Designing for Flood Levels Above the Minimum Required Elevation After Hurricane Ian

Recovery Advisory 1

July 2023 (Revised May 2025)

FEMA

DR-4673-FL RA 1

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1. Purpose and Intended Audience

This Recovery Advisory outlines observations from Hurricane Ian in Florida, DR-4673-FL, that provide insights regarding building improvement opportunities. These recommendations are applicable to buildings experiencing similar issues and need not be limited to the state or disaster in which they were observed.

Flooding in Florida from Hurricane Ian in 2022 extended far beyond mapped Special Flood Hazard Areas (SFHAs) and often exceeded base flood elevations (BFEs) depicted on the Flood Insurance Rate Maps (FIRMs), by several feet in some areas. Lessons learned from Hurricane Ian can help guide repair and reconstruction efforts in designing new or retrofitting existing buildings to improve resiliency to future flood damage. This Recovery Advisory discusses how Flood Insurance Studies (FISs), Flood Insurance Rate Maps (FIRMs), and base flood elevations (BFEs) are established and provides guidance on elevating buildings to minimize flood damage in cases where flood levels exceed the minimum required elevation (Figure 1). The State of Florida has adopted a regulatory flood elevation for construction, as such, this Recovery Advisory uses design flood elevation (DFE) to reference the minimum elevation requirement.

The intended audience for this Recovery Advisory is designers, local and emergency management planners, home and building owners, and operators. It may also be helpful to any stakeholders involved in selecting lowest floor elevations for new construction in areas either affected by Hurricane Ian or with similar hazards. To properly address the hazard as well as the necessary measures required to select a building elevation, portions of this Recovery Advisory include in-depth technical information. Readers are encouraged to review the entire document to gain an understanding of the general principles; consultation with a design professional may be needed for implementation. Note that this Recovery Advisory provides recommendations that are primarily applicable to buildings subject to damage from storm surge, waves, and/or erosion. Although buildings subject to riverine flood hazards should also consider designing above the DFE, the process by which those additional risks are quantified is beyond the scope of this Recovery Advisory.

1.1. This Recovery Advisory Addresses

- Building Damage When Flood Levels Exceed the Lowest Floor
- Required Design Considerations
- How High Above the Minimum Required Elevation a Building Should be Elevated
- Additional Design Considerations for Mitigating Flood Damage

Figure 1: Three neighboring buildings with varying degrees of elevation and damage on Fort Myers Beach, Florida, after Hurricane Ian. The right-most building has the lowest elevation of the three and the most damage to the lower levels, whereas the middle building has the highest elevation and minimal damage to the lower levels.

Terminology

Flood Insurance Rate Map (FIRM): Official map of a community on which FEMA has delineated the Special Flood Hazard Areas (SFHAs), the base flood elevations (BFEs) and the risk premium zones applicable to the community.

Flood Insurance Study (FIS): A compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. When a flood study is completed for the National Flood Insurance Program (NFIP), the information and maps are assembled into an FIS. The FIS report contains detailed flood elevation data in flood profiles and data tables.

Special Flood Hazard Area (SFHA): An area having special flood, mudflow, or flood-related erosion hazards and shown on a Flood Hazard Boundary Map (FHBM) or a Flood Insurance Rate Map (FIRM) as Zone A, AO, A1–A30, AE, A99, AH, AR, AR/A, AR/AE, AR/AH, AR/AO, AR/A1–A30, V1–V30, VE or V.

Base Flood Elevation (BFE): The elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year. The BFE is shown on the FIRM for zones AE, AH, A1–A30, AR, AR/A, AR/AE, AR/A1–A30, AR/AH, AR/AO, V1–V30 and VE.

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

"How High Above the DFE a Building Should be Elevated" for additional information on the DFE and freeboard. Some communities adopt flood maps with elevations that exceed the BFEs and become their adopted DFEs.

Stillwater Elevation: The surface of the floodwater referenced to a vertical datum, including tides and storm surge, excluding all wave effects.

Stillwater Depth: The difference between the stillwater elevation and the ground elevation.

2. Building Damage When Flood Levels Exceed the Lowest Floor

When flood levels exceed the lowest floor elevation of a building, there can be a sudden onset of damage. The type of building damage varies based on the type of flooding experienced. When flooding occurs as inundation flooding (low velocity and without waves) in Zone A areas, the structure may be submerged and contents will get wet, but it often occurs without causing extensive structural damage. However, if the water from inundation flooding does not equalize on the inside and outside of the structure, the hydrostatic loads have the potential to cause structural damage if the building was not designed to withstand the hydrostatic loading.[1] In contrast, severe flood damage is likely in areas where waves and high velocities accompany flooding as moving water and breaking waves impart large structural loads on the building. In Zone V and Coastal A Zone areas, waves are capable of causing significant damage to some buildings (Figure 2) as a result of the energy of coastal waves striking and undermining buildings. As water depths increase, higher waves may be present resulting in higher breaking wave loads. The action of wave crests striking the elevated portion of a structure is known as "wave slam." Wave slam introduces lateral and vertical loads on the lower portions of the elevated structure. For example, for a residential structure and a 5-foot stillwater depth, when the wave crest extends above the bottom of the floor joist by 1 foot, 312 pounds per foot (lb/ft) is exerted by lateral wave slam. In comparison, wave crests extending above the bottom of the floor joist by 2 feet and 3 feet exert 624 lb/ft and 936 lb/ft, respectively, due to wave slam.[2]

[1] Wet floodproofing techniques may be utilized as a retrofit measure to enable the hydrostatic loads to equalize on the inside and outside of a building. See NFIP Technical Bulletin 7, *Wet Floodproofing Requirements and Limitations* (FEMA 2022), for information on techniques and compliance requirements.

[2] Wave slam loads are based on equation 8.7 in FEMA P-55, *Coastal Construction Manual, Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas* (2011).

Figure 2: Image (top) shows waterfront houses damaged by coastal flood effects such as waves and velocity in Bonita Springs, Florida. Image (bottom left) shows siding damage above the lowest floor and significant scour, image (bottom center) shows complete loss of a deck as well as damage to glass doors, image (bottom right) shows structural damage to a concrete column and complete loss of a porch.

FIRMs depict the regulatory limits of flooding, flood elevations, and flood hazard zones for the 1% annual-chance (100-year) flood event. Buildings constructed to the elevations shown on a FIRM only safeguard to the base flood, as designated by the BFE. Some storms impacting coasts, rivers, or both result in flood levels that exceed the BFE. The dark blue line in Figure 3 shows the probability (y-axis) of a flood event that will result in floodwaters above the 100-year flood level during a given time period (x-axis). As shown on the figure, there is an 18% chance the 100-year flood level will be exceeded in a 20-year period, a 26% chance it will be exceeded in a 30-year period, and a 51% chance it will be exceeded in a 70-year period. Elevating above the BFE can significantly improve the building's and its associated utility system's resilience. Likewise, buildings sited just outside of the SFHA (beyond the 100-year flood hazard area), but especially those within the 500-year flood hazard area, can still have a significant chance of being flooded. For those within the 500-year flood hazard area (i.e., shaded Zone X) the probability of flooding occurrence for that structure is somewhere between the red (500-year) and blue (100-year) lines in Figure 3. Note that the figure does not represent a water surface elevation but rather the probability of exceedance of a given mean recurrence interval (MRI). While the probability of exceedance of the MRI does not change with sea level rise, erosion, and land use change, the water surface elevation associated with the MRI may change.

