

Best Practices for Minimizing Flood Damage to Existing Structures



FEMA

HURRICANES IRMA AND MARIA IN PUERTO RICO

Recovery Advisory 4, March 2018

Purpose and Intended Audience

The purpose of this Recovery Advisory is to identify best practices for using wet floodproofing techniques to reduce flood damage to new or existing residential and non-residential concrete buildings that are not substantially improved or substantially damaged as defined by the National Flood Insurance Program (NFIP) and local codes. However, an overview of methods to achieve NFIP compliance for new construction or existing buildings that are substantially improved or substantially damaged is also provided.

The intended audience for this advisory is anyone involved in the repair of existing residential or non-residential structures. This includes designers, builders, emergency managers, public officials, policy or decision-makers, building code officials, contractors, and home or building owners.

This Recovery Advisory Addresses

- Achieving NFIP compliance. New construction and existing buildings that have been substantially improved or substantially damaged must be made to comply with NFIP requirements and local building codes. These terms are defined below.
- Best practices for existing construction. Buildings built before their communities joined the NFIP, if they have not been substantially damaged or substantially improved, are not required to comply with NFIP regulations. It is recommended that owners of these buildings implement best practices to reduce flood risk and the costs of post-flood damage repairs. Guidance is provided for a number of wet floodproofing techniques.

Unless otherwise noted, all photos are from Hurricanes Irma and Maria Mitigation Assessment Team (MAT) observations in Puerto Rico.

Achieving NFIP Compliance

New construction and substantially improved and substantially damaged buildings located in Special Flood Hazard Areas (SFHAs) in NFIP communities must fully comply with NFIP regulations and local building codes (Substantial improvement and substantial damage are defined in “Terminology” on page 2). When NFIP compliance is required, local floodplain management regulations in Puerto Rico require the flood protection level at the minimum BFE plus freeboard of 1 foot for residential structures and most commercial structures. This requirement is set out in Puerto Rico Planning Regulation No. 13 Special Flood Hazard Areas Regulation (Legislative Assembly of Puerto Rico, 2010).

National Flood Insurance Program (NFIP) Regulations in Puerto Rico

This Recovery Advisory focuses on best practices for existing construction for which compliance with the NFIP is not required. All 78 municipalities in Puerto Rico participate in the NFIP: 74 municipalities are integrated in one large NFIP community, and 4 are independent NFIP communities. Although municipalities do not operate their own insurance programs, private flood insurance options are prevalent on the island. Puerto Rico’s Planning Regulation No. 13 Special Flood Hazard Areas Regulation, effective January 7, 2010, established lowest floor elevation requirements for residential buildings to be at least 1 foot above the base flood elevation (BFE), with commercial buildings at or above the BFE.

Flood Protection Level

This advisory uses “flood protection level” to refer to the required level of protection for new construction, substantial improvement, and substantial damage when NFIP compliance is required, or the desired level of protection for existing construction when compliance is not required.

The BFE is defined as the elevation of the one-percent-annual chance flood depth relative to the datum specified on a community's Flood Insurance Rate Map (FIRM); areas affected by the base flood are shown as Special Flood Hazard Areas (SFHA).

Note that Puerto Rico's Planning Regulation No. 13 freeboard requirement is more restrictive than the 2009 *International Building Code* (ICC IBC, 2009a) and 2009 *International Residential Code* (ICC IRC, 2009b), currently enforced in Puerto Rico, which requires a freeboard of 1 foot above the BFE for V Zone construction.

