VOLUME 2: **WATER**

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

WATER

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Located in Upper Marlboro, Maryland, Home Innovation Research Labs (Home Innovation) was founded in 1964 as a wholly-owned, independent subsidiary of the National Association of Home Builders (NAHB). Originating as a small product testing laboratory, Home Innovation has since grown to become a full-service market research, building science research, consultant, product testing laboratory, and accredited third-party certification agency dedicated to issues related to the homebuilding industry.

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FOREWORD

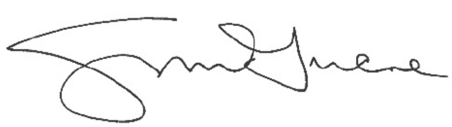
According to the National Oceanic and Atmospheric Administration, the United States spent $145 billion in 2021 recovering from natural disasters, which included wildfires, tropical cyclones, floods, tornados, drought conditions, and extreme winter storm events. To mitigate the impact of natural disasters, the U.S. Department of Housing and Urban Development (HUD) continues to develop technical guidance to improve the resilience of housing.

Resilience is characterized by a community's ability to minimize damage and recover quickly from extreme events and changing conditions.

The *Designing for Natural Hazards: A Resilience Guide for Builders & Developers* series was developed with a technical advisory group that included subject matter experts from a wide range of industry stakeholders. The experts were tasked with identifying above-code construction techniques to improve the resilience of residential buildings. A consensus process was used with the goal of creating a set of practical, actionable guidelines for builders and developers. The guidelines are intended for new construction, improvements before a natural disaster, and major reconstruction efforts after natural disasters, especially where entire communities need to be rebuilt.

The technical advisory group recognized that when natural disasters occur, certain damage is more likely than other types of damage. To address this challenge, the technical advisory group recommended a mitigation strategy that prioritizes high-frequency damage over damage that rarely occurs—based on post-disaster damage assessment reports. This novel approach encourages improving those parts of the building that typically get damaged first. It can also maximize the impact of disaster mitigation grants by preventing future damage to homes.

The resilience guides are an excellent addition to HUD's PD&R Disaster Recovery Took Kit. These guides should be updated periodically based on post-disaster damage assessment data—from future natural disasters. The resilience guides will be valuable resources to builders and developers seeking to incorporate resilience in housing.



Solomon Greene
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INTRODUCTION TO VOLUME 2: WATER

Designing for Natural Hazards is a set of resiliency guides for builders and developers. It is segmented into five short volumes, each focusing on a specific natural hazard type, as illustrated below:

This guide is **Volume 2: Water,** which highlights the damage caused by water from storms and flooding; in addition, the guide identifies resilient construction practices that can eliminate or minimize water damage in a meaningful way.

BACKGROUND

HUD tasked Home Innovation Research Labs (Home Innovation) to develop a set of practical, actionable guidelines for builders and developers to design and construct residential buildings, neighborhoods, and accessory structures in a manner that could improve residential resilience and integrate resiliency throughout the entire community. The ***Designing for Natural Hazards*** guides accomplish this task by providing technical content in a very straightforward manner that is easy for a layperson to understand while also providing references for design professionals, builders, developers, and public officials to dive deeper into the necessary details. These resilience guides are not intended to substitute for engineering or architectural project design work; instead, the technical guidance identifies the components that can be enhanced or improved to achieve above-code performance that should make residential buildings and other community assets more resilient.

The ***Designing for Natural Hazards*** guides focus on new construction and major reconstruction after natural disasters, especially reconstruction in areas where entire communities need to be rebuilt after catastrophic events. The guides do not focus on minor repairs or renovations that are common after typical natural disaster events and do not address commercial buildings, although many of the construction practices identified are also applicable to multifamily mixed-use buildings with wood framing.

To make the guides as practical and have as much input and buy-in as possible, Home Innovation employed many of the same approaches used to assemble the Technical Advisory Group (TAG) when helping develop the American National Standards Institute (ANSI) standards. Specifically, Home Innovation recruited a balanced number of stakeholders to reach consensus on the approach to developing content. In addition, all Task Group meetings were open to the public, and input was solicited beyond the members of the TAG and its Task Groups. Although these guides were not developed in accordance with the requirements of an ANSI standard, the approach to these guides mirrored that spirit and intent of creating a voluntary, consensus document.

HOW TO USE THE GUIDES

The ***Designing for Natural Hazards*** guides are intended to be used by a wide range of stakeholders, including design professionals, builders, developers, and even prospective homebuyers. The guides differ from other resiliency programs and resources because they are not a prescriptive program or list of improvements. Instead, the resilience guides are designed to be flexible and allow users to focus on either a single resilient construction practice or multiple resilient construction practices, depending on the user's specific needs.

The technical content is provided on a single, double-sided page for each resilient construction practice. These "one-pagers" are intended to be printed and used as stand-alone documents for a builder or developer to specify an above-code construction practice. The one-pagers can also be given to a prospective homebuyer or building owner as a supplemental marketing document to highlight the resilient construction features that have been included in a new building.

Each one-pager includes key information about the specific natural hazard and resilient construction practice that will minimize or eliminate potential damage. The front of each document identifies (1) the damage expected by the hazard (as shown in the photo); (2) the frequency that a specific type of damage occurs; (3) a description of the resilient construction practice that can minimize damage; (4) a description of the mitigation strategy; and (5) a summary of the cost and benefit of implementing the resilient construction practice. The back of the document provides additional design guidance details, including (1) multiple design variations and supplemental resilient construction practices; (2) the corresponding level of difficulty associated with implementing alternative resilient construction practices; (3) the relative cost of implementing the various options; and (4) technical references that provide more information for each design option.

Because the resilient construction practices summarized in these guides are intended to be implemented in areas where the building code does not specify resilient construction practices, builders cannot rely on a building code official to verify that the practices have been followed. Therefore, builders who undertake these resilient construction practices will need to either incorporate the practices into their internal quality assurance process or hire a third-party organization to confirm that the resilient construction practice(s) was appropriately included in the design and constructed per their specification, which will require some additional detail beyond the one-pagers.

Defining Water Damage and Resilient Construction

Water damage can occur from flooding or wind-driven rain. The Federal Emergency Management Agency (FEMA) defines flooding as "a temporary overflow of water onto land that is normally dry. It is the most common natural disaster in the United States. [Floods] result from rain, snow, coastal storms, storm surge, and overflows of dams and other water systems." FEMA defines wind-driven rain as "rain [that] is propelled into a covered structure by wind, that is considered wind-driven rain and is not covered under your flood insurance policy." For this ***Designing for Natural Hazards*** guide, the Water Task Group focused on flooding and wind-driven rain as natural hazards.

The first undertaking for the Water Task Group was to identify typical damage that happens when either flooding or wind-driven rain or storm events occur. To that end, the group reviewed case studies of major storm events, such as hurricanes, published by FEMA and HUD. The Task Group discussed the water damage described in the reports, then reviewed a wide range of technical resources—for example, resources from FEMA, HUD, the American Society of Civil Engineers (ASCE), the International Code Council (ICC), and the Insurance Institute for Business & Home Safety (IBHS)—to identify the most relevant resilient construction content to be included in the Water one-pagers.

