=4160.

meet or exceed the NFIP criteria. Homes that do not meet the definitions of Substantial Damage or Substantial Improvement are not required to be elevated. However, even if not required, homeowners should consider elevating to minimize damage in the event of a flood. Elevating homes to or above the BFE will substantially lower flood insurance premiums.

It is the community's responsibility to determine whether a building has sustained Substantial Damage or if proposed improvements are considered Substantial Improvements. The local official may ask homeowners for information about the costs to repair damaged homes and market value information based on a recent property appraisal. Other methods to estimate market value can be found in FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010). The Substantial Damage and Substantial Improvement requirements are included in community floodplain management regulations and building codes.

Know the Flood Risk before Repairing or Reconstructing the Home

Homeowners, builders, and design professionals need to know the flood risk for the location of the home in order to determine how high a home needs to be elevated. Most flooding that occurs is from either riverine or ocean sources. The first step in identifying flood risk is to determine whether a home is located within an SFHA and what BFE applies. This is done by reviewing the relevant FIRM and Flood Insurance Study (FIS), and talking to local floodplain administrators or building officials. The local official will confirm the location of the home using information from the FIRM and FIS. In addition, information on the source and type of flooding risks that could potentially affect the property, such as velocity flows, wave action, debris impact, and depth of flooding, is necessary to determine the type of foundation needed and other requirements.

FIRMs and ABFE Maps

Post-Hurricane Sandy ABFE maps are available for parts of New York and New Jersey at http://www.region2coastal.com/sandy/abfe.

FIRMs for all other participating communities are available at https://msc.fema.gov and information on the publication of FIRMs is available at http://www.floodsmart.gov.

Even homes elevated sufficiently to meet minimum NFIP criteria can experience flooding above the base flood. Many communities require that homes be elevated above the BFE. Consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation* (2013), for more information.

Advisory Base Flood Elevations: FEMA recommends that the best available data be used to plan for new construction and for homes that are being elevated or undergoing significant reconstruction or repair. This will ensure that all recovery construction is built stronger, safer, and less vulnerable to future flooding events.

Some communities have adopted the ABFEs issued after Hurricane Sandy. In those communities, reconstruction and repair of residential buildings that have been determined to have incurred Substantial Damage or are undergoing Substantial Improvement must be elevated to the ABFE rather than the BFEs shown on the Effective FIRM. Freeboard, which is additional elevation above the ABFE or Effective BFE, may also be required by the community.

New FIRMs. FEMA will begin to release new preliminary flood hazard information through work maps and eventually preliminary FIRMs to replace the ABFE data. Similar to the advisory data, the revised flood hazard information will be posted on FEMA's Geoplatform and http://www.Region2Coastal.com for public review and use as it becomes available. Stakeholders are encouraged to check these Web sites frequently as FEMA will replace the advisory data with the preliminary data as it is developed through the year. Preliminary FIRMs will undergo a public review period and statutory appeal period prior to being adopted by communities as the Effective FIRM. In certain locations, the new FIRMs may result in higher base flood elevations or higher risk zone designations than are shown on current FIRMs. These new base flood elevations and flood risk zones will affect the minimum building requirements.

Once the new FIRMs are published, the NFIP flood premiums will be rated using the new flood zones and BFEs. Homes elevated to the previous BFE will have flood insurance rated based on the new FIRMs and may be subject to higher premiums. Homeowners who already have elevated homes should reevaluate their risk based on the ABFEs, even if their homes had only minor damage or were not damaged during Sandy.

Construction Types of Buildings Damaged in Hurricane Sandy

The damaged homes observed by the FEMA MATs were of several different construction types, including wood frame, masonry, and masonry veneer. Some homes had basements, some had crawlspaces, some had masonry piers, and some were slabs-on-grade. Figure 2 shows these typical foundation types. The homeowner, in conjunction with the local official and/or design professional, can decide the best course of action for a damaged home based on information from the Substantial Damage determination, the condition of the building, and an evaluation of the flood risk. Possible actions may include elevating the home, relocating it to a site outside the SFHA, or demolishing it and building a new home.

If the home can be elevated, the type of compliant foundation design that can be used is determined by the construction type, foundation type, and the flood zone in which the home is located. For example, generally the most appropriate elevation technique for frame homes is to elevate on extended foundation walls or open foundations. Techniques used for masonry homes include: 1) extend the walls of the home upward and raise the lower floor to or above the required elevation; and 2) abandon the lowest floor by converting it to a garage or storage area, and move the living area to an upper floor. In terms of foundation types, slab-on-grade homes are generally more difficult to elevate than homes on basement, crawlspace, or pier foundations. Elevating homes with basement foundations involves elevating or relocating utility equipment usually found in basements and filling in the basement.