Terminology

NFIP regulations define substantial improvement and substantial damage in Title 44 of the Code of Federal Regulations Section 60.3:

Substantial Improvement: Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the structure's market value before the start of construction. This term includes structures that have incurred substantial damage, regardless of the actual repair work performed. The term does not, however, include either of the following:

1. Any structural improvement project whose purpose is to correct existing violations of state or local health or sanitary or safety code specifications that have been identified as the minimum necessary for safe living conditions by local code enforcement.
2. Any alterations to a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Substantial Damage: Damage of any origin sustained by a structure whereby the cost of restoring the structure to its pre-damage condition would equal or exceed 50 percent of the structure's pre-damage market value. *Substantial damage is implied to be included in each mention of substantial improvement throughout this advisory, as the requirements for floodplain management and building code regulation compliance are identical.*

Residential and non-residential buildings are defined by the IRC and IBC:

Residential Buildings: Detached one- and two-family dwellings and townhouses not more than three stories. The IRC applies to buildings that are "detached one- and two-family dwellings and townhouses not more than three stories above grade plane in height with a separate means of egress and their accessory structures not more than three stories above grade plane in height." Additionally, FEMA floodplain management guidance describes residential buildings as those in which people live, sleep, or are cared for on a 24-hour basis.

Non-Residential Buildings: All non-residential structures and critical facilities, as well as residential occupancies other than dwellings within the scope of the IRC. The IBC's scope applies to all buildings and structures that are not within the scope of the IRC, but some buildings and structures defined by the IBC are residential in nature.

Communities must evaluate proposals for all repairs, alterations, additions, and other improvements in the floodplain to determine whether the combined work (repairs and improvements) constitutes substantial improvement. Additionally, communities must enforce building codes and floodplain management regulations to increase structural resistance to future flooding. Residential and non-residential buildings (defined in “Terminology” on page 2) may achieve NFIP compliance using the following techniques:

- **Relocation:** Taking the property out of the SFHA by moving the existing structure to another location. Relocation can eliminate future flood risk, achieve NFIP compliance, and eliminate the need for owners to carry flood insurance. Both residential and non-residential buildings can use relocation techniques.
- **Elevation:** Raising the structure so the first finished floor is at or above the required flood protection level. This may be done by raising the existing structure on an elevated foundation support structure or structural fill (depending on the flood zone), or by demolition and replacement with an elevated structure on site. Elevation can maximize risk reduction, achieve NFIP compliance, and reduce flood insurance premiums. Both residential and non-residential buildings can use elevation techniques.
- **Dry Floodproofing:** Making structures substantially impermeable to the required protection level. This may be done by using floodproofing materials and construction techniques to minimize seepage of floodwater through walls, by installing watertight shields over doors and windows, and by installing pumps and other equipment to control seepage and prevent sewer backup. Dry floodproofing can reduce risk, achieve NFIP compliance, and reduce flood insurance premiums. Concrete or masonry structures may be suitable for dry floodproofing, but wood frame structures typically are not, according to *Floodproofing Non-Residential Buildings* (FEMA P-936, 2013). Only non-residential buildings can use dry floodproofing techniques.
- **Demolition:** The community may acquire and demolish the structure on site.

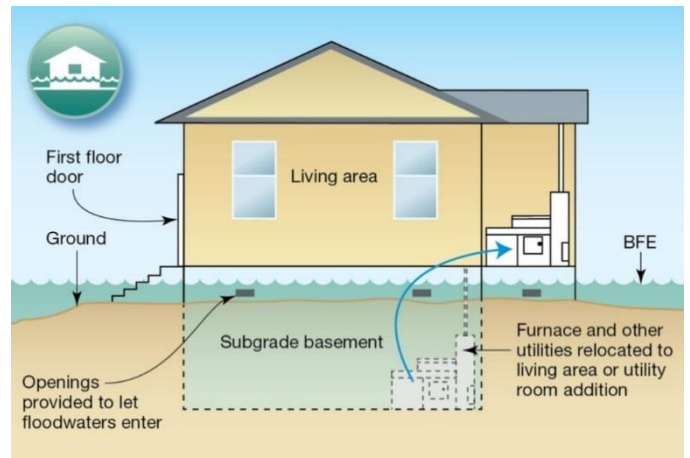


Figure 1. Wet floodproofing techniques for a house. From FEMA P-259 (Figure 1-10).

Wet Floodproofing for Existing Construction

Non-conforming existing residential and non-residential buildings built before communities joined the NFIP are not required to comply with NFIP regulations unless they have incurred substantial damage or are proposed to be substantially improved. Owners of these existing buildings may elect to implement best practices that reduce flood risk and the costs of post-flood damage repairs and system restoration.