For those building in an area already designated as one of FEMA's high-risk flood zones or Special Flood Hazard Areas, nearly all of the flood-related resilient construction practices in this guide will apply, in addition to other requirements. However, if building a more water-resilient residential building outside a high-risk flood zone (that is, in moderate- to low-risk flood zones), this guide can help builders implement the practices incrementally by adding one or more flood-resilient features to the building. The resilient wind-driven rain construction practices can be employed in areas where hurricanes and other major storms are not common; in high-wind areas, a robust roof design may already be required.

FEMA publishes a flood calculator that estimates the potential cost of flood and water damage on the basis of the depth of floodwater in the building, as illustrated in Figure 1.

Frequency of Damage Type

After familiarizing themselves with specific damage caused by flooding and wind-driven rain events described in various disaster reports, the Water Task Group was asked to determine the type of damage most likely to occur when considering all possible damage from water. Estimating the cost of water damage is generally straightforward whenever it occurs, but pinpointing where a flood will happen is impossible. Instead, FEMA and the National Flood Insurance Program (NFIP) rely on flood maps to determine the risk of flooding on the basis of flood zones. The flood maps, historically, have been inaccurate,

Figure 1. Federal Emergency Management Agency Cost of Flooding Calculator
Source: FEMA, National Flood Insurance Program

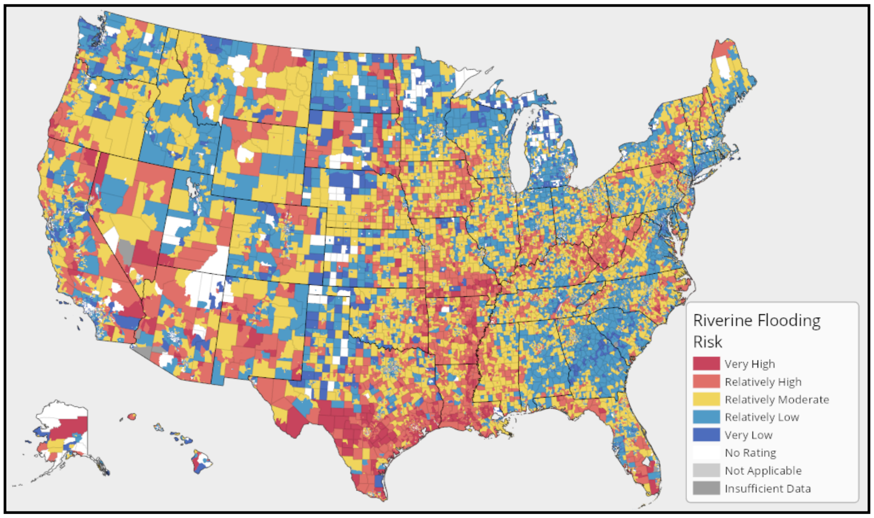


Figure 2. River/Inland Flood Zone
Source: FEMA

so FEMA states, "Flood hazards change over time. Updated flood maps provide a more accurate picture of a property's flood risk. To better reflect your current flood risk, the National Flood Insurance Program (NFIP) and the Federal Emergency Management Agency (FEMA) use the latest technology and data to update flood maps nationwide."

The U.S. Geological Survey (USGS) "provides information about the magnitude and frequency of floods based on records of annual maximum instantaneous peak discharges. This is a list of current USGS flood frequency reports published by state" (https://www.usgs.gov/mission-areas/water-resources/science/flood-frequency-reports).

The Water Task Group characterized most damage types as high-frequency occurrences when flooding events happen. Figure 2 illustrates the risk of flooding near inland rivers and other bodies of water (for example, in the Midwest during springtime, along the Mississippi River).

Prioritizing High-Frequency Damage for Resilience

Because these resilient construction practices are intended for areas outside FEMA's high-risk flood zones or Special Flood Hazard Areas, several participants on the Technical Advisory Group recommended prioritizing high-frequency-damage areas of the building as the most practical mitigation strategy for resilience. Many were concerned that if funding for above-code practices and strategies were limited, or if a builder wanted to invest in a specific resilient construction practice above all others, knowing what was most important to do would be difficult if not for some level of prioritization. Data about the frequency of damage type are necessary for builders and developers to prioritize the resilient construction practices that will yield the greatest benefit—or the least amount of damage—to the building. The damage frequency metrics on the one-pagers are intended to provide builders and developers with a general idea of the frequency and severity of possible damage so that cost alone is not driving the mitigation strategy.

For example, on the basis of case studies and FEMA's mitigation assessment team reports, elevating the building is a critical factor in minimizing damage due to flooding. The cost metric is defined qualitatively, illustrating a range of incremental costs based on the implementation of additional practices. As mentioned earlier, tools and calculators exist that estimate damage cost on the basis of the NFIP.

Grouping Resilience Practices

The Water Task Group believed that licensed design professionals and subject matter experts would be able to prioritize resilient construction practices without much guidance. However, given the multiple options and design alternatives on the one-pagers, the Task Group thought that recommending some bundling of multiple one-pagers would still be valuable so that a builder or developer could offer a prepackaged system of resilient construction practices, similar to other resiliency programs.

The most basic prepackaged system of resilient construction practices could be as simple as selecting the basic practice for each of the one-pagers in the Water Guide to encourage some baseline level of resilience. The Task Group also explored a "Good, Better, and Best" approach to grouping the one-pagers, in which the basic levels of resilience would be branded as "Good," the more advanced practices could be combined with those basics to offer a "Better" option, and the most comprehensively resilient practices could be considered a "Best" level of resilience. Table 1 provides an example of this type of approach for Water Resilience, in which the one-pagers are grouped on the basis of the frequency of occurrences.

Certain resilient construction practices may be alternatives, whereas others may be additional practices to be implemented. This method allows for even further customization of a "Good, Better, and Best" approach for a builder or developer looking for this type of guidance.

Table 1. Example of "Good, Better, and Best" Approach to Resilient Construction Practices for Water

	USING MULTIPLE 1-PAGERS		
	GOOD	**BETTER**	**BEST**
Roof Underlayment & Vents	High Frequency	High Frequency	High Frequency
Wall Assembly	High Frequency	High Frequency	High Frequency
Utilities & Mechanical Equipment	High Frequency	High Frequency	High Frequency
Freeboard Elevation	High Frequency	High Frequency	High Frequency
Leak Prevention & Ice Dam	X	Moderate Frequency	Moderate Frequency
Piling & Pier Foundation	X	Moderate Frequency	Moderate Frequency
Breakaway Construction	X	X	Low Frequency
Connectors & Fasteners	X	X	Low Frequency

NEXT STEPS AND FUTURE RESEARCH

As resilient construction practices evolve, the one-pagers in this guide should be updated to reflect improvements or modifications. Additional work can be done using existing NFIP data and collaboration with USGS to characterize typical damage and claims data (if available) and thereby improve the damage frequency metric.

The Water Task Group discussed better building materials, such as new wall sheathing products designed to be water and mold resistant. Those new products were beyond the scope of the one-pagers, but their use was noted as a potential solution in the future because paying a premium upfront for a better wall sheathing product could avoid the added cost of major renovation and replacement of water-damaged building materials in the future.

Using better materials is not a new concept; FEMA proposed similar types of building materials in its publication titled, "Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program." FEMA states, "'Flood [damage]-resistant material' is defined by the NFIP as 'any building product [material, component, or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage.' The term 'prolonged contact' means at least 72 hours, and the term 'significant damage' means any damage requiring more than cosmetic repair. 'Cosmetic repair' includes 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. In addition to these requirements, individual materials that are considered flood damage-resistant must not cause degradation of adjacent materials or the systems of which the material is a part." The materials are further classified in Figure 3.