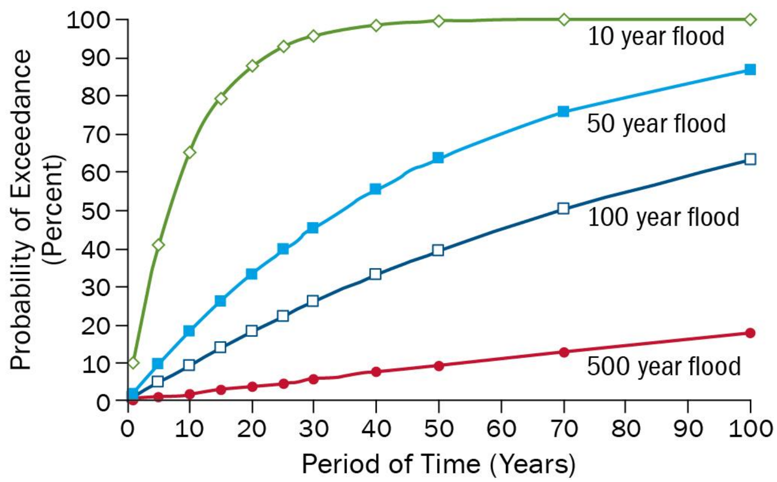


Figure 3: Probability under current conditions of a flood exceeding the 10-year (10% annual-chance), 50-year (2% annual-chance), 100-year (1% annual-chance), and 500-year (0.2% annual-chance) flood level during a given period of time (assuming no sea level rise)

3. Required Design Considerations

To meet the NFIP minimum requirements, new buildings, buildings with substantial damage[3,4] undergoing reconstruction, and buildings undergoing substantial improvement[5] must be elevated so that their lowest floor,[6] or the lowest horizontal structural member of the lowest floor (where required), 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 minimum building elevation is often referred to as the Design Flood Elevation (DFE). The amount of freeboard to be added depends on a number of factors. Building owners and designers should consult with building officials and floodplain managers regarding minimum elevation requirements.

3 Substantial damage is defined in 44 CFR § 59.1 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% of the market value of the structure before the damage occurred."

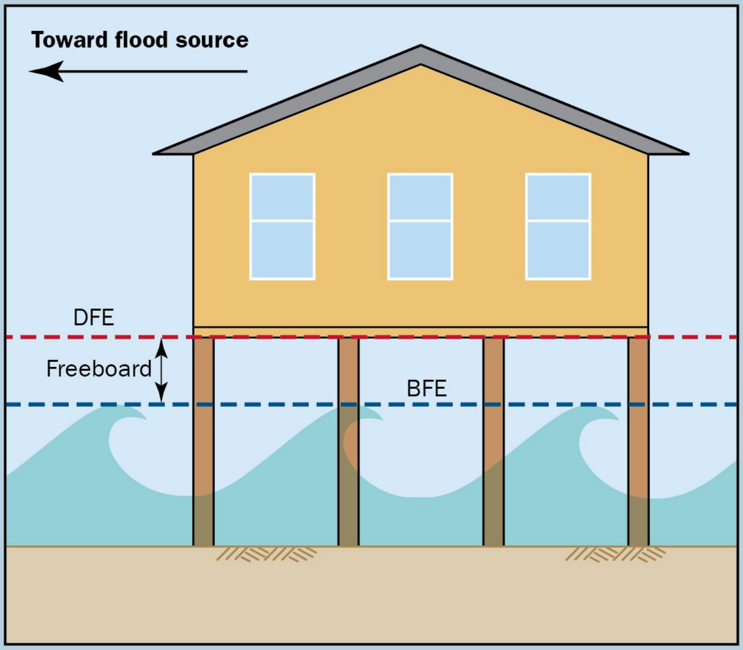
4 Refer to FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010b) for more information.

5 Substantial improvement is defined in 44 § CFR 59.1 as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50% 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."

6 In Zone A, lowest floor means the top of the lowest floor; in Zone V (and Coastal A Zone per ASCE 24/ICC/FBC), lowest floor means the bottom of the lowest horizontal structural member of the lowest floor.

Terminology

Freeboard: A factor of safety usually expressed in feet above a flood level for the purposes of floodplain management. “Freeboard” tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed. (44 CFR § 59.1)



The freeboard graphic depicts the freeboard condition for Zone V (and Coastal A Zone per ASCE 24/ICC/FBC) where the elevation requirement is to the bottom of the lowest horizontal structural member of the lowest floor. In Zone A, the elevation requirement is to the top of the lowest floor.

3.1. NFIP Requirements and Mapping Guidance

FEMA issues FIRMs, which are then adopted by communities that regulate floodplain development. SFHAs (e.g., Zone VE, Zone AE) delineated on FIRMs reflect the nature of the flood conditions expected during the base flood. FIRMs also typically show a shaded Zone X, which denotes areas that are outside the SFHA but are subject to flooding with a 0.2% annual chance of occurrence (500-year flood). FIRMs show BFEs associated with a flood that has a 1% annual chance of occurrence (Figure 4). BFEs in coastal areas include wave effects and are higher than storm surge stillwater levels. Shaded Zone X elevations typically do not include wave effects.

FEMA FIRMs and FISs are used in the regulation of the minimum NFIP requirements. The NFIP is a program that makes flood insurance available in those states and communities that agree to adopt and enforce floodplain management ordinances to reduce future flood risk. Participation in the NFIP is voluntary and is contingent on community compliance with NFIP floodplain management regulations. The NFIP minimum requirements apply to areas designated as Special Flood Hazard

Areas (SFHAs) by FEMA. Constructing a building to the minimum NFIP requirements—or constructing a building outside of the SFHA—does not guarantee the building will not be damaged by flooding. In order to make informed decisions during repair and reconstruction, designers, local and emergency planners, building owners and operators, and other interested stakeholders should understand the following:

- FIRMs are based on modeling of the best available topographic, hydrologic, hydraulic, development, and climate conditions data available at the time the FIS was prepared. 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 streamline or shoreline location, bathymetry, land characteristics, and actual risk during a base flood event.
- The BFE is the flood level with a 1% annual chance of exceedance in any given year. In coastal areas, the BFE includes the contribution of waves and is not representative of any individual storm but is derived from an analysis of many potential and historical storm responses.
- The Limit of Moderate Wave Action (LiMWA) indicates where wave heights are 1.5 feet. The 1.5-foot wave is designated on the FIRMs because waves up to this height are known to cause Zone V type damage to foundations and other light-framed structural elements. To reduce damage, FEMA encourages building to Zone V standards, such as constructing on deep open foundations, in the area between the Zone V boundary and the LiMWA, also known as the Coastal A Zone.
- Flood elevations can and do exceed the BFE and extend beyond the mapped boundaries of the SFHA. In some recent storms (Sandy [2012], Michael [2018], and Ian [2022]), flood levels exceeded the BFEs by several feet in numerous areas and flood inundation extended far beyond the SFHA shown on the FIRMs.