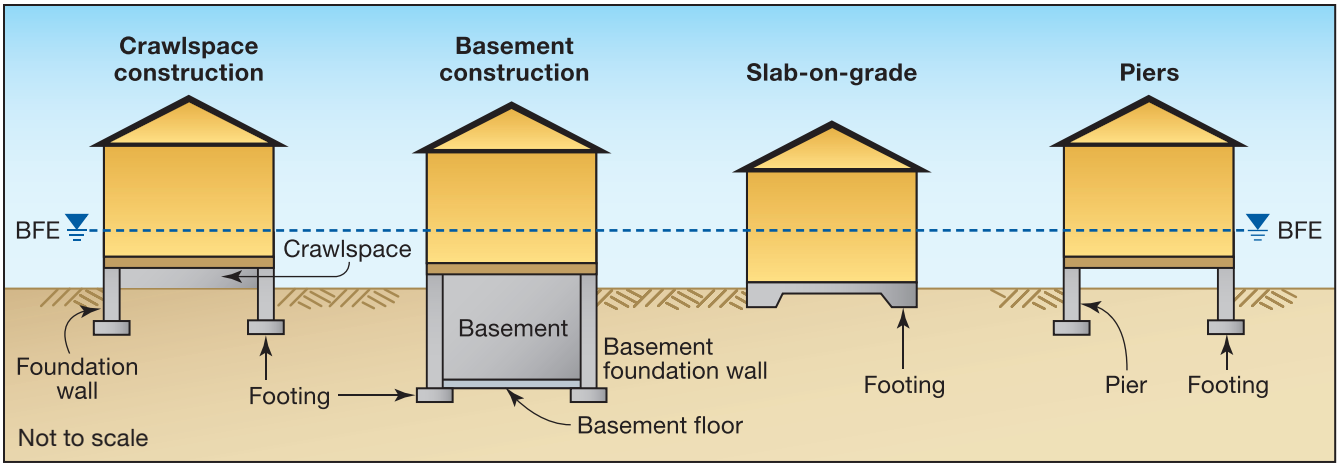

Figure 2: Types of homes observed in the disaster area

Compliant Designs for Homes Located in Zone A

Homes located in Zone A should have foundations that comply with local floodplain management and building code requirements. Compliance with the requirements and determination of NFIP flood insurance premiums are based on the elevation of the top of the lowest floor, which is defined as the lowest floor of the lowest enclosed area including the basement. However, unfinished or flood damage-resistant areas, usable solely for parking of vehicles, building access, or storage in an area other than a basement are not considered lowest floors, provided the areas are not built so as to render the structure in violation of the applicable design requirements. For more specific information about the NFIP criteria, consult Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation* (2013).

All new homes and homes determined to have sustained Substantial Damage or that will be Substantially Improved must adhere to the following criteria:

- All buildings must be properly **anchored** to resist, flotation, collapse, and lateral movement.
- The **top of the lowest floor must elevated to, or above, the required elevation** (Figure 3).
- Homes can be elevated on perimeter foundation walls, or on piles, piers, or columns. If permitted by the community, elevation can also be achieved by placing fill under the structure. If the community permits fill to be placed below the BFE, the fill must be compacted and protected against **scour and erosion**. It is easiest to place fill before a home is constructed or, for existing homes, when the home is temporarily relocated.
- **Basements are not permitted**. To be compliant, existing below-grade areas must be backfilled.
- Walls of enclosed areas below elevated homes must have **flood openings** that allow floodwaters to automatically equalize during an event. For more information, consult FEMA NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (2008).
- Enclosed areas below elevated buildings are permitted to be used only for **parking, building access, and storage**.
- **Utilities**, including electrical, heating, ventilation, plumbing, air-conditioning equipment (including ductwork) must be elevated above the BFE, or specifically designed to prevent water from entering or accumulating within the components during flooding.
- **Flood damage-resistant construction materials** must be used below the BFE. For more information, consult FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements* (2008).
- When the lowest floor is set, and again prior to final inspection, builders must obtain **elevation certificates** to document compliance. Owners need these certificates to obtain NFIP flood insurance.
- Construction of the home and other development must not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

Terminology

Scour: Localized loss of soil, often around a foundation element due to flood flow obstruction or interaction. Scour can be determined by procedures included in FEMA P-55, Coastal Construction Manual (2011).

Erosion: Process of gradual wearing away of land masses. Erosion estimations should be based on local historical data. These data can be obtained from local and State agencies, universities, site-specific studies, and consultation with a design professional knowledgeable about the area.