The Water Task Group was familiar with material types but stated that better products are needed. This area could benefit from more new product development.

NFIP	Class	Class Description
ACCEPTABLE	5	Highly resistant to floodwater[1] damage, including damage caused by moving water.[2] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[3] Materials in this class are permitted for partially enclosed or outside uses with essentially unmitigated flood exposure.
ACCEPTABLE	4	Resistant to floodwater[1] damage from wetting and drying, but less durable when exposed to moving water.[2] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[3] Materials in this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection.
UNACCEPTABLE	3	Resistant to clean water[4] damage, but not floodwater damage. Materials in this class may be submerged in clean water during periods of flooding. These materials can survive wetting and drying, but may not be able to be successfully cleaned after floods to render them free of most[3] harmful pollutants.
UNACCEPTABLE	2	Not resistant to clean water[4] damage. Materials in this class are used in predominantly dry spaces that may be subject to occasional water vapor and/or slight seepage. These materials cannot survive the wetting and drying associated with floods.
UNACCEPTABLE	1	Not resistant to clean water[4] damage or moisture damage. Materials in this class are used in spaces with conditions of complete dryness. These materials cannot survive the wetting and drying associated with floods.

Figure 3. FEMA's Flood Damage-Resistant Materials Requirements Table 1.
Source: FEMA

Damage caused by water intrusion due to roof failure.

ROOF UNDERLAYMENT & VENTS

A secondary roof-sealing strategy using underlayment products can significantly reduce water infiltration through the roof when the primary roof covering is lost or damaged. Wind damage can result in extensive and costly water intrusion damage from water infiltration. Water infiltration can saturate attic insulation, drywall, and wall cavities, causing both structural damage and the potential for mold growth. Depending on the volume of water, water infiltration can also lead to significant damage to any non-waterproof surface inside the home (carpets, furniture, electronics, etc.).

Damage Frequency

HIGH

Construction Practice

Water infiltration can be reduced by applying a secondary barrier.

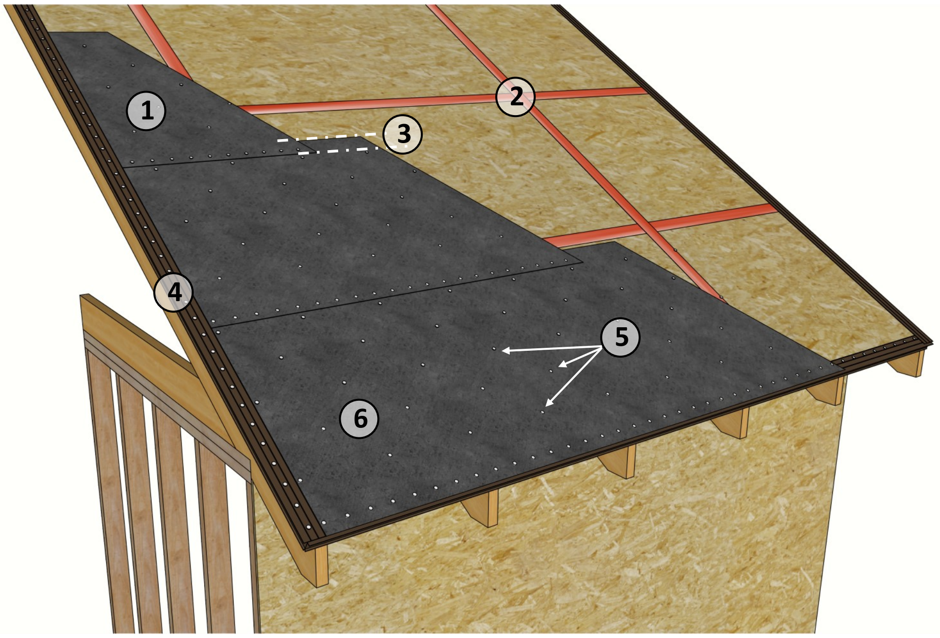
Mitigation Strategy

Robust secondary water barrier.

Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Additional layers of protection from water infiltration drastically decrease the chance of potentially costly water damage and avoid the potential for major damage.

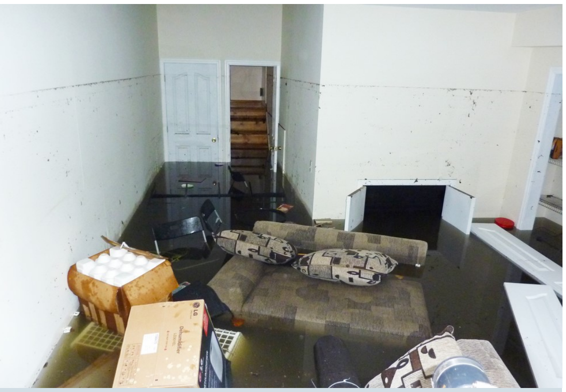


1. One layer of ASTM D226 Type II, ASTM D4869 Type IV, or ASTM D6757
2. 4-in.-wide (minimum) self-adhering modified bitumen tape at sheathing joints
3. 4-in. overlap
4. Metal drip edge
5. Stagger runs
6. Annular ring or deformed shank nails with metal or plastic caps. Cap diameter not less than 1 in. Nail shank diameter not less than 0.083 in. Metal cap thickness not less than 32-gauge sheet metal or 0.01 in. for power-driven fasteners. Plastic cap outside edge thickness not less than 0.035 in.

GUIDANCE	DIFFICULTY	COST
Roof Underlayment		
Tape/seal all vertical and horizontal seams in roof sheathing. [1,2]	Easy	$
Tape/seal all vertical and horizontal seams in roof sheathing, and cover roof deck with #30 felt or an equivalent synthetic underlayment. [1,2,3]	Moderate	$$
Use self-adhering polymer-modified bitumen membrane over the entire roof deck. [1,3]	Moderate	$$$$
Mechanically Fastened Roof Underlayment		
Fasten underlayment with annular-ring or deformed shank roofing fasteners with minimum 1-in.-diameter caps 6 in. on center (o.c.) along the laps and 12 in. o.c. spacing, vertically and horizontally, in the field. [1]	Moderate	$
Roof and Attic Vents		
Install soffit and ridge vents that have been tested and have passed wind-driven rain tests in Florida's Building Codes Approval or Testing Application Standard TAS-100. [4]	Easy	$
Conditioned Attic—Designed and installed in accordance with building code and product manufacturer instructions and to perform in a specific climate region. [5]	Complex	$$$

RESOURCES

1. ASTM D1970/D1970M-21 *Standard Specification for Self-Adhered Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection*.
2. AAMA 711-13 *Voluntary Specification for Self-Adhering Flashing Used for Installation of Exterior Wall Fenestration Products*.
3. 2020 *FORTIFIED Home™ Standard*. Insurance Institute for Business & Home Safety (IBHS).
4. Testing Application Standard (TAS) No. 100(A)-95 Test Procedure for Wind Driven Rain Resistance and/or Increased Windspeed Resistance of Soffit Ventilation Strip and Continuous or Intermittent Ventilation Strip and Continuous or Intermittent Ventilation System Installed at the Ridge Area. *2014 Florida Test Protocols for High-Velocity Hurricane Zones*. International Code Council (ICC). March 2014.
5. BSI-119: Conditioned Unconditioned. *Building Science Insights*. Building Science Corporation.