More information on coastal FIRMs, FISs, and BFEs is available in the following FEMA publications: Section 3.6 of FEMA P-55, *Coastal Construction Manual* (2011), and Fact Sheet No. 3 in FEMA P-499, *Home Builder's Guide to Coastal Construction* (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.

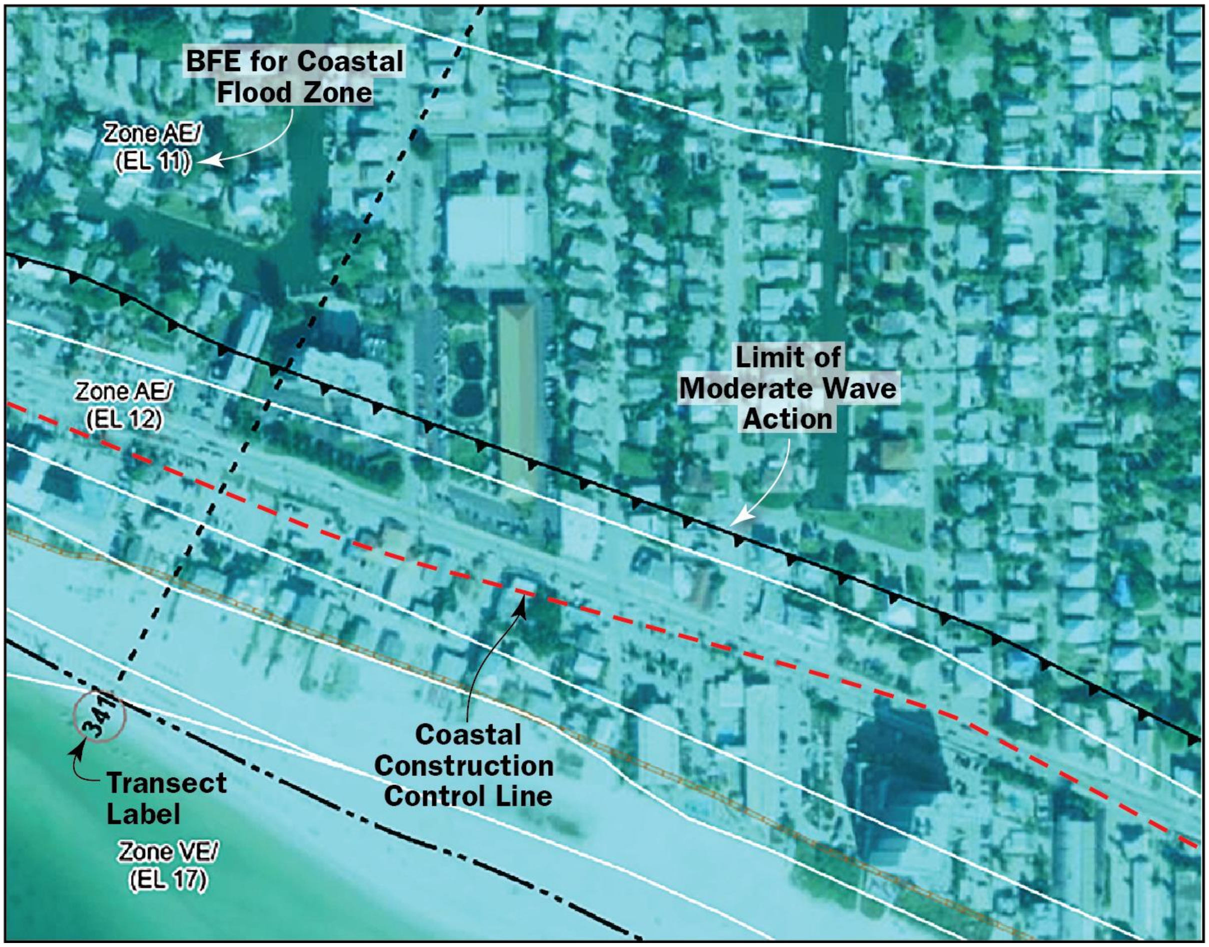


Figure 4: Sample FIRM showing Zone AE, the Limit of Moderate Wave Action (LiMWA), and Zone VE. BFEs for each zone are noted in parentheses below the Zone AE/VE text. The BFEs are site specific and vary by location. The Coastal Construction Control Line (CCCL) is overlayed onto the FIRM and shown for reference purposes only. The CCCL is discussed later in this Recovery Advisory.

The two Florida Gulf Coast counties primarily impacted by Hurricane Ian storm surge (Lee and Collier), were both in a map adoption process when the storm hit in September 2022. Lee County now has updated maps that went into effect in November 2022. Collier County has preliminary FIRMs that provide an understanding of current risks but are not the final regulatory products. These map updates include delineating the Limit of Moderate Wave Action (LiMWA), which is depicted as a solid black line with arrows pointing in the direction of the area with additional wave-associated risk (Figure 4). Residents and business owners living or working in the Coastal A Zone should be aware of the potential wave action risks along with floating debris, erosion, and scour that could cause significant damage to their property. Additional guidance on the importance of designing for the Coastal A Zone is available in Fact Sheet No. 1.3 in FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010a).

3.2. Building Codes and Floodplain Management Regulations

The International Codes (I-Codes) generally serve as the basis for most state building codes.[7] Building codes may contain freeboard requirements or reference other documents with freeboard requirements. The International Building Code (IBC) requires buildings to be designed and constructed in accordance with the American Society of Civil Engineers' (ASCE) standard for *Flood Resistant Design and Construction* (ASCE 24) and the International Residential Code (IRC) implements many of the same requirements presented in ASCE 24. ASCE 24 defines elevation and protection height requirements based on the flood hazard zone and the importance of the building. The building's use and importance places it in a Flood Design Class per the ASCE 24-14 standard. ASCE 24 also contains requirements above the NFIP for items such as flood openings in Zone V breakaway walls and measuring the elevation in Coastal A Zones to the lowest horizontal structural member supporting the lowest floor. ASCE 24-14 requirements are summarized in the FEMA publication, *HIGHLIGHTS OF ASCE 24-14 Flood Resistant Design and Construction* (2015); the Flood Design Class requirements and categorizations are provided on pages 4 and 5. Buildings must be elevated as high as the freeboard requirement in the building code or reference standard or floodplain management regulations. For example, Florida adopted 1 foot of freeboard in its residential building code and several communities in Florida have adopted additional freeboard (above the 1-foot requirement) in their floodplain management regulations. Owners may choose to build even higher.

In Florida, there is a Coastal Construction Control Line (CCCL) program, see Figure 4. The CCCL establishes a jurisdiction for application of special siting and design criteria; it is not designed to limit development. The CCCL is meant to address activities that could cause beach erosion, destabilize dunes, damage upland properties, or interfere with public access. Development activities along Florida's sandy shorelines need to consider the CCCL and include any local standards that may be more stringent than the rest of the coastal building zone. The CCCL program is governed by Chapter 161.053 in the Florida Statues. In most instances, a permit from Florida's Department of Environmental Protection is required for construction and excavation activities seaward of the CCCL.