While relocation, elevation, and dry floodproofing can be used by owners of existing buildings, these techniques can be very difficult and expensive to design, construct, and maintain. Therefore, owners of existing buildings may want to consider lower cost wet floodproofing techniques described below to reduce vulnerability to future flooding in cases where compliance is not required. These techniques will not ensure compliance with the NFIP.

Wet floodproofing allows water into the structure in a manner that minimizes flood damage by adding hydrostatic openings, using flood-damage-resistant materials, and protecting utilities and key equipment and/or contents (Figure 1). Although wet floodproofing cannot be used to achieve NFIP compliance or reduce flood insurance premiums, it can provide useful partial protection to residential and non-residential buildings.



Figure 2. Typical concrete frame residential structure with a concrete roof in Vega Baja.

Existing Flood-Damage-Resistant Building Features Used in Puerto Rico

Many existing residential and commercial buildings in Puerto Rico are constructed using one or more of the following features that make them ideal for application of wet floodproofing techniques:

- **Flood-Damage-Resistant Framing:** Many residential and non-residential structures in Puerto Rico use concrete frames with uninsulated concrete or masonry infill walls and a concrete roof deck as shown in Figure 2. Both concrete and masonry are classified as flood-damage-resistant structural materials, according to FEMA Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (FEMA TB-2, 2008b). Additionally, based on MAT observations made following Hurricanes Irma and Maria as well as Hurricane Georges (1998), this type of construction demonstrated greater resistance to flood and wind-driven rain damage than conventional wood or light steel-framed construction with a wood or metal roof deck.
- **Flood-Damage-Resistant Interior Finishes:** Based on MAT observations of residential concrete buildings with masonry infill walls under construction at the time of Hurricanes Irma and Maria, the typical interior finishes of the buildings consist of a ½-inch-thick layer of concrete as shown in Figure 3; these are classified as flood-damage-resistant materials per FEMA TB-2. Additionally, most electrical outlets or fixtures in the building were observed to be placed 2 feet or higher above the floor, which can help minimize the risk of flood damage in smaller flood events (Figure 3). Finally, general observations from the current MAT indicated that most buildings used ceramic tiles or other floor finishes on their lowest floor that were classified as flood-damage-resistant materials per FEMA TB-2.
- **Elevated Utility Equipment:** Many residential and non-residential concrete buildings with concrete roof decks observed by the MAT had solar water heaters and other utility equipment anchored to the roof deck that were generally successful in resisting flood, wind, and wind-driven rain damage from Hurricanes Irma and Maria (Figure 4). Additionally, most structures in Puerto Rico observed by the MAT had their electric meters elevated several feet above grade on a structural wall or a concrete mast (Figure 5). Both practices are consistent with building utility guidance provided in *Protecting Building Utility Systems from Flood Damage* (FEMA P-348, 2017).



Figure 3. Typical concrete interior finishes on a residence under construction in Yabucoa.



Figure 4. Solar water heater and water tank anchored to concrete roof in Rincon.



Figure 5. Electric meter elevated on concrete mast in house under construction in Yabucoa.

Install Hydrostatic Openings

Hydrostatic openings are required by the NFIP in foundation and enclosure walls below the BFE to equalize water (hydrostatic) pressures caused by standing floodwaters that can damage or destroy structures. Figure 6 shows an example of hydrostatic openings, circled in red. The openings need to be placed within 1 foot of grade to be effective. Refer to FEMA Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (FEMA TB-1, 2008a), for additional details on installation requirements for hydrostatic openings.

Use Flood-Damage-Resistant Materials

The NFIP defines flood-damage-resistant materials as “any building product capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage.” “Prolonged contact” is considered at least 72 hours, and “significant damage” can include any damage requiring more than cosmetic repairs, such as cleaning, sanitizing, and resurfacing. The NFIP requires flood-damage-resistant materials to be used for structures and finishes below the BFE in SFHAs to reduce damage and facilitate post-flood recovery. Refer to FEMA TB-2 for additional details on flood-damage-resistant materials.