Damage to wall components due to bulk water and water infiltration.

Damage Frequency

HIGH

Construction Practice

Using water-resistant materials for construction and techniques that allow for easy repair/replacement helps mitigate water damage if/when it occurs.

Mitigation Strategy

Material considerations on the exterior and interior of the home can greatly mitigate damage.

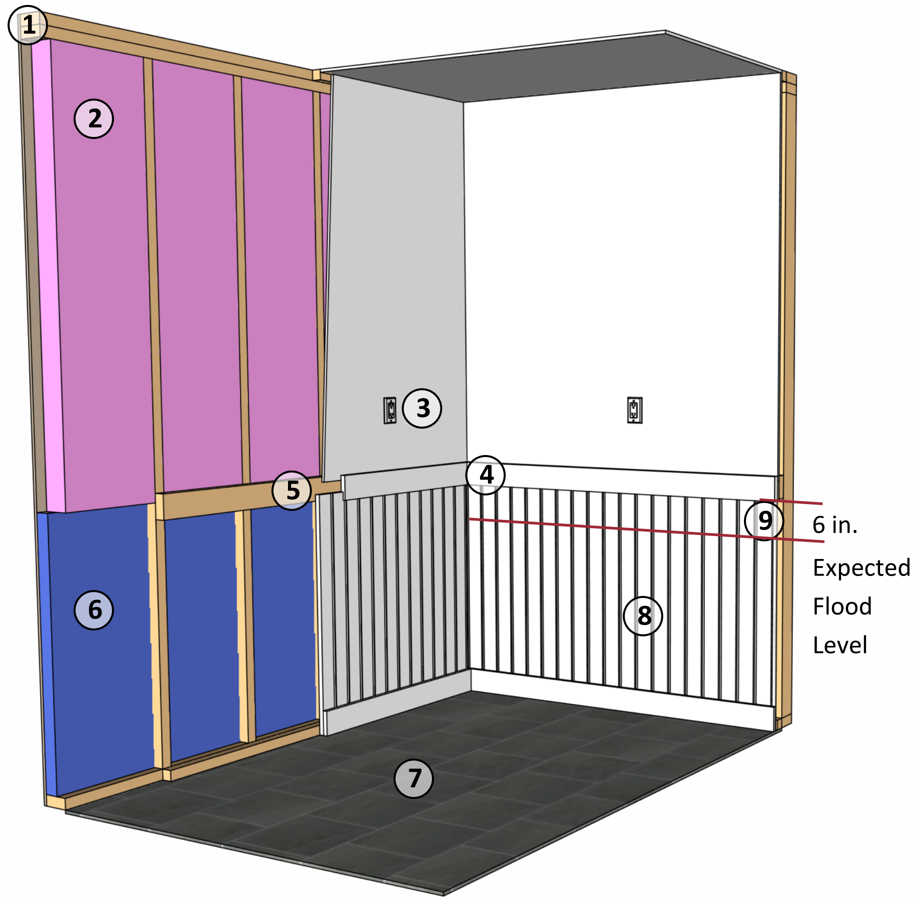
Cost & Benefit

Cost range to implement: $–$$$

Benefit: Allows for easier recovery after a flooding or bulk water event, avoiding potential major damage.

WALL ASSEMBLY

Reduce and limit secondary damage from water intrusion through the selection of materials and construction techniques. Construct walls to allow for easy repair when water damage occurs. Material considerations on the exterior and interior of the home can greatly mitigate damage.

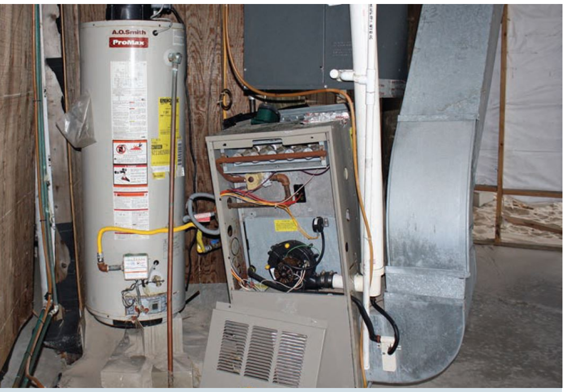


1. Preservative-treated lumber
2. Batt insulation above gap in wallboard
3. Elevated outlets
4. Chair rail
5. ½-in. gap in wallboard to prevent wicking
6. Closed-cell or plastic foam insulation
7. Water-resistant flooring
8. Replaceable wainscot
9. Chair rail installed 6 in. above expected flood level

GUIDANCE	DIFFICULTY	COST
Wall Materials		
Use flood-resistant materials referenced in FEMA Fact Sheet 1.7 or Table 2 of FEMA Technical Bulletin 2. [1,2]	Moderate	$–$$
Spray studs with borate treatment to a minimum of 4 ft. or 12 in. above base flood elevation (BFE) in field (all first floor and floor joists, if applicable). [3]	Easy	$
Block and use galvanized screws to attach non-paper-faced gypsum at least 4 ft. above BFE on all first floor walls. [3]	Easy	$–$$
Use closed-cell spray foam as water-resistant wall insulation. [3]	Moderate	$$$
Move wall insulation to exterior of frame with no cavity insulation. [3]	Moderate	$$
Wall Exterior Cladding		
Use a drainage plane material designed to be used behind the cladding. [3,4]	Moderate	$$
Use vinyl or cement-based cladding and trim. [3]	Easy	$–$$
For wood and cement-based siding, fur out siding for better cladding drainage. Allow for back venting at top and bottom of cladded wall. [3]	Moderate	$$
When using vinyl- and cement-based cladding systems, use a solid sheathing, such as oriented strand board (OSB), behind the drainage plane material. [4]	Moderate	$$

RESOURCES

1. Fact Sheet No. 1.7 Coastal Building Materials. *Home Builder's Guide to Coastal Construction.* FEMA-499. 2010.
2. *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas.* NFIP Technical Bulletin 2. FEMA. 2008.
3. *Borate-Treated Wood for Construction.* Forintek Canada Corp. 2002.
4. BSD-111: Flood and Hurricane Resistant Buildings, *Building Science Digests*. Building Science Corporation. 2006.



Rising floodwater damage.
Source: FEMA P-942 Figure 3-56

Damage Frequency

HIGH

Construction Practice

Relocate utilities, plumbing fixtures, and mechanical equipment to prevent damage from rising water.

Mitigation Strategy

Prevent utilities and mechanical equipment from getting wet.