3.3. 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 their communities to see if height restrictions exist and work with the communities to relax those restrictions to achieve improved flood damage resilience.

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[7] This was the case for the Florida Building Code (FBC) until the 7th edition (2020) FBC, which used the 6th Edition (2017) FBC as the base code and took into account the 2018 I-Codes. Further details on the development of the 7th edition (2020) FBC can accessed here under the Analysis of Changes to the 7th Edition (2020) Florida Building Code: floridabuilding.org/fbc/Links_to_Code_Resources.html

3.4. Importance of the Building to the Community

Certain buildings and facilities (e.g., police stations, fire stations, emergency operations centers, storm shelters, 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, manufacturing facilities, and utilities) are either critical or essential to the community and should be capable of carrying out operations immediately after a severe storm or are a facility that poses a high risk to the public if damaged by flooding. To maintain needed functionality or to reduce risk to the public, essential or high-risk 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 and other higher requirements.

3.5. Federal Grant Requirements

Projects utilizing federal funding for elevating or reconstructing buildings may have additional elevation requirements. Specific federal grant requirements can be found in the grant's Notice of Funding Opportunity (NOFO) or Notice of Funding Availability (NOFA), depending on the funding opportunity.

4. How High Above the Minimum Required Elevation a Building Should be Elevated

Before selecting an elevation, building owners and designers should decide whether the minimum required elevation mandated by a state or community is sufficient to protect a particular building or additional elevation is needed. FEMA recommends building owners and operators, designers, local and emergency management planners, and other interested stakeholders review available FIRMs and FISs, evaluate possible future conditions, and consider the building owner and operator's risk tolerance when determining appropriate building elevations.

4.1. Recommended Considerations

The selection of an appropriate elevation must include consideration of locally adopted requirements, as well as other factors such as the importance of the building's function to the community during and after a hazard event. This section discusses factors to consider in selecting a building elevation.

4.1.1. AGE OF THE EFFECTIVE FLOOD ANALYSIS

FISs and FIRMs are based on data collected for model creation at the time the FIS is prepared. BFEs and flood hazard zones shown on FIRMs are established during a study process that takes several years from project inception to completion. The topographic data and flood hazards often represent different years of that study timeline and may understate actual flood risk because of changes in the topography and development. In such cases, FEMA recommends elevating buildings above the BFE and extending flood-resistant construction practices outside the mapped SFHA. The associated FIS documentation for any referenced FIRM provides the date of the technical studies establishing the BFEs and flood hazard zones.

4.1.2. AVAILABILITY OF PRELIMINARY FIRMS

When FISs are completed, the FIRMs are first issued as “Preliminary” maps to enable the public to review and submit comments and appeals, if applicable. 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 available and higher than effective BFEs, owners, operators, planners, designers, and communities should consider utilizing the preliminary BFEs for the design basis.

4.1.3. BUILDING OWNER AND OPERATOR TOLERANCE FOR DAMAGE, DISPLACEMENT, AND DOWNTIME

Many building owners or operators never want to go through the disruption and damage sustained during Hurricane Ian or a similar event again. To avoid such disruption, building operators need to be involved in building design decisions relating to flood risk reduction and should understand their risk tolerance in order to determine whether they can work with the building owner or need to make alternative decisions regarding their operations. Reducing the probability of similar disruption requires using higher design elevations that incorporate future conditions when repairing and rebuilding buildings and equipment or when constructing flood barriers (where permitted). Increased design elevations and other flood-resistant design and construction practices should be incorporated to the maximum extent feasible.

4.1.4. ESSENTIAL FACILITIES

FEMA recommends that all essential facilities[8] be elevated or protected to a minimum of the higher of the code-mandated elevation, the community-mandated elevation, or the 500-year flood elevation. Communities should also consider using an elevation exceeding the flood of record[9] as an additional criterion for the elevation/protection level for essential facilities.

4.1.5. FUTURE CONDITIONS

Building owners, designers, and communities should consider how future conditions (such as sea level rise, subsidence, shoreline erosion, and increased storm frequency/intensity) may influence flood characteristics over the life of the building when deciding how high to elevate a building. See subsection on future conditions.

4.1.6. RESIDUAL RISK

The U.S. Army Corps of Engineers defines residual risk as the flood risk that remains if a proposed flood damage reduction project is implemented as well as the consequence of capacity exceedance (USACE n.d.a). Understanding residual risk is critical for making risk tolerance decisions as well as

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[8] In addition to those facilities specifically defined by ASCE 24 as essential, communities may designate buildings such as schools and utilities as essential facilities.

[9] Refers to the highest recorded flood elevation for a given location.

for selecting an appropriate freeboard amount. Residual risk is discussed in NFIP Technical Bulletin 10, *Reasonably Safe from Flooding Requirement for Building on Filled Land* (FEMA 2023) and *Flood Risk Assessment and Reduction Community Guidebook* (Charlotte-Mecklenburg Storm Water Services 2021).

4.2. Future Conditions

Because FIRMs reflect conditions at the time of the FIS, owners, operators, planners, designers, and communities should consider how future conditions (such as sea level rise, subsidence, shoreline erosion, increased storm frequency/intensity, land use change, and levee settlement and failure) may influence flood characteristics over the life of a building when deciding how high to elevate the building or how high to specify flood protection elevations. Most buildings have a functional life span of many decades, so considering future conditions is important when designing new buildings or when performing significant renovations or retrofits of existing ones. This section focuses on how to account for future conditions of coastal flood hazards and presents methods to account for sea level rise and coastal erosion as well as the associated wave height increases.

4.2.1. RELATIVE SEA LEVEL RISE

Rising sea levels have been well documented at National Oceanic and Atmospheric Administration (NOAA) tide gages in Florida and throughout the coastal United States. Sea level rise rates vary by location. For example, the tide gage in Naples, Florida, which is the nearest Gulf of Mexico tide gage for Lee and Collier Counties, has recorded an average relative sea level rise of 3.2 millimeters/year (1.0 foot/century) since 1965. Figure 5 depicts the relative sea level records for Naples, Florida, between 1965 and 2022. If this rate of sea level rise continues, 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 (NOAA 2021), sea levels could rise several feet in the next century, significantly increasing the risk of flooding to buildings inside and outside the SFHA in coastal communities.