Protect Building Utility Systems and Key Equipment/Contents

A significant portion of flood damages and service losses to structures can be attributed to a loss of building utility systems needed to support building operations. These systems include mechanical, electrical, plumbing, and other utility elements, and key equipment and contents, such as medical devices in hospitals and files (hard-copy and electronic) in offices. Residences, businesses, and community facilities are all impacted when building utility systems and key equipment/contents are damaged and cause delays in post-flood building re-occupancy. Building utility systems and key



Figure 6. Example of hydrostatic openings (red circles). From FEMA TB-1 (cover image).



Figure 7. A cantilevered platform to elevate a residential air conditioning compressor and protect it from flooding. From FEMA P-348 (Figure 3-2).



Figure 8. Example of dry floodproofed vault used to protect fuel pump equipment in a high-rise building. From FEMA P-942, RA-6 (Figure 1).

equipment/contents can be protected by adapting relocation, elevation, and dry floodproofing techniques described in the previous section, as illustrated in Figures 7 and 8. Refer to FEMA P-348 and FEMA P-936 for additional details on protecting building utility systems and key equipment and contents.

Wet Floodproofing Best Practices

FEMA recommends the following best practices for applying wet floodproofing techniques to minimize flood damage and service losses to existing residential and non-residential buildings where compliance is not required. Note, the recommended best practices outlined below are intended for use with structures two stories or higher with concrete framing, concrete or masonry infill walls, concrete roof deck, and basic interior wall finishes.

Hydrostatic Openings and Lowest Floor Use

Add hydrostatic openings to the lowest floor in accordance with FEMA TB-1 wherever the design flood elevation is estimated to be 2 feet or more above the lowest floor. This will greatly reduce the risk of structural damage or building collapse from unbalanced hydrostatic forces, which can increase rapidly with increasing flood depth.

For health and safety reasons, *do not use the lowest floor for living space*, since the lowest floors of existing buildings in SFHAs are likely to be subject to inundation and post-flood cleanup following major flood events.

Flood-Damage-Resistant Materials

Confirm all existing structural and finish materials are flood-damage-resistant in accordance with FEMA TB-2. Where existing materials are damaged and need to be replaced, consider the structural and finish materials listed in Table 1. Refer to FEMA TB-2 for additional options.

Table 1. Recommended Flood-Damage-Resistant Structural and Finish Materials. From FEMA TB-2.

Flood Damage Resistant Structural Wall and Ceiling Materials	Flood Damage Resistant Structural Floor Materials
Brick face, concrete, or concrete block concrete masonry units (CMUs)	Concrete, pre-cast or cast-in-place
Cement board/fiber-cement board	Naturally decay-resistant lumber (redwood, cedar)
Pressure-treated plywood, treated with alkaline copper quaternary (ACQ) or copper azole (CA)	Recycled plastic lumber (RPL), fiber-reinforced or of high-density polyethylene (HDPE)
Solid, standard structural lumber (2 in. x 4 in.)	Pressure-treated plywood, treated with ACQ or CA
Flood-Damage-Resistant Finish Wall and Ceiling Materials	Flood-Damage-Resistant Finish Floor Materials
Concrete	Clay tile
Metal cabinets or doors	Ceramic/porcelain tile (with mortar set)
Glass blocks	Terrazzo tile
Latex paint	Vinyl tile or sheets (homogeneous, with chemical-set adhesives only)



Figure 9. Heating, Ventilation, and Cooling (HVAC) equipment (red ovals) anchored to concrete roof deck in Humacao.