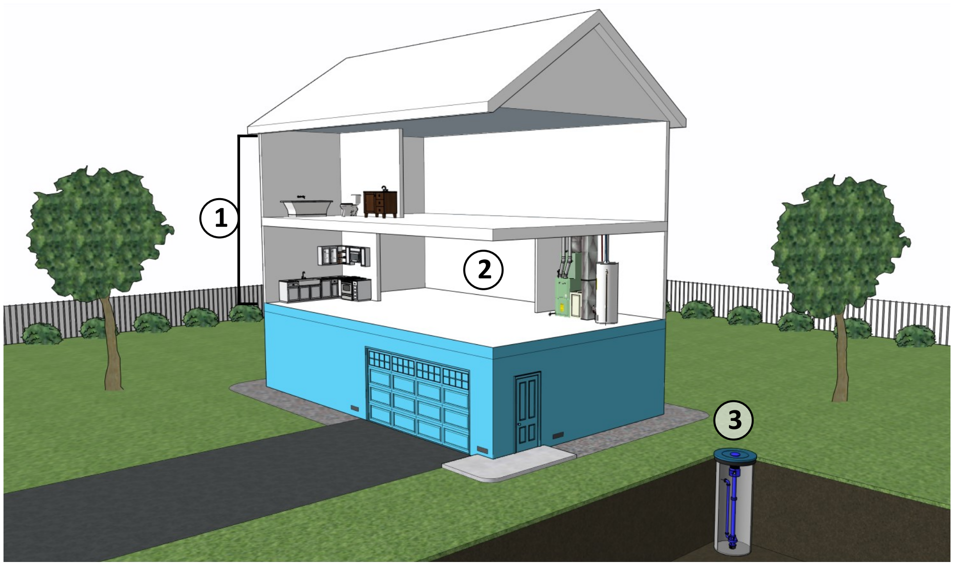
Cost & Benefit

Cost range to implement: $–$$$

Benefit: Reduces damage, aids in the restoration of utility services and building function, and avoids the potential for moderate damage.

UTILITIES & MECHANICAL EQUIPMENT

Best practice is to locate components on the landward side of the structure and to elevate items above the base flood elevation (BFE); those below BFE should be placed in a floodproof enclosure. Damaged components can contribute to an inability to use or access the facility until the components are repaired, which can delay the repair and recovery process. When equipment essential to a building utility system cannot be elevated, relocated, or dry-flood-proofed, quick-connect mechanisms (often called "flanged connections" or "service flanges") can be used to disconnect components before the onset of flooding. If the disconnected equipment is small or lightweight, it can be moved to a location above the anticipated flood level and quickly reconnected after floodwater recedes. If the equipment is too large or heavy to move or is damaged, having quick-connect mechanisms allows for the connection of temporary equipment such as boilers, chillers, and generators until damaged equipment is repaired or replacement equipment is delivered. Although installing quick-connect mechanisms may not eliminate flood damage and service losses associated with flooded building utility systems, this measure can reduce damage and speed up the restoration of utility services and building function.



1. All electrical components, wiring, and mechanical equipment is above flood level
2. Flood protection level
3. Sealed well

GUIDANCE	DIFFICULTY	COST
Install backflow valves on the sanitary sewer lateral or the internal plumbing branch serving below-grade fixtures. [1,2]	Easy	$
Install quick-connect mechanisms on equipment essential to a building utility system, allowing for fast replacement of components, where allowed by code. [1]	Moderate	$–$$
Locate HVAC equipment and electrical panel box above the 0.2-percent-annual-chance (or 500-year) flood elevation or higher. [1,2]	Easy	$
Electrical systems, equipment, and components; heating, ventilating, air-conditioning; plumbing appliances and plumbing fixtures; duct systems; and other service equipment shall be— *Good:* Located above BFE. *Better:* Protected to the 0.2-percent-annual-chance (or 500-year) flood elevation or higher if required by the authority having jurisdiction. *Best:* Located above the 0.2-percent-annual-chance (or 500-year) flood elevation or higher. [1,2]	Easy	$–$$
Install backflow valves on the sanitary sewer lateral or the internal plumbing branch serving below-grade fixtures. [1,2]	Easy	$
Install quick-connect mechanisms on equipment essential to a building utility system, allowing for fast replacement of components, where allowed by code. [1]	Moderate	$–$$

RESOURCES

1. *Protecting Building Utility Systems From Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems, 2nd ed.* FEMA P-348. 2017.

2. *Protecting Your Home and Property From Flood Damage: Mitigation Ideas for Reducing Flood Loss.* FEMA P-805 2010.

DESIGNING FOR NATURAL HAZARDS
A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

Rising floodwaters damaging a home.

Damage Frequency

HIGH

Construction Practice

Raise structure above predicted flood levels. Resilience is achieved by raising structure above the minimum required.

Mitigation Strategy

Reduce the risk of floodwater damaging home by raising level of home.

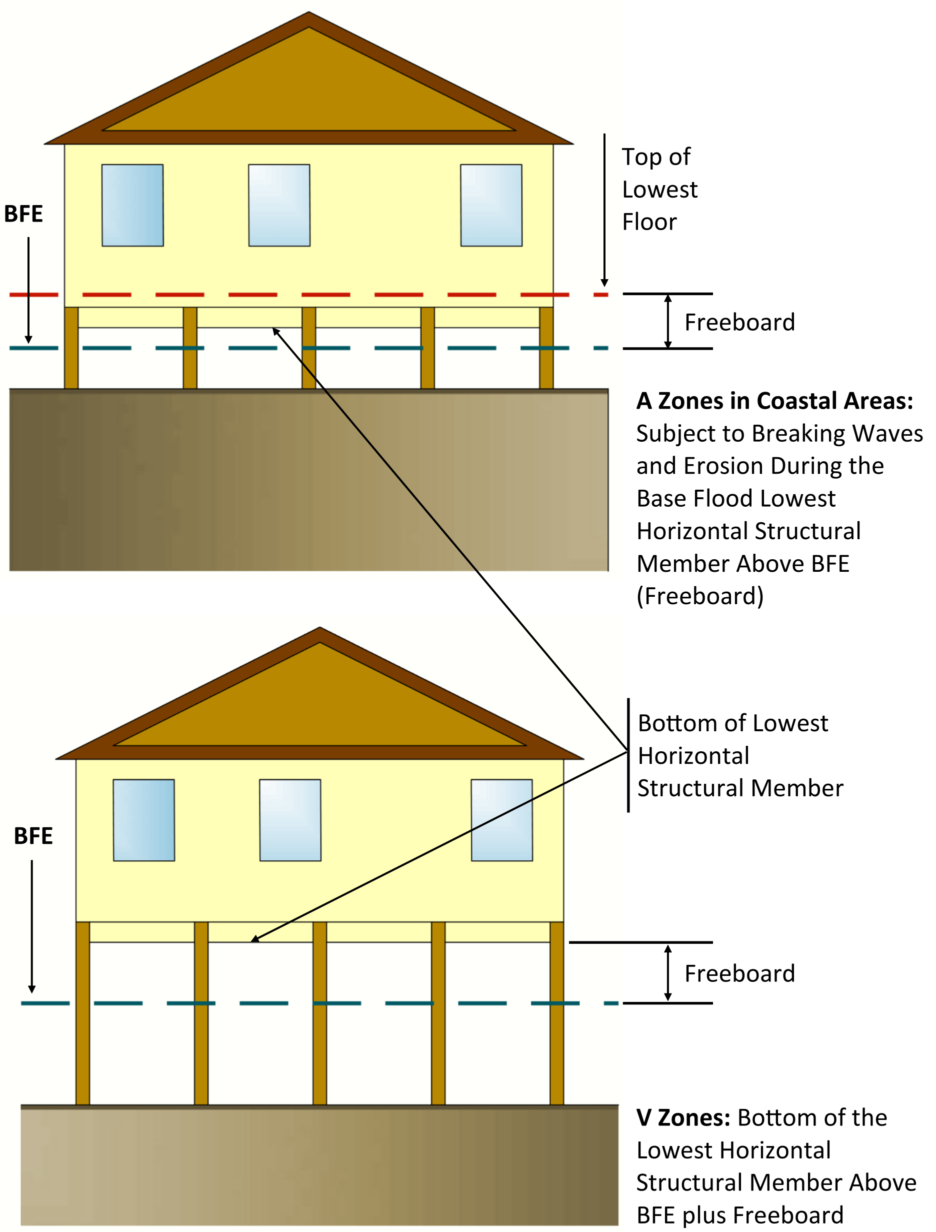
Cost & Benefit

Cost range to implement: $$–$$$$

Benefit: Decreases chances that rising floodwater damages home and potentially avoids major damage.