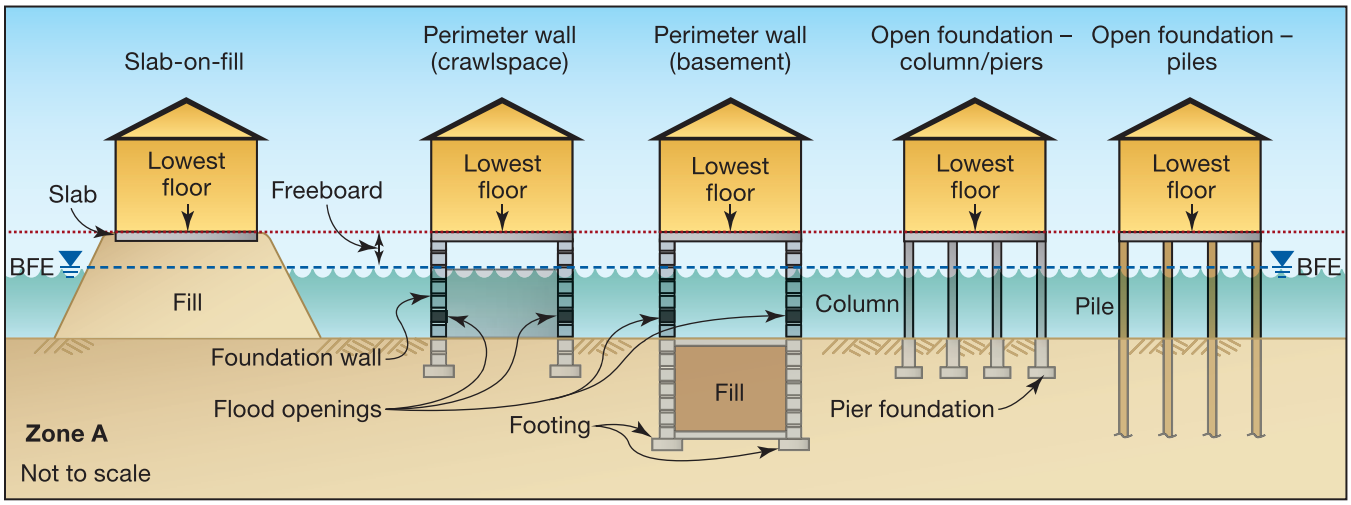

Figure 3: Examples of NFIP-compliant homes in Zone A where the top of the lowest floor is located above the BFE

Compliant Designs for Homes Located in Zone V

The NFIP criteria, the community's floodplain management regulations, and building codes all require homes in coastal high hazard areas (Zone V) to have open foundations (piers, columns, or piles). Open foundations are required in areas subject to high-velocity wave action because the reduced surface area of the foundation reduces the hydrodynamic and breaking wave loads acting on the building and the building's vulnerability to scour and erosion. Foundation performance in areas subject to storm surge and wave loads improves significantly with a deep, open foundation. These foundations, including alternatives described in this fact sheet, are usually constructed with treated timber, concrete, or steel piles driven to a depth such that the strength of the foundation is not compromised by the erosion and scour common for coastal storm surges. Because the NFIP requires a licensed engineer or architect to design and certify foundations for buildings in Zone V, as well as many of the other factors that go into designing foundations, some decisions about types of foundation elements and connections are the responsibility of the registered design professional.

All new homes and homes determined to have sustained Substantial Damage or that will be Substantially Improved must adhere to the following criteria:

- All residential buildings must be properly **anchored**. The NFIP requires open pile or column foundations and structures attached thereto to be anchored to resist flotation, collapse, and lateral movement due to the effects of wind and water loads acting simultaneously on all building components.
- **Open foundations** (piers, pilings, or columns) are required (Figure 4). Closed foundations, such as solid masonry or concrete walls, and use of fill, are not permitted.
- **Basements are not permitted**. To be compliant, existing below-grade areas must be backfilled to or above the adjacent ground surface.
- The **bottom of the lowest horizontal structural member of the lowest floor must elevated to the required elevation.**
- Enclosed areas below elevated buildings are permitted to be used only for **parking, building access, and storage**.
- Areas below elevated buildings must be **free of obstructions**. The space below the lowest floor can be enclosed by non-supporting breakaway walls, open-wood lattice work, and insect screening intended to collapse under wind and water loads. For more information, consult FEMA NFIP Technical Bulletin 5, *Free of Obstruction Requirements for Buildings Located in Coastal High Hazard Areas* (2008).
- **Walls must be designed to break away** under base flood conditions when used to enclose areas below elevated buildings. For more information, consult FEMA NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls* (2008).
- **Flood damage-resistant construction materials** must be used below the BFE. For more information, consult FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements* (2008).
- **Utilities**, including electrical, heating, ventilation, plumbing, and air-conditioning equipment (including ductwork) must be elevated on platforms, which may be attached to the building above the BFE.
- When the lowest floor is set, and again prior to final inspection, builders must obtain **elevation certificates** to document compliance. Owners need these certificates to obtain NFIP flood insurance.
- The design and methods of construction must be **certified by a registered design professional** to be in accordance with an accepted standard of practice for meeting Zone V design requirements.

The current accepted standard of practice is ASCE 24, *Flood Resistant Design and Construction*. The IRC allows ASCE 24 to be used as an alternative to the Zone V requirements. FEMA recommends that designers use it when designing homes in Zone V. ASCE 24 has more detailed criteria and commentary and specifically requires foundation designs to account for **erosion and scour**, among other considerations.