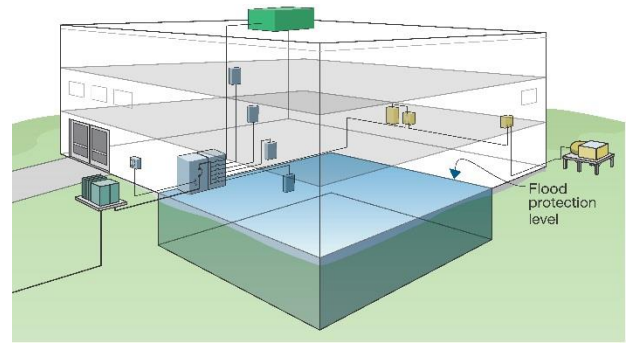


Figure 10. Electrical equipment relocated to the upper floor of a non-residential building to protect it from flooding. From FEMA P-348 (Figure 5-13).

Building Utility Systems and Key Equipment/Contents

Use the following techniques from FEMA P-348 to protect various building utility systems from flood damage and/or extended service losses:

- Heating, Ventilation, and Cooling (HVAC) Systems:** Relocate any equipment that is at or below grade to the roof of the structure (Figure 9) or onto an elevated platform (Figure 7). Secure the equipment for wind pressures and seismic forces using corrosion-resistant anchors or straps. Where possible, relocate air conditioning ducts above the flood protection level.
- Electrical Systems:** Confirm the electric meter is sufficiently elevated to the established flood protection level or as high as permissible (Figure 5). Elevate the main service panel, branch circuits, and outlets above the flood protection level wherever possible (Figure 10). Electrical components that cannot be elevated should be isolated from the rest of the system using ground-fault circuit interrupter (GFCI) receptacles and installed in a manner that facilitates quick replacement if they are flooded.
- Emergency and Standby Power Systems:** Consider an emergency power system for critical facilities or buildings where main power tends to be unreliable. Install the emergency generator above the flood protection level, and ensure that all back-up power system components – fuel tanks, fuel pumps, transfer switches, and ventilation stacks – are elevated or protected from flooding. Refer to *Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability* (FEMA P-1019, 2014) for additional details.
- Plumbing and Solar Water Heaters:** Confirm the water meter is sufficiently elevated to the established flood protection level or protected from flooding, if possible. Solar water heaters and water tanks should be secured to the concrete roof deck using corrosion-resistant anchors or straps to resist wind pressures and seismic forces (Figure 4). Install backflow valves in drain waste and vent (DWV) pipes in the sanitary sewer lateral to help prevent wastewater backup when the sanitary sewer system is surcharged.
- Fuel Systems and Tanks:** Elevate fuel system components where possible and use submersible pumps in areas subject to flooding. Place above-ground tanks above the flood protection level on an elevated platform or frame capable of resisting flood, wind, and seismic forces, and secure the tank to the frame using corrosion-resistant straps (Figure 11). Underground tanks should be secured to a concrete slab with corrosion-resistant straps or held down by helical earth anchors beneath the anticipated erosion and scour depth to resist buoyancy, and sealed to prevent water infiltration.

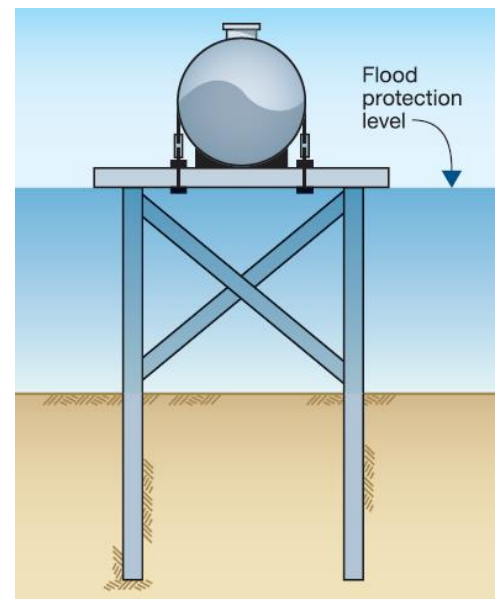


Figure 11. Elevated fuel tank secured with straps and anchored to a supporting frame. From FEMA P-348 (Figure 4-32).

- **Conveyances (Elevators and Lifts):** Elevator enclosures should be designed to resist all flood forces, including erosion and scour. Elevator and lift equipment, such as electrical controls and hydraulic pumps, should be located above the flood protection level when possible. Refer to FEMA Technical Bulletin 4, *Elevator Installation* (FEMA TB-4, 2010) for additional details.