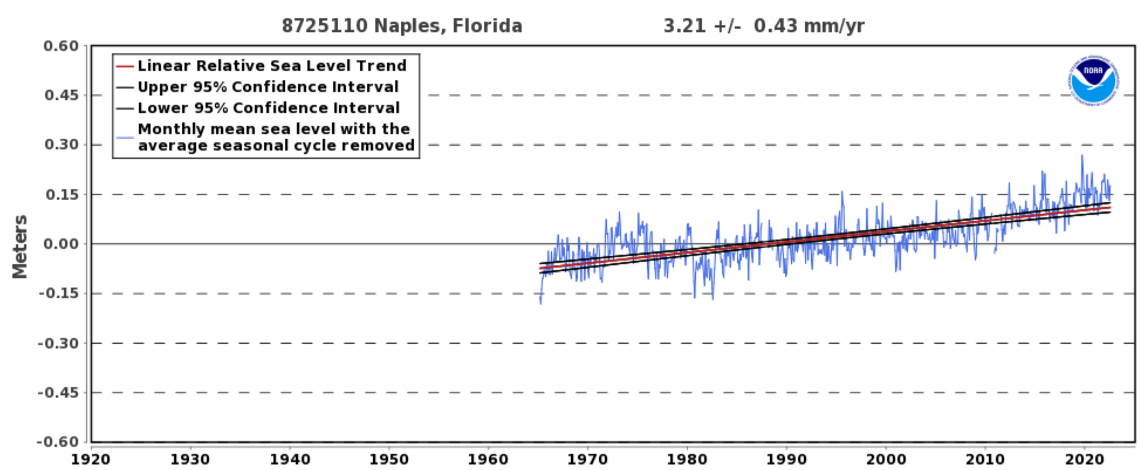

Figure 5: Relative Sea Level Trend, Naples, Florida. Credit: NOAA/National Ocean Service

At a minimum, FEMA recommends accounting for a continuation of the relative sea level rise rate equal to the historical rate. Detailed historical relative sea level data for U.S. coastal stations are available from NOAA's Center for Operational Oceanographic Products and Services Tides and Currents (tidesandcurrents.noaa.gov/sltrends/). However, owners, designers, and coastal communities should consider planning for relative sea level rise above the historical trend to further increase the resilience of buildings that may face higher future rates of sea level rise. Based on the 2022 NOAA relative sea level rise projection[10] for Naples, Florida, 2.9 feet of relative sea level rise is projected over the next 50 years (USACE. n.d.b). Whereas the historical sea level rise rate of 3.2 millimeters/year only results in a 0.5-foot relative sea level rise over 50 years (NOAA n.d.). Some states specify which future sea level rise projections should be used as a minimum. Alternatively, various public resources are available, such as the U.S. Army Corps of Engineers' (USACE's) Sea Level Tracker (climate.sec.usace.army.mil/slr_app/), to determine future relative sea level rise projections. USACE's Sea Level Tracker includes vertical land movement estimates, which account for local subsidence or uplift, so these factors do not need to be accounted for separately. Section 3.3.4 of FEMA P-55 provides additional discussion on sea level rise, subsidence, and uplift.

Resilient Florida Program – Sea Level Impact Projection (SLIP) Study Requirement

Florida requires corporate bodies of the state to perform a Sea Level Impact Projection (SLIP) Study if state funds are being utilized for a construction project within the coastal building zone.[11] These requirements are set forth in Section 161.551 of the Florida Statutes and details are provided in the Florida Administrative Code 62S-7.012, "SLIP Study Standards" (Florida Department of State 2010a). Per 62S-7.014, "Implementation of SLIP Study findings," the findings of a SLIP Study are required for informational and awareness purposes only and do not represent elevation requirements (Florida Department of State 2010b).

Although the SLIP Study requirement only impacts specific construction projects in Florida, it may also be utilized as guidance for recommended minimum requirements for non-state funded projects. Highlights of the criteria outlined in the "SLIP Study Standards," which are most applicable to this Recovery Advisory are listed below by their section designation:

(1) Show the amount of sea level rise expected over 50 years or the expected life of the structure, whichever is less. The amount of sea level rise expected must be calculated using the following criteria:

(1.a) The sea level rise scenarios used for analysis must, at a minimum, include the NOAA Intermediate-High sea level rise scenario from the NOAA Technical Report NOS Center for Operational Oceanographic Products and Services (NOS CO-OPS) 083, Global and Regional Sea Level Rise Scenarios for the United States (2017).

[10] Projected based on NOAA et al. 2022 Scenario 1.5 (Intermediate-High) with a 0.83 non-exceedance probability.

[11] Per 2019 Florida Statute Title XI 161.54, Coastal building zone "means the land area from the seasonal high-water line landward to a line 1,500 feet landward from the coastal construction control line as established pursuant to s. 161.053, and, for those coastal areas fronting on the Gulf of Mexico, Atlantic Ocean, Florida Bay, or Straits of Florida and not included under s. 161.053, the land area seaward of the most landward velocity zone (V-zone) line as established by the Federal Emergency Management Agency and shown on flood insurance rate maps."

(1.d) *The contribution of land subsidence to relative local sea level rise must be included. NOAA calculates the land subsidence contribution for each local tide gauge and the subsidence is included in each of the NOAA sea level projections.*

The complete Rule for Section 62S-7.012 can be accessed here flrules.org/gateway/ruleno.asp?id=62S-7.012.

To facilitate the SLIP study requirements, Florida provides an online SLIP tool[12] that can be accessed here floridadep-slip.org/Map.aspx.

4.2.2. COASTAL EROSION

The two primary types of coastal erosion are erosion associated with shoreline retreat (from sea level rise and other chronic natural processes) and storm-induced erosion. This section provides an overview of the methods used for estimating these primary types of coastal erosion. Although storm-induced erosion that is not associated with dune loss or retreat may also pose a large risk to buildings during flood events, methods to account for this type of erosion are not presented herein because of the complexity of the erosion process.[13] This Recovery Advisory focuses on how erosion affects ground elevations (Figure 6) and, thus, results in increased flood depths. This Recovery Advisory does not provide detailed guidance on evaluating overland wave characteristics following dune loss.

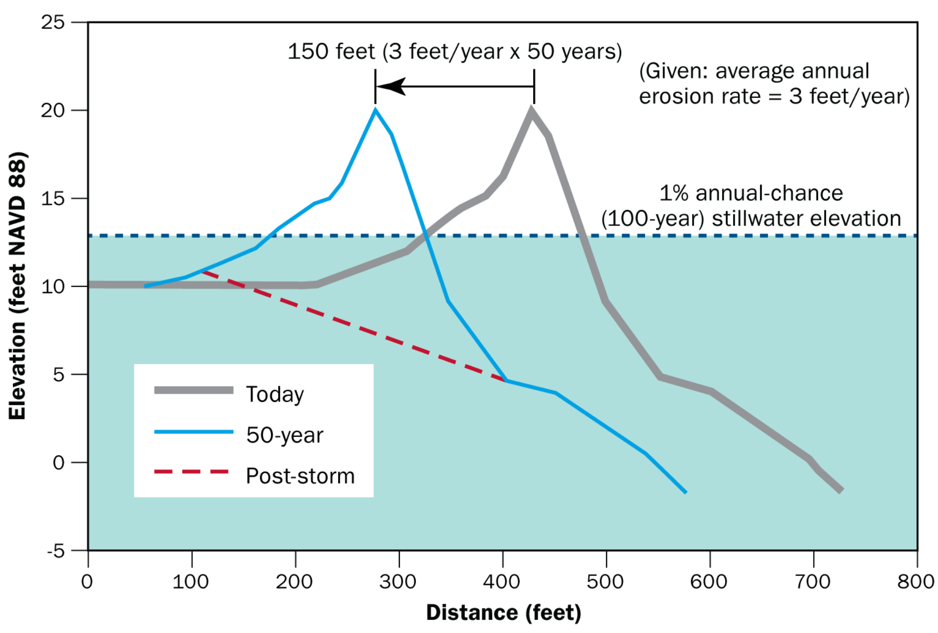

Figure 6: Erosion's effects on ground elevation, shoreline retreat, and dune migration