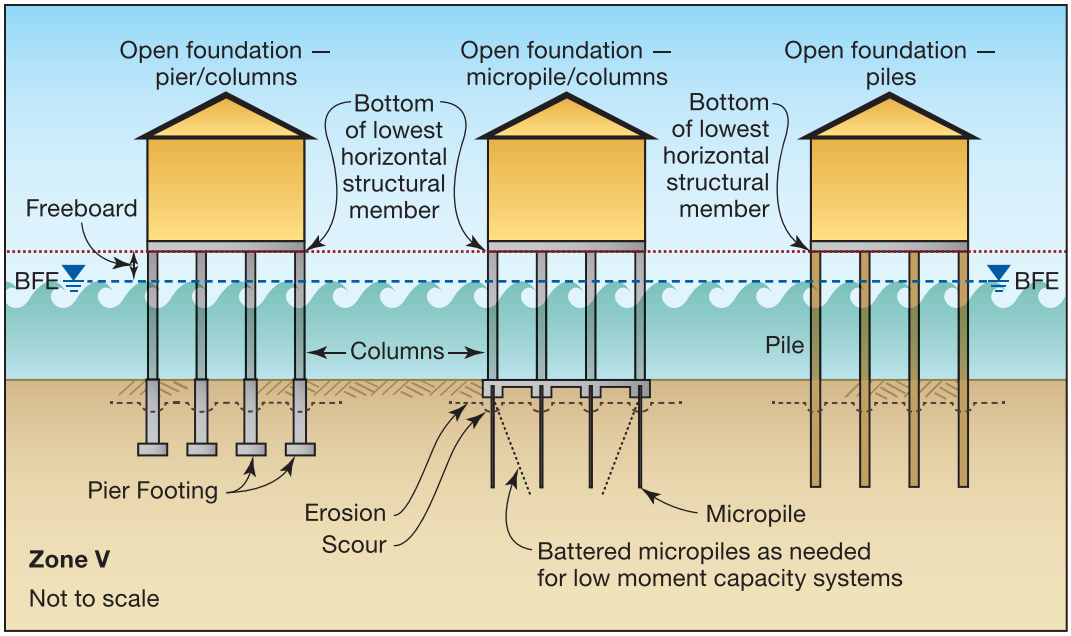

Figure 4: Examples of NFIP-compliant foundations in Zone V in which the bottom of the lowest horizontal structural member is located above the BFE

- All new residential buildings must be **landward of the reach of mean high tide** to protect these buildings from damaging waves. Further, man-made alteration of sand dunes and mangrove stands is prohibited if potential for flood damage is increased.

Solutions for Elevated Construction on Open Foundations

Homes on small lots or with limited access require special methods to elevate-in-place (Figure 5). Small lots may not have adequate space on which to relocate a home while new foundation piles are driven. Horizontal and vertical clearances needed to elevate-in-place and drive traditional piles may also be inadequate. Alternative (non-timber pile) open foundations may be more feasible when lot size is a constraining factor.

One solution for elevating a home on a small lot is to place a system of concrete columns and construct grade beams to support the elevated home. For more information on grade beams, consult Section 10.5.6 of FEMA P-55, *Coastal Construction Manual* (2011).

Another option for elevating a home on a small lot, if permitted by local building codes, is to incorporate deep foundation elements, such as micropiles, into the footings to increase building support and resist the lateral and uplift loads caused by high winds, flooding, scour, or erosion. Foundation elements such as micropiles or helical piles can

Figure 5: Elevating tightly spaced homes, such as these in Breezy Point, NY, presents construction challenges

be installed even if there are minimal horizontal or low vertical clearances, and when there are limitations on disturbance to neighboring homes.

Achieving proper open foundation designs for small lots may require owners to consult with a geotechnical engineer and a structural engineer, who may also need to work with an elevation contractor and a specialty foundation contractor. The need to protect neighboring homes and utilities also affects construction risks and costs, and will need to be considered when selecting the appropriate foundation alternative.

Pier Foundations

Pier (a type of column) foundations are typically constructed of either reinforced concrete or reinforced masonry columns. Piers are generally placed on footings to support the elevated home. Without footings, piers function as short piles and rarely have sufficient capacity to resist uplift, lateral, and gravity loads. Additionally, when exposed to lateral loads, discrete footings can rotate (Figure 6) and therefore, piers supported by discrete footings are not recommended in coastal environments.

Figure 6: Discrete pier footings undermined by erosion and scour in Mantoloking, NJ

Piers supported with continuous concrete footings provide much greater resistance to lateral loads because the footings can act as an integrated unit to resist rotation. The integrated footing system must be steel reinforced to resist moment forces that develop at the base of the piers as a result of lateral loads on the foundation and elevated home.

Pier foundations are typically shallow due to excavation constraints and are appropriate only where there is limited potential for erosion and scour. To prevent the continuous footing system from being undermined, the foundations must extend below the maximum estimated depth for long- and short-term erosion and localized scour.