FREEBOARD ELEVATION

Elevated structures can significantly reduce the damage caused by floodwater. Designing structures above predicted flood heights also reduces hydrodynamic and hydrostatic loads and can reduce debris impact forces. An additional benefit is that elevated structures tend to have lower NFIP flood insurance rates. Special attention must be paid to the flood zone in which the structure is located, as potential solutions can vary. Always follow local codes, regulations, and procedures, and obtain an elevation certificate from a professional.



GUIDANCE	DIFFICULTY	COST
Coastal A Zone: Elevate lowest floors to the base flood elevation plus 1 ft. OR Coastal V Zone: Use BFE as a baseline (the bottom of the lowest horizontal structural member [LHSM] should be above BFE). [1]	Easy	$$–$$$
BFE + 2–3 ft. or 500-year, whichever is greater. [1]	Moderate	$$–$$$
BFE + 4 ft. [1]	Moderate	$$$–$$$$

RESOURCES

1. *Quick Reference Guide: Comparison of Select NFIP and Building Code Requirements for Special Flood Hazard Areas.* FEMA. 2012.

Meltwater can be trapped behind ice dam and seep under shingles.

LEAK PREVENTION & ICE DAM

Flashing and drip edges protect the most vulnerable areas of the roof, such as joints, changes in slope, penetrations, the perimeter, and valleys. These weak points are the most likely places for a leak due to the potentially high volume of watershed by the roof. Ice dams can interfere with the roof's ability to shed water, which could cause water to seep underneath the shingles, eventually penetrating the roof deck and draining down into the cavity below. Water infiltration can saturate attic insulation, drywall, and wall cavities, causing both structural damage and the potential for mold growth. Depending on the volume of water, it can also lead to significant damage to any non-waterproof surface inside the home (carpets, furniture, electronics, etc.).

Damage Frequency

MODERATE

Construction Practice

Secondary water barrier, flashing, drip edge, and ice dam protection using an ice and water shield.

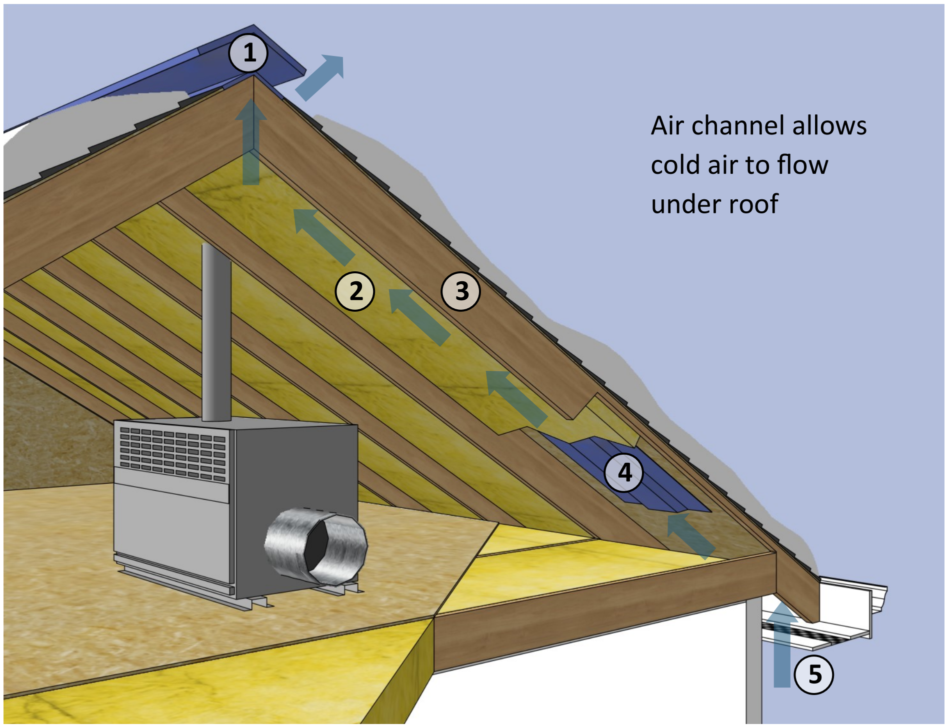
Mitigation Strategy

Robust secondary water barrier, sufficient attic insulation, and attic vent.

Cost & Benefit

Cost range to implement: $–$$$

Benefit: Additional layers of protection from water infiltration at key locations drastically decrease the chance of potential water damage and avoid the potential for major damage.



1. Cold air exits via ridge vent
2. Batt insulation
3. Rafter
4. Air channel
5. Cold air enters roof space via soffit vent

GUIDANCE	DIFFICULTY	COST
Drip Edge and Flashing		
Drip Edge: Install drip edge on top of the underlayment (except where over is required and enforced by code). [1]	Easy	$
Flashing: Install flashing at wall and roof intersections, at every change in roof slope or direction, and around roof openings. [2,3]	Easy	$
Ice Dam		
Insulation 1: For fiberglass batts, mineral wool batts, and blown cellulose installed in ceiling framing cavities, do not taper the ceiling joists at the top plate condition; install an additional plate above to meet the roof rafters' birdsmouth. Do not allow insulation to obstruct the ventilation channel or the soffit vents. [4,5]	Easy	$
Insulation 2: Use raised-heel roof trusses, or Increase the depth of ceiling joists to allow for the installation of additional cavity insulation. [4]	Moderate	$$
Insulation 3: Install closed-cell spray foam insulation to full depth of ceiling cavities. [4]	Complex	$$$
Insulation 4: Install a cold roof assembly with continuous soffit vent at base and Boston ridge vent, or similar, at peak. [4]	Complex	$$–$$$
Mechanical and Plumbing: Locate heat sources (mechanical equipment, ducts, hot-water piping, etc.) inside the insulation envelope. [5]	Moderate	$$
Waterproofing: The ice and water barrier or shield should wrap over the edge of the sheathing to seal the end. The flashing goes over the ice and water shield, and the underlayment extends over the top of the flashing. If the roof is fully covered with the ice and water barrier or shield, install a strip of additional ice and water shield over the flashing. [6]	Easy	$–$$

RESOURCES

1. 2020 *FORTIFIED Home™ Standard*. Insurance Institute for Business & Home Safety (IBHS).
2. Section R903.2 Flashing. 2018 IRC.
3. Section R905.2.8 Flashing. 2018 IRC.
4. BSD-135: Ice Dams. *Building Science Digests*. Building Science Corporation. 2006.
5. BSI-097: De-Icing Ice Dams. *Building Science Insights*. Building Science Corporation. 2018.
6. ASTM D1970/D1970M-21 *Standard Specification for Self-Adhered Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection*.