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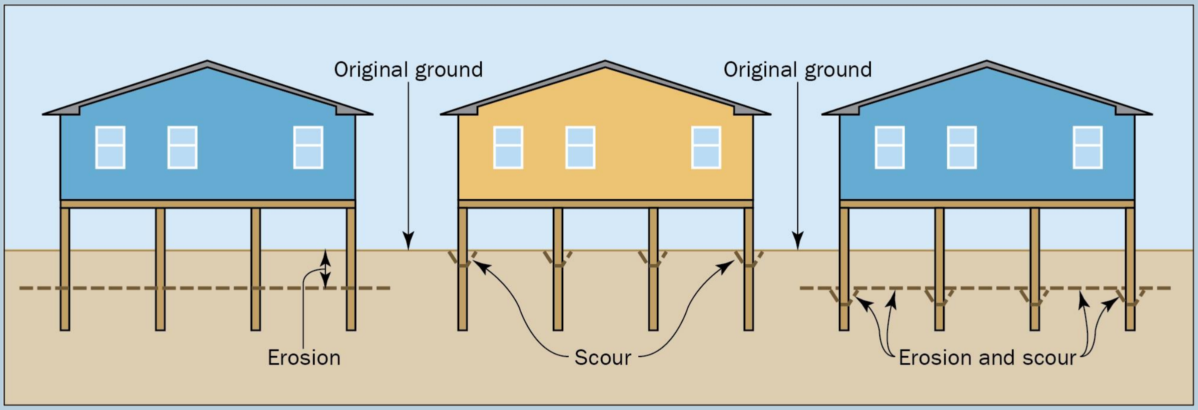
[12] Florida's SLIP tool currently uses sea level rise scenarios published in 2017. As projections are updated, it may be appropriate to use more recently published scenarios.

[13] Wide spread coastal erosion was observed during Hurricane Ike and is documented in Hurricane Ike Recovery Advisory: *Erosion, Scour, and Foundation Design* (FEMA 2009a). Designers may need to consider further increasing the foundation system's embedment depth to account for additional storm-induced erosion.

Scour and Erosion

Erosion is a lowering of the ground surface over a large area, usually brought on by a coastal storm or long-term shoreline recession. Erosion increases the unbraced length of vertical foundation elements and increases the stillwater depth at the building, allowing larger waves to reach the foundation.

Scour is a localized loss of soil immediately around an object or obstruction. Scour also increases the unbraced length of vertical foundation elements but does not act to increase the stillwater flood depth across which waves propagate. Thus, scour can be ignored for wave height and flood load calculation purposes. Walls, columns, pilings, pile caps, footings, slabs, and other objects found under a coastal building can contribute to localized scour.



Depending on the building location, soil characteristics, and flood conditions, a building may be subject to either coastal erosion or scour, or both. Refer to Section 8.5.11 of FEMA P-55 for additional information on scour. Refer to Chapter 10 of FEMA P-55 for guidance on designing foundations to withstand the effects of erosion and scour.

Methods for Estimating Shoreline Retreat Erosion

Erosion associated with shoreline retreat refers to the inland movement of the shoreline due to various processes, including sea level rise, subsidence (or conversely uplift), wave action, longshore drift (transport of beach sediment), and the interruption of longshore drift. Section 8.5.2 of FEMA P-55, outlines procedures to estimate future effects of coastal erosion. State Coastal Zone Management agencies should be consulted for applicable local erosion rates. Alternatively, various public resources, such as the U.S. Geological Survey's (USGS's) Coastal Change Hazards Portal (marine.usgs.gov/coastalchangehazardsportal/), can be used to determine historical erosion rates that may also be termed shoreline change rates.

Methods for Estimating Storm-Induced Dune Loss

Erosion associated with storm-induced dune loss refers to complete dune removal due to storm conditions. Evaluating potential of storm-induced dune loss is critical for structures built on or near a dune system as the loss of the dune may undermine the structure's foundation if the foundation was not designed to accommodate the dune erosion. Section 3.6.8 of FEMA P-55 outlines procedures to estimate storm-induced dune erosion.

An upcoming guidance document will include detailed processes for evaluating coastal erosion and provide information pertaining to the flood calculations required for ASCE standard for *Minimum Design Loads and Associated Criteria for Building and Other Structures* (ASCE 7-22), Supplement 2. The anticipated publication date is late 2023.

4.2.3. INCREASED WAVE HEIGHT

This section introduces general wave theories as well as methods for calculating wave heights. The methods herein can be utilized to determine potential wave height increases when the stillwater depth is increased. Stillwater depth may increase above the mapped 100-year stillwater depth as a result of sea level rise or factors such as selecting a 500-year stillwater elevation.

Overland wave propagation is limited by numerous factors, including water depth and obstructions. Depth-limited waves occur when the wave height exceeds the wave height that can be supported by the local water depth and the wave breaks. Depth-limited waves are common at the shoreline before obstructions. Overland waves, which travel inland from the shoreline, experience wave height reductions as the grade rises and as waves interact with obstructions. Thus, as local flood depths increase due to relative sea level rise and erosion, wave heights may increase as the water depths will support higher waves.

Breaking wave heights (H_b) for depth-limited waves may be calculated by multiplying the local stillwater depth by the wave height coefficient. The wave height coefficient may be taken as 0.78. Because the breaking wave height represents the highest wave that can be supported by the local water depth, the wave heights utilized for building design need not exceed the breaking wave height.

Overland wave heights may be calculated using the “ratio wave height method.” For this method, the future wave height may be calculated by multiplying the wave height derived from an FIS by the ratio of the future stillwater depth to the 100-year stillwater depth (also known as the 1% annual-chance flood depth) in the FIS. The design parameters in Figure 7 used in conjunction with Step 11 of Figure 8 (equations shown in figure) further detail this process. As shown in Figure 7, the process outlined in Figure 8 assumes 70% of the total wave height is above the stillwater elevation.

Assuming the wave height will equal the breaking wave height is more conservative than calculating the wave height with the ratio wave height method. In Zone V, areas where there is minimal coastal protection or obstruction, and areas where breaking waves are present, FEMA recommends that the breaking wave assumption be used unless a detailed analysis has been completed to verify the survival of the dune or the effectiveness of the seawall. In the remaining flood zones, the ratio wave height method may be used.