In some case, existing pier foundations may be retrofitted with grade beams to provide enhanced lateral support. See the section titled "Pile Foundations" for more information on grade beams.

Pile Foundations

Pile foundations are required in Zone V coastal environments so that waves can pass more easily under elevated homes. Traditional piles are typically constructed of treated timber, steel, or precast concrete and are driven into the ground to a depth required to resist vertical and lateral loads from gravity, wind, and flood forces. Pile foundations use the soil's resistance to support the elevated home.

Critical aspects of a pile foundation include the pile size and spacing, installation method, embedment depth, bracing, and the connection to the elevated home. Piles that are properly sized, spaced, installed, and braced, and have adequate embedment into the soil (with consideration for erosion and scour effects) will perform properly and allow the home to remain standing and intact following a design flood event. For more information about scour and erosion, refer to Section 3.1.1.2 of FEMA P-757, *Mitigation Assessment Team Report: Hurricane Ike in Texas and Louisiana* (2009).

Piles can be used with or without grade beams. When used without grade beams, piles extend to the lowest floor of the elevated home. Improved performance is achieved when the piles extend beyond the lowest floor to an upper floor level, although owners should check with an insurance agent to understand how the extended piles will be rated for flood insurance. Using grade beams provides resistance to rotation (also called "fixity") in the top of the embedded piles and improves stiffness of the pile foundation system against lateral loading.

When used together, piles and grade beams work together to support the elevated home and transfer vertical and lateral loads imposed on the elevated home and foundation to the ground below. Design and installation of grade beams should include the following concepts:

- Grade beam design criteria should include resisting lateral flood loads from both hydrodynamic forces and flood-borne debris impacts.
- Grade beams are to provide horizontal bracing of piers or piles and should not directly support any vertical load-carrying elements such as floor slabs. They should be designed to be self-supporting between vertical foundation members, such as piles, to account for cases when erosion and scour extend below the grade beam. According to NFIP requirements, grade beams that are structurally connected to slabs are considered to be the lowest horizontal structural member supporting the slab, which is a nonconforming use below BFE and severely increases flood insurance premiums if present.

Micropile Foundations

Foundations supported on micropiles function similarly to deep pile foundations. Micropiles are defined in the International Building Code (IBC) as 12-inch-diameter (305mm) or less, bored, grouted-in-place piles incorporating steel pipe (casing) and/or steel reinforcement. When used for new construction, traditional driven piles are typically more cost effective than micropiles. However, micropiles may be the only feasible and cost effective retrofitting solution when access is limited, horizontal or vertical clearances are limited, or when strict control of vibrations and settlement is required (Figure 7).

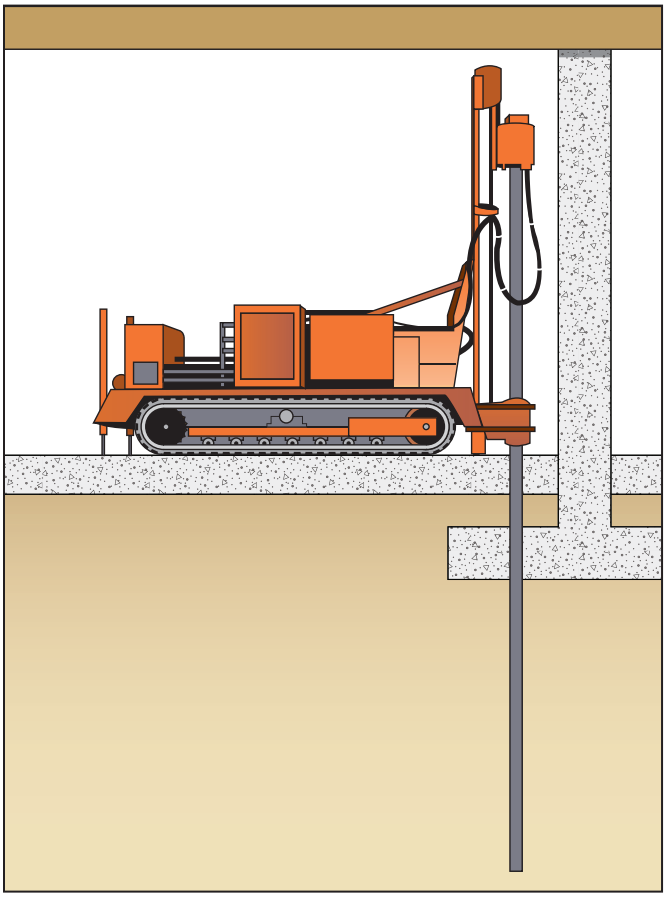

Figure 7: Example of a micropile drill rig

Micropiles are usually smaller in diameter than traditional piles and can be designed to perform under a wide variety of soil conditions. Micropiles can be designed to resist compressive, tensile, or shear structural loads for most situations (Figure 8a). The equipment used to install these piles is compact (such as small, front-end loader attachments), and results in less disturbance and vibration to existing homes than traditional pile-driving equipment.