DESIGNING FOR NATURAL HAZARDS
A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

Damage from Hurricane Katrina in the Gulf Coast.
Source: FEMA P-549

PILING & PIER FOUNDATION

Overreliance on nails and thin metal strapping and poor alignment of pilings have resulted in unsupported beam conditions. Bracing designs should not require substantial notching of pilings to provide a bearing seat for the brace, and they can easily become too deep and compromise structural performance. Considerations should be made on using timber materials with higher grades. Although closed foundations can be constructed, open foundations are recommended.

Damage Frequency

MODERATE

Construction Practice

Properly embed piers and pilings to minimize risk of foundation being compromised.

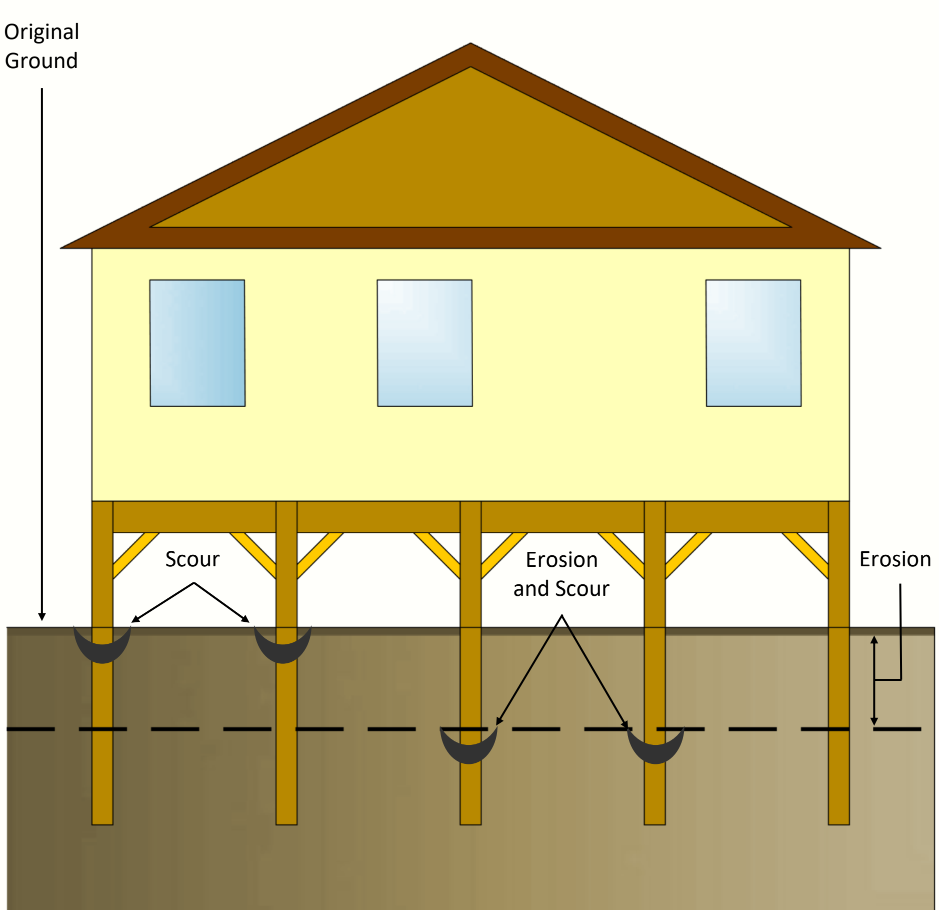
Mitigation Strategy

Proper planning for design and construction of piling and piers to mitigate storm and flooding damage.

Cost & Benefit

Cost range to implement: $–$$$

Benefit: Results in a strong foundation that is resistant to flooding and storms and avoids the potential for major damage.



Distinguishing between coastal erosion and scour. A building may be subject to either or both, depending on the building location, soil characteristics, and flood conditions.

GUIDANCE	DIFFICULTY	COST
Embedment should account for anticipated erosion, scour, and flood loads. [1,2]	Easy	$–$$$
Never notch pilings more than 50% of the piling's cross-section. [3]	Easy	$–$$$

RESOURCES

1. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th ed. Volume I.* FEMA P-55. 2011.
2. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th ed. Volume II.* FEMA P-55. 2011.
3. Section 13.1.1 Layout. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th ed. Volume II.* FEMA P-55. 2011.

Breakaway wall with no damage to structure.
Source: FEMA P-2023

Damage Frequency

LOW

Construction Practice

Design walls to break away due to pressure from floodwaters and waves.

Mitigation Strategy

Walls designed to break away when loaded with rising water. The water passes through the structure, rather than dislodging it.

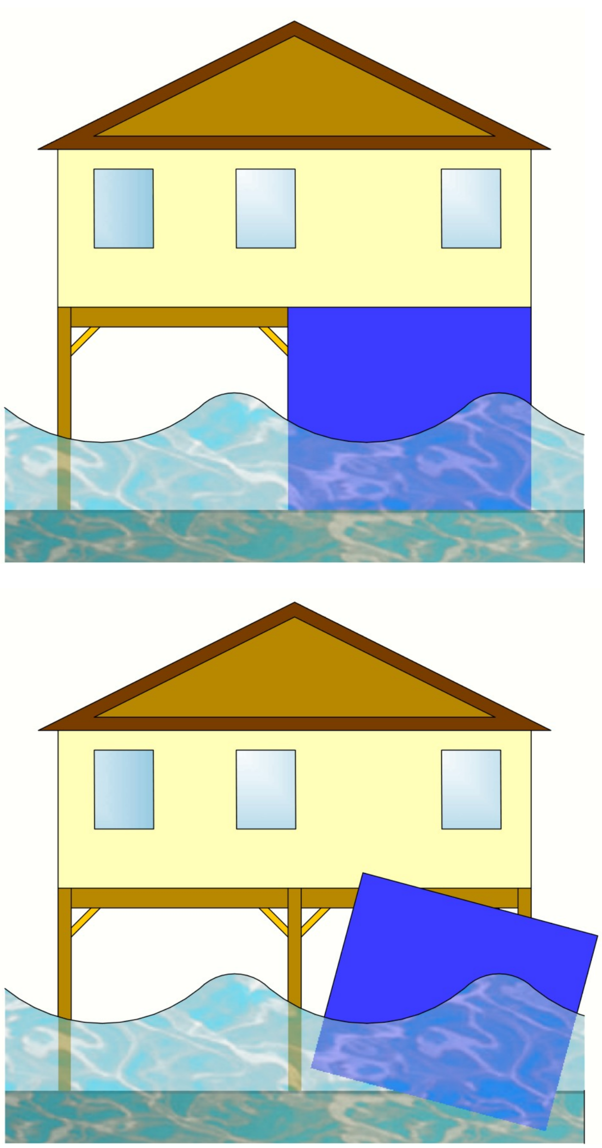
Cost & Benefit

Cost range to implement: $–$$

Benefit: Reduces damage to main structural supports for structure and avoids the potential for medium damage.

BREAKAWAY CONSTRUCTION

Breakaway walls are not required in all flood zones but are a good technique for enclosing spaces. Special care must be used to ensure that walls can properly break away, as the incorrect use of anchor bolts or incorrect sheathing installation can tie the breakaway walls back to the structure of the building, effectively rendering them useless and potentially causing additional damage. Utilities should not be attached to or pass through breakaway walls. Breakaway walls should be designed to break into smaller sections so that they are less likely to damage the foundation or the upper portions of buildings and to reduce the size of flood-borne debris.