Use the following techniques to elevate key equipment and contents:

- Locate critical records, files, documents, computer servers, high-value equipment, and stock on an upper floor whenever possible.
- If this is not practical, elevate vulnerable equipment and contents above the flood protection level using racks, shelves, and/or pedestals that are installed to resist lateral movement from flood forces. For heavy equipment, overhead hoists or clearances to accommodate forklifts may be needed to facilitate relocation.

References and Useful Links

References

- FEMA. 2008a. *Openings in Foundation Walls and Walls of Enclosures*. FEMA TB-1. <https://www.fema.gov/media-library/assets/documents/2644>.
- FEMA. 2008b. *Flood Damage-Resistant Materials Requirements*. FEMA TB-2. <https://www.fema.gov/media-library/assets/documents/2655>.
- FEMA. 2010. *Elevator Installation*. FEMA TB-4. <https://www.fema.gov/media-library/assets/documents/3478>.
- FEMA. 2014. *Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability*. FEMA P-1019. <https://www.fema.gov/media-library/assets/documents/101996>.
- FEMA. 2012. *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Buildings, Third Edition*. FEMA P-259. <https://www.fema.gov/media-library/assets/documents/3001>.
- FEMA. 2013. *Floodproofing Non-Residential Buildings*. FEMA P-936. <https://www.fema.gov/media-library/assets/documents/34270>.
- FEMA. 2013. *Hurricane Sandy Recovery Advisory 5: Designing for Flood Levels Above the BFE After Hurricane Sandy*. FEMA P-942. <https://www.fema.gov/media-library/assets/documents/30966>.
- FEMA. 2017. *Protecting Building Utility Systems From Flood Damage, Second Edition*. FEMA P-348. <https://www.fema.gov/media-library/assets/documents/3729>.
- International Code Council. 2009a. *International Building Code*. ICC IBC. <https://codes.iccsafe.org/public/document/details/toc/745>.
- International Code Council. 2009b. *International Residential Code*. ICC IRC. <https://codes.iccsafe.org/public/document/details/toc/754>.
- Legislative Assembly of Puerto Rico. 2010. *Planning Regulation No. 13 Special Flood Hazard Areas*

Useful Links

Association of State Floodplain Managers (ASFPM). “Hurricanes Harvey, Irma & Maria News, Updates & Resources.” <https://floods.org/?menuid=841>.

Federal Alliance for Safe Homes (FLASH). “Publications, Resources, and Programs.” <http://flash.org/resources.php>.

FEMA. “FEMA Puerto Rico.” <https://www.facebook.com/FEMAPuertoRico>. Note, this Facebook page was created for the Hurricanes Irma and Maria recovery process and is regularly updated with useful information.

FEMA. “The National Flood Insurance Program.” <https://www.fema.gov/national-flood-insurance-program>.

FEMA. 1993. *Wet Floodproofing Requirements*. FEMA TB-7. <https://www.fema.gov/media-library/assets/documents/3503>.

Insurance Institute for Business and Home Safety (IBHS). “Flood Archives.” <https://disastersafety.org/flood/>.

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

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

You may also sign up for the FEMA Building Science e-mail subscription, which is updated with publication releases and FEMA Building Science activities. Subscribe at <https://public.govdelivery.com/accounts/USDHSFEMA/subscriber/new>.

Visit the Building Science Branch of the Risk Management Directorate at FEMA’s Federal Insurance and Mitigation Administration at <https://www.fema.gov/building-science>.

To order publications, contact the FEMA Distribution Center:

Call: 1-800-480-2520

(Monday–Friday, 8 a.m.–5 p.m., EST)

Fax: 240-699-0525

E-mail: FEMA-Publications-Warehouse@fema.dhs.gov

Additional FEMA documents can be found in the FEMA Library at <https://www.fema.gov/library>.

Please scan this QR code to visit the FEMA Building Science Web page.