Current best practices, including Federal Highway Administration (FHWA) criteria described in FHWA NHI-05-039, *Micropile Design and Construction Guidelines Manual* (FHWA 2005) should be used to develop micropile design capacity. Micropiles can be used for underpinning applications, such as halting structural movement, repairing or replacing inadequate foundations, and providing scour and erosion protection, and can transfer loads to deeper, more competent bearing strata.

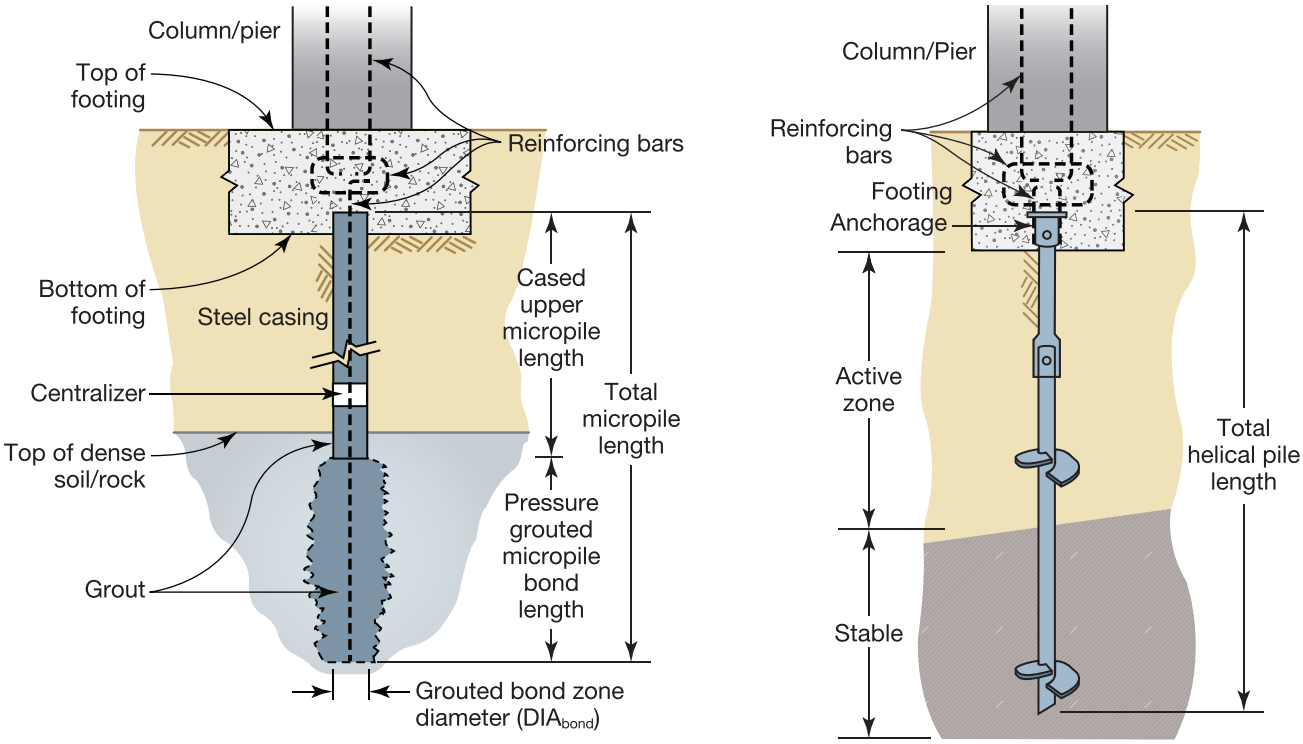

Figure 8: Example of a grouted micropile (8a) and a helical pile (8b)

With a relatively small diameter, micropiles have limited lateral capacity compared to larger traditional piles, and may require grade beams or bracing to resist lateral loads, including flood loads. The bracing must be designed to limit deflections under flood forces when exposed by scour and erosion, or under other conditions of reduced lateral soil support such as areas of soft, weak soils, soils with seismic liquefaction potential, or in areas where subsurface voids are present.

A detailed geotechnical investigation must be completed to determine the quality of the bearing soil or rock strata, whether grouting is needed to fill voids, and to select an installation method (i.e., drilling through rock or boulders vs. driving piles through soft material).

Helical piles are a type of micropile with an auger helix on the end of a slender shaft, which is drilled into the ground (Figure 8b). A helical pile is defined in the 2012 IBC as a manufactured steel, deep foundation element consisting of a central shaft and one or more helical bearing plates. Each helical bearing plate is formed into a screw thread with a uniform defined pitch.

Helical bearing plates attached to the central shaft act as the bearing surface to resist compressive forces from the elevated structure. Increased bearing capacities can be provided by using larger diameter helixes or by attaching more piles to the foundation. As with other micropiles, there is little lateral resistance provided by the helical pile itself, so resistance must be provided by a strong moment-resisting connection to the foundation. Helical piles can be a cost-effective solution to deep/open foundation requirements where access and vertical and horizontal clearances are limited.