GUIDANCE	DIFFICULTY	COST
All walls below the elevated lowest floor designed to be breakaway. [1]	Easy	$
No walls or partitions below the elevated lowest floor. [1]	Moderate	$$

RESOURCES

1. *Home Builder's Guide to Coastal Construction.* FEMA P-499. 2010.
2. *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings.* NFIP Technical Bulletin 9. FEMA. 2021.

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

Corroded metal connectors and fasteners.
Source: NFIP Technical Bulletin 8

Damage Frequency

LOW

Construction Practice

Minimize corroded and rusted structural connectors by using galvanized or stainless steel materials.

Mitigation Strategy

Minimize or retard widespread corrosion or failure of straps, hangers, and joist-beam ties.

Cost & Benefit

Cost range to implement: $–$$

Benefit: Structural components are not prematurely weakened due to rust and oxidation, and using these materials avoids the potential for medium to major damage.

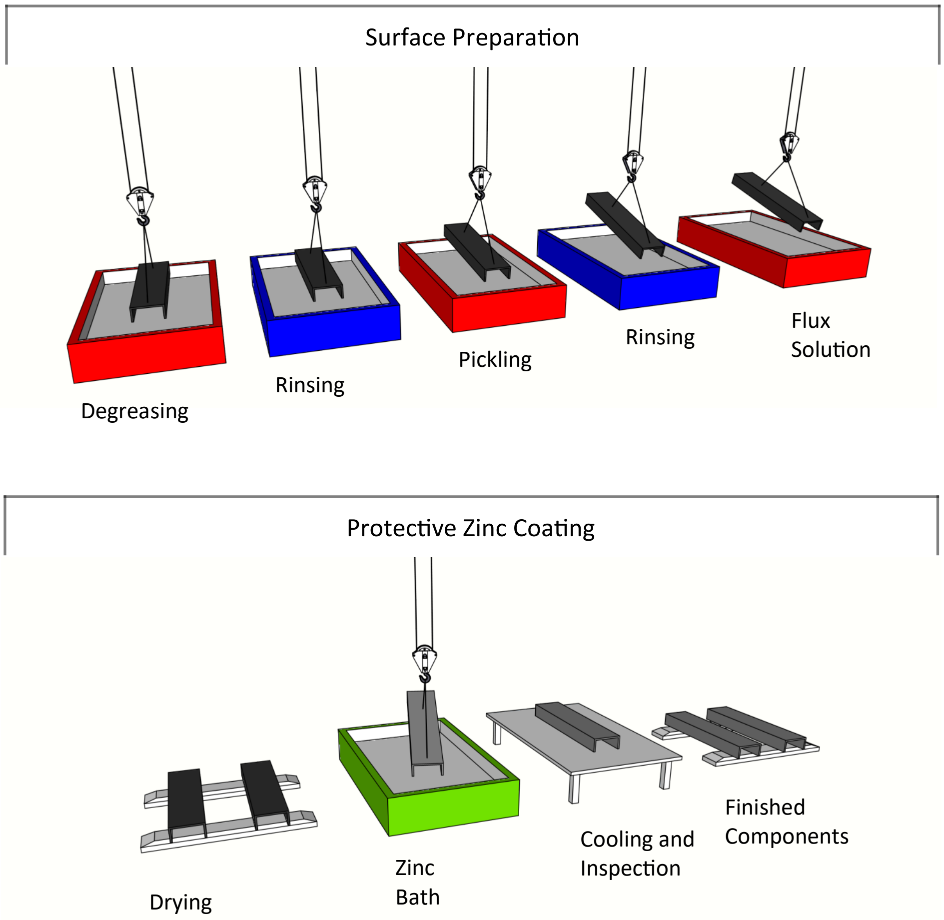
CONNECTORS & FASTENERS

Metal connectors and fasteners deteriorate over time, especially when buildings are within 3,000 ft. of the ocean. Local floodplain management regulations require the use of flood damage-resistant materials for floodplain construction, which includes connectors and fasteners.

Oxidation can extend into the base metal, resulting in the loss of effective anodic protection and rapid deterioration of the light-gauge metal connector.

Use corrosion-resistant connectors specifically designed to resist wind and water forces that could create irregular loading, causing building assemblies to fail prematurely over time and during a storm event. Recognizing that these connectors have different levels of coatings is key to ensuring the proper lifespan for a structure (stainless steel, galvanized, etc.).

GALVANIZED FASTENER PROCESS



GUIDANCE	DIFFICULTY	COST
Use a zinc-galvanized coating, 22-gauge minimum (G90), for connectors. Nails, bolts, washers, and other fasteners should meet ASTM A153 standards for coating thickness. [1,2]	Easy	$
Use 16-gauge hot dipped galvanized connectors (G185) meeting ASTM F2329 standards or stainless steel connectors meeting ASTM A240 or A580 standards for connectors within 3,000 ft. of coastal areas. [1,3,4,5]	Easy	$$
Ensure that all connections can be inspected and are accessible for corrosion inspection and replacement. [6]	Moderate	$$

RESOURCES

1. ASTM A653/A653M-20 *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*.
2. ASTM A153/A153M-16a *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*.
3. ASTM F2329/F2329M-15 *Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners*.
4. ASTM A240/A240M-20a *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*.
5. ASTM A580/A580M-18 *Standard Specification for Stainless Steel Wire*.
6. *Corrosion Protection for Metal Connectors and Fasteners in Coastal Areas.* NFIP Technical Bulletin 8. FEMA. 2019.

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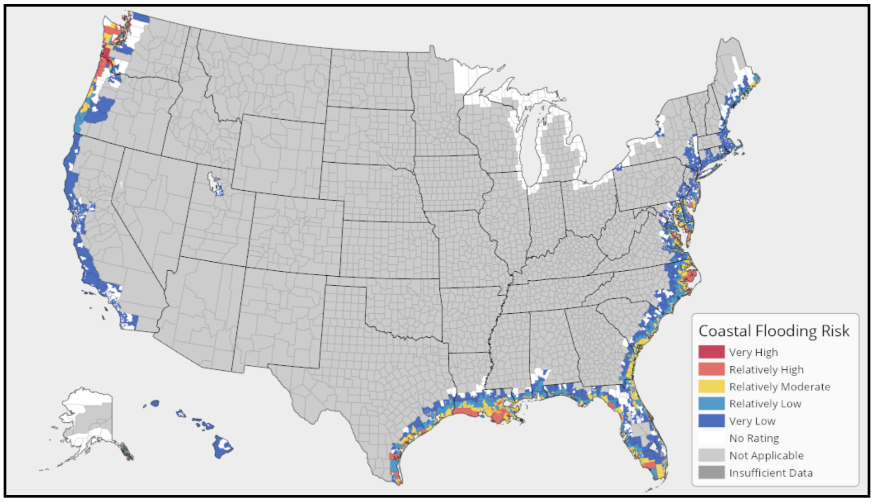
FEMA's Interactive Coastal Flood Risk Map illustrates the risk by county: https://hazards.fema.gov/nri/coastal-flooding.



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How to Stay Safe When a Flood Threatens. FEMA V-1005. March 2018. https://www.ready.gov/sites/default/files/2020-03/flood_information-sheet.pdf.

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MAY 2023