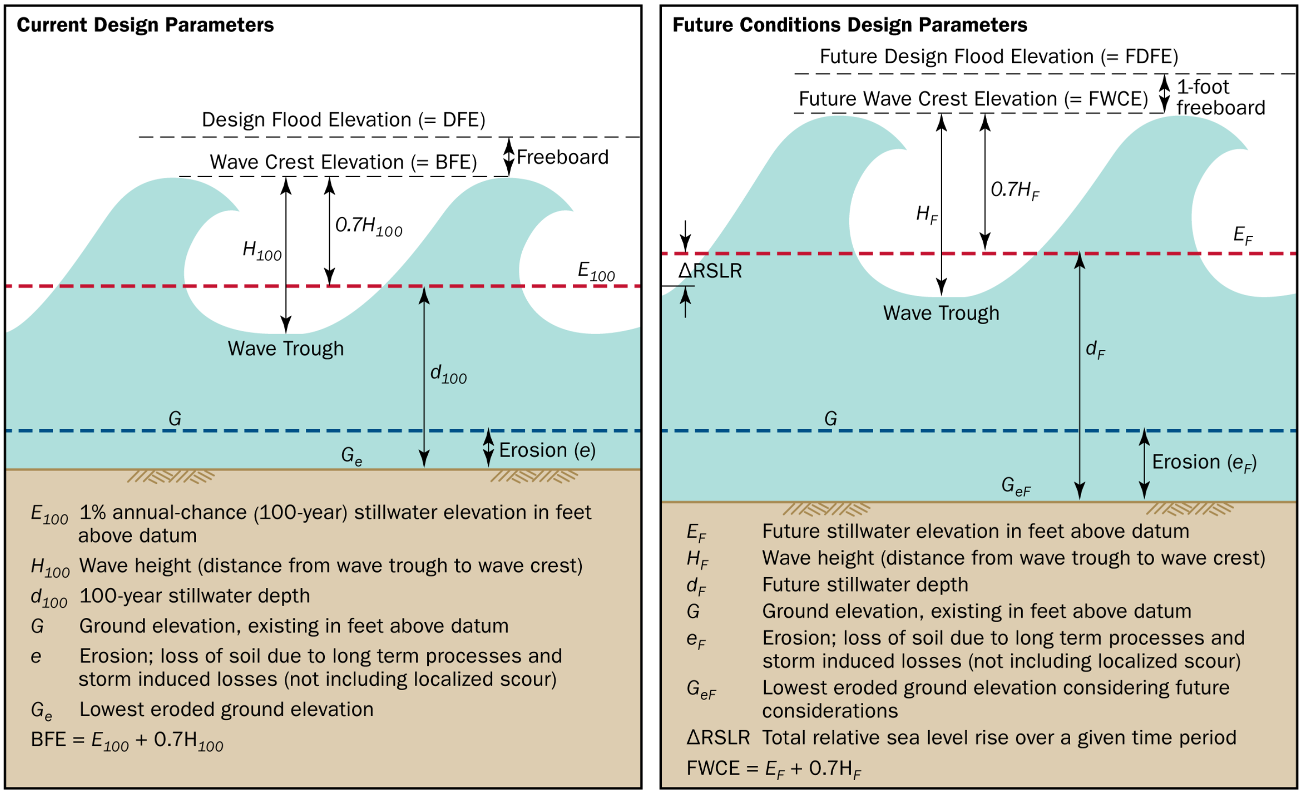


Figure 7: Overview of design parameters for current and future flood conditions

4.2.4. DETERMINING FLOOD ELEVATIONS BASED ON FUTURE CONDITIONS

Future flood condition design parameters, as depicted in Figure 7 and discussed in the previous subsections, may be determined by numerous methods, one of which is outlined in 14 steps in Figure 8 and summarized in the following bulleted list. The 14 steps include:

Data Collection (Step 1)

- Base Flood Elevation (BFE)
- 1% annual-chance (100-year) stillwater elevation (E_{100})
- ground elevation (G)
- total relative sea level rise (ΔRSLR)

Defining Current Design Parameters (Step 2 through Step 6)

- Eroded ground elevation (G_e),
- 1% annual-chance stillwater depth (d_{100})
- Mapped wave height (H_{100})

Defining Future Conditions Design Parameters (Step 7 through Step 11)

- Future stillwater elevation[14] (E_F)
- Future vertical erosion (e_F)
- Future eroded ground elevation (G_{eF})
- Future 1% annual-chance stillwater depth (d_F) d
- Future wave height (H_F)

Defining Future Conditions Design Elevations and Anticipated Flood Zone (Step 12 through Step 14)

- Future wave crest elevation (FWCE)
- Future Design Flood Elevation (FDFE)[15,16]
- Future flood zone

[14] Future storm intensification is not noted in Step 7 of Figure 7, but should be included in the future stillwater elevation when data are available.

[15] The FDFE calculation, shown in Step 13 of Figure 8, includes 1 foot of recommended freeboard to account for the uncertainty of the 100-year storm used to determine the initial BFE as well as some uncertainty in the accuracy of future projections.

[16] Although the FDFE contains the DFE terminology, the FDFE is non-regulatory.