Design Considerations

To successfully elevate a home on an open foundation, site-specific conditions must be identified. Once the site-specific conditions are identified and evaluated, a proper design can then be implemented.

Site-Specific Design Considerations for Homes Elevated on Open Foundations

Some of the site-specific factors that must be considered include soil conditions; the required elevation; the flood, wind, and seismic loads the building must be designed to resist; and whether the existing home is structurally sound enough to elevate-in-place. Table 1 presents design considerations for elevating buildings on open

Table 1: Design Considerations for Elevating Buildings on Open Foundations in Zone V (and Coastal A Zones)

Overall Category	Data Needed	Consider
State and local requirements	State and local building code requirements Local flood ordinance requirements Zoning ordinance requirements BFE or ABFE, if applicable Natural resources conservation regulations	Open foundations are required in Zone V For new homes and homes that have sustained Substantial Damage or will be Substantially Improved, open foundations including piers, columns, and piles, and micropiles may be used Elevating to (or above) the BFE/ABFE will help protect the home in future storms and reduce flood insurance costs
Structural condition of home	Structural strength of load paths. Determine whether the home is structurally strong enough to be lifted	How connections can be improved to strengthen the home
	Structural strength of the existing footings. Determine whether the footings are adequate for the proposed modification	How the footings can be strengthened or replaced
Geotechnical condition of site	Determine whether a shallow foundation is feasible	Piers/Columns are appropriate for shallow foundations
	Determine whether a deep foundation is required	Piles, piers/columns and micropiles are appropriate for deep foundations
	Predicted flood conditions, including the effects of scour and long-term erosion	Piling and Pier/Column foundations with footings and grade beams can be designed to withstand 3-foot wave loads, but may fail if erosion and scour undermine the foundation Micropile foundations may not be able to withstand lateral loads when exposed by scour and erosion
	Elevation of the water table	Grade beams can be elevated above the water table, but the pile or pier/column must be designed to resist cantilever action, moments, and deflection at the top. Deeper embedment may be necessary
	Potential for exposure to water or salt-laden air	Provide corrosion protection if needed Anchors should be galvanized or grouted underground to mitigate corrosion Where there are corrosive soils or a shallow variable groundwater table and the micropile is subject to increased corrosion, micropiles should be fully grouted
Access, horizontal and vertical clearance on the lot	Availability of access for large construction equipment to the lot or possibility of temporarily relocating the home	Traditional driven-pile foundations are often preferred if there is enough room to temporarily move the home while the new open foundation is constructed.
	Adequacy of horizontal and vertical clearances and access	Pile-driving technologies are available depending on site constraints, including low-head-room rigs or hammers, to elevate the home in place. These technologies are typically associated with micropiles When buildings are very close together, excavating to construct columns/piers with spread footings or grade beams could adversely affect neighboring buildings When buildings are very close together, lifting beams may not have required clearance for installation
Basements and crawlspaces	Presence of a basement or crawlspace	Basements must be filled in if NFIP compliance is required or desired Existing basement or crawl space walls must be analyzed to determine if additional reinforcement is required to resist design loads associated with elevating the building, as well as the loads of the design level event
Utilities	Presence of utilities located below the BFE/ABFE; utilities include mechanical, electrical, and plumbing (MEP) and heating, ventilation and air conditioning (HVAC) equipment	Utilities and their controls should be elevated above the BFE/ABFE

foundations. Once all of this information has been evaluated, the design professional will be able to prepare cost estimates to determine which foundation design is the best value. Table 2 presents relative costs and a number of considerations associated with elevating homes on different foundation types.

Table 2: Comparison of Relative Costs and Considerations Associated with Elevating Homes on Alternative Open Foundations in Tight, Narrow Lots

Consideration		Column/Pier Foundation	Traditional Pile Foundation	Micropile Foundation
Requires moving home off footprint		No	Yes	No
Elevate-in-place		Yes	No	Yes
Impacts to neighboring properties		Medium to High	High	Low
Cost	Foundation	$	$$$	$$
	Foundation connection	$$	$	$$
	Elevation	$$	$$$	$$
Ease of installation		Yes	Maybe	Yes
Design basis		IBC[1]/ASCE 24/FEMA P-55[2]	IBC[1]/ASCE 24/FEMA P-55[2]	IBC[1]/ASCE 24/ FEMA P-55[2]/ FHWA NHI-05-039[3]

1 IBC = International Building Code
2 FEMA P-55, *Coastal Construction Manual* (2011)
3 FHWA, *Micropile Design and Construction Guidelines Manual* (2005)

Open Foundation and Elevation Design Process

The design process for elevating homes on open foundations is shown in Figure 9.

Pile design: Pile design requires some additional steps.

- Remove existing structure to allow access for pile-driving equipment
- Determine pile depth based on pile load and soil strata
- Determine pile spacing based on pile capacity, building loads, and span capacity of the building and grade beams
- Achieve lateral capacity by increasing the number of piles or by properly connecting batter piles/anchors to the piles and footings with a pile cap
- Design the new access to the building and utility extensions

Micropile installation: Contractor qualifications should be specified prior to bidding elevation projects. Qualifications should include prior experience, bonding/insurance, licensure, and familiarity with local construction and soil types. To ensure the foundation is installed properly, micropile installation should be supervised by an experienced contractor who has recently completed similar projects in similar soils. Geotechnical conditions can vary greatly across one property and an experienced contractor will be able to make field decisions when obstructions, refusal, voids, soft soils, and other unanticipated subsurface conditions are encountered. To be successful, micropiles must be installed with an adequate embedment and must be able to resist the load capacity. Load testing of piles is recommended to verify design calculations and the adequacy

Figure 9: 12-step design process for elevating homes

of a contractor's installation methods. Regardless of the resistance measured during installation or through load testing, the minimum embedment depth specified by the design professional must be satisfied for the pile to perform as designed.

Useful Links and Resources

Publications

- ASCE (American Society of Civil Engineers). ASCE 24, *Flood Resistant Design and Construction*.
- ASCE. ASCE 7, *Minimum Design Loads for Buildings and Other Structures*.

FEMA (Federal Emergency Management Agency). 2008. FEMA NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures*. Available at http://www.fema.gov/library/viewRecord.do?id=1579.

FEMA. 2008. FEMA NFIP Technical Bulletin 2, *Flood Damage Resistant Materials Requirements*. Available at http://www.fema.gov/library/viewRecord.do?id=1580.

FEMA. 2008. FEMA NFIP Technical Bulletin 5, *Free of Obstruction Requirements*. Available at http://www.fema.gov/library/viewRecord.do?id=1718.

FEMA. 2008. FEMA NFIP Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls*. Available at http://www.fema.gov/library/viewRecord.do?id=1722.

FEMA. 2009. *Homeowner's Guide to Retrofitting*. FEMA P-312. Available at http://www.fema.gov/library/viewRecord.do?id=1420.

FEMA. 2009. *Mitigation Assessment Team Report: Hurricane Ike in Texas and Louisiana*. FEMA P-757. Available at https://www.fema.gov/library/viewRecord.do?id=3577.

FEMA. 2009. Hurricane Ike Recovery Advisories. Available at http://www.fema.gov/library/viewRecord.do?id=3539.

FEMA. 2009. *Recommended Residential Construction for Coastal Areas Building on Strong and Safe Foundations*. FEMA P-550. Available at http://www.fema.gov/library/viewRecord.do?id=1853.

FEMA. 2010. *Substantial Improvement/Substantial Damage Desk Reference*. FEMA P-758. Available at http://www.fema.gov/library/viewRecord.do?id=4160.

FEMA. 2011. *Coastal Construction Manual*. FEMA P-55. Available at http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=1671.

FEMA. 2012. *Changes in the Flood Insurance Program: Preliminary Considerations for Rebuilding*. Available at http://www.dec.ny.gov/docs/water_pdf/fpmfemacfip.pdf.

FEMA. 2012. *Comparison of Select NFIP and Building Code Requirements for Special Flood Hazard Areas*. FEMA Quick Reference Guide. Available at http://www.fema.gov/library/viewRecord.do?id=5701.

FEMA. 2012. *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures*. FEMA P-259. Available at http://www.fema.gov/library/viewRecord.do?id=1645.

FEMA. 2013. *Flood Insurance Reform Act of 2012: Impact of changes to the NFIP*. Available at http://www.fema.gov/library/viewRecord.do?id=7187.

FEMA. 2013. Hurricane Sandy Recovery Advisories and Fact Sheets. Available at http://www.fema.gov/building-science/hurricane-sandy-building-science-activities-resources.

- RA1: *Improving Connections in Elevated Coastal Residential Buildings*
- RA3: *Restoring Mechanical, Electrical and Plumbing Systems in Non-Substantially Damaged Residential Buildings*
- RA5: *Designing for Flood Levels Above the Base Flood Elevation*

FHWA (Federal Highway Administration). 2005. *Micropile Design and Construction Guidelines Manual*, FHWA NHI-05-039.

ICC (International Code Council). 2012. *International Building Code*. Country Club Hills, IL.

ICC. 2012. *International Residential Code for One- and Two-Family Dwellings*. Country Club Hills, IL.

Web Sites

Deep Foundation Institute, http://www.dfi.org/default.asp

International Association of Certified Home Inspectors, house raising, http://www.nachi.org/house-raising.htm

International Association of Structural Movers, http://www.iasm.org/index.html

Information on FEMA FIRMs, www.msc.gov and www.floodsmart.gov

Post-Hurricane Sandy ABFE maps for parts of New York and New Jersey, www.region2coastal.com/sandy/abfe

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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