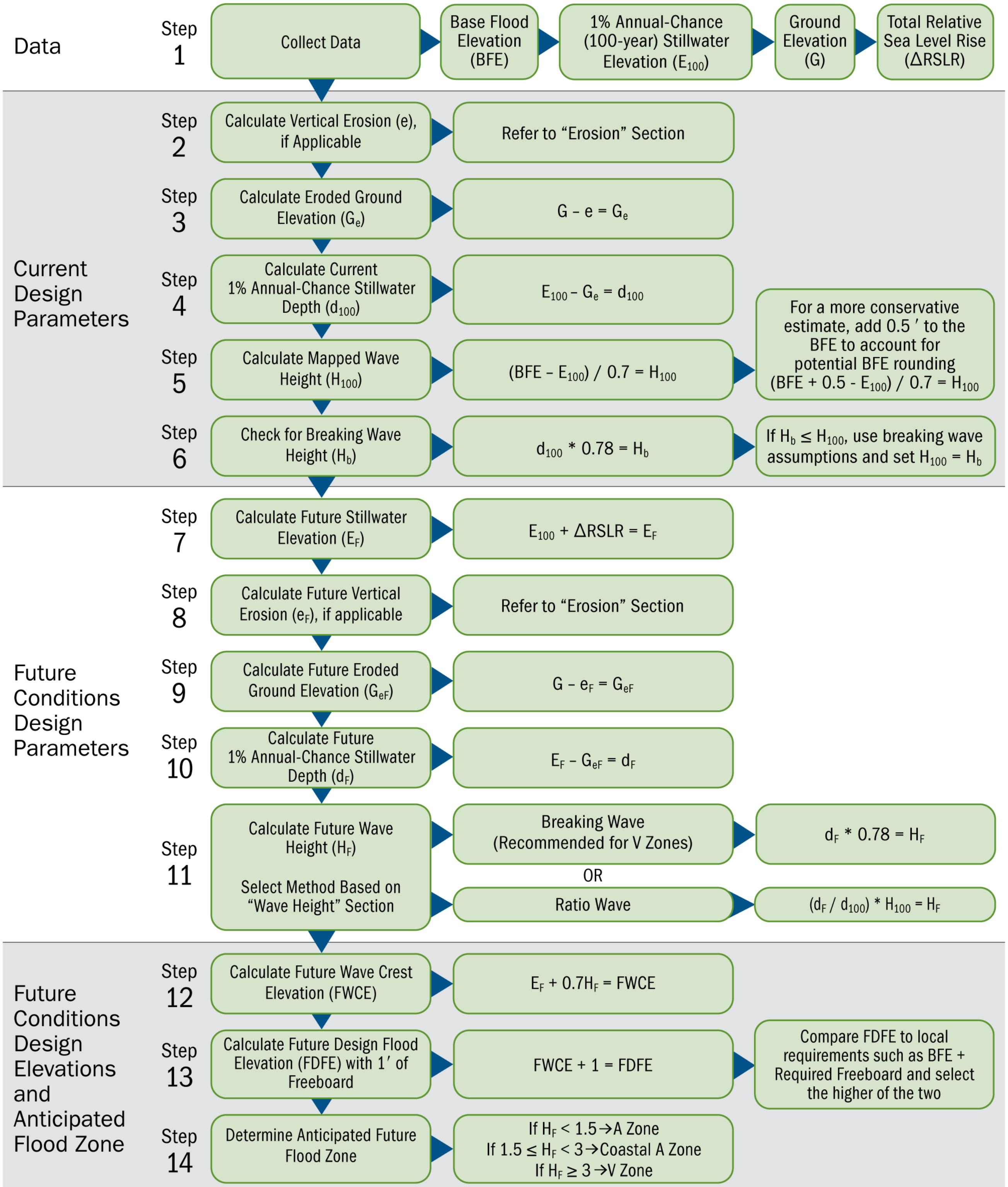


Figure 8: Process for determining flood elevations based on future conditions (Units: feet)

4.2.5. ANTICIPATING FUTURE FLOOD ZONES

While selecting an elevation above the projected future flood elevation is critical for resilience, considering the future flood zone is also important. Constructing a building that meets the requirements of the future flood zone, as depicted in Figure 9, will help ensure the building has a foundation that can withstand future flood conditions. For example, using a deep open foundation as shown in Figure 9 (A), would benefit a building being retrofitted or to be constructed in a Zone A that is anticipated to be in either a Zone V or a Coastal A Zone in the future. The deep open foundation will enable future waves to pass below the structure without damaging the foundation. Chapter 10 of FEMA P-55 provides guidance on foundation design in coastal areas. Additionally, elevating a building to the FDFE by utilizing a crawlspace as shown in Figure 9 (B), or other acceptable Zone A foundation type, would benefit a building being retrofitted or to be constructed in a Zone X that is anticipated to be Zone A in the future. The FDFE in a Zone X can be calculated by utilizing the 100-year stillwater elevation from the adjacent Zone A as the BFE because wave effects are not anticipated in mapped Zone X areas.

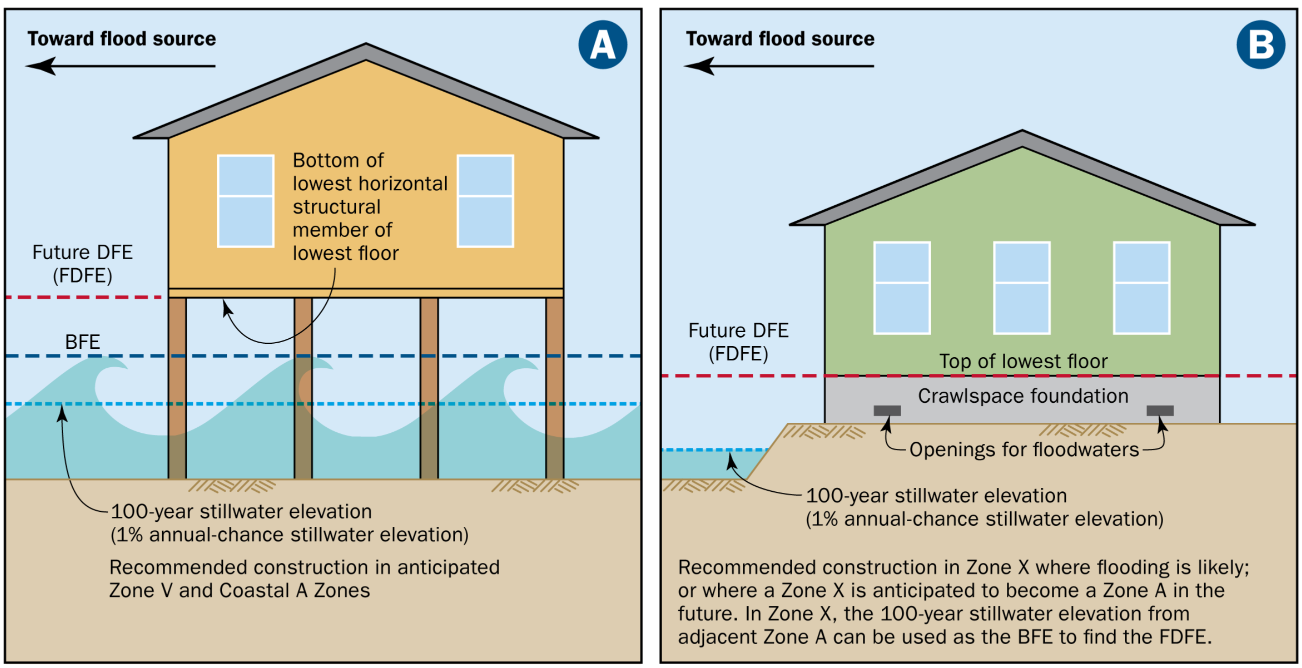


Figure 9: Examples of recommended construction and elevation for anticipated future flood zones

4.3. Summary of Considerations for Selecting a Building's Elevation

In summary, when selecting how high a building should be elevated, many factors should be considered. First, all applicable building codes and floodplain management regulations must be met. Further, if the project is being funded by a federal grant, all applicable federal grant requirements must also be met. Once the minimum elevation that meets all requirements is determined, additional factors that inform an increase above the minimum elevation should be considered, including future conditions, preliminary FIRMs, age of the effective flood analysis, and tolerance for damage, displacement, and downtime, as well as residual risk. Lastly, the desired elevation must not exceed any height restrictions.

5. Additional Design Considerations for Mitigating Flood Damage

In addition to the design considerations described in other sections of this Recovery Advisory, the following recommendations can help building owners minimize damage in the event that future flood events occur above the minimum required elevation. While not addressed in this Recovery Advisory, FEMA recommends that buildings within a hurricane-prone region[17] that are retrofitted to account for additional flood elevation also be retrofitted to resist high-wind hazards. Retrofitting for high-wind hazards such as wind-driven rain and wind-borne debris will increase the resilience of the building such that it may not only survive the flood hazards but also the wind hazards associated with hurricanes. Guidance for wind retrofits can be found in various FEMA publications, including FEMA P-804, *Wind Retrofit Guide for Residential Buildings: In Hurricane-Prone Regions* (2023); FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007); and FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010a).

5.1. Design Loads

In flood zones, design loads and conditions (e.g., hydrostatic, hydrodynamic, wave, floating debris impact, or other loads, and long-term and storm induced erosion and scour) should be calculated using the future stillwater elevation and wave conditions. As a best practice, loads can be based on the FDFE, which includes freeboard.

Property owners sometimes ask if elevating a home will result in higher wind loads on the building. Calculations indicate that although wind pressures on elevated buildings are nominally higher than for non-elevated buildings and will need to be designed for, the greatly increased resilience from flood loads more than offsets this relatively minor cost (FEMA 2009b). Although the incremental wind load is generally small, the increased wind loads should be considered in the building's foundation design, overall load path from its roof to the foundation, as well as the components and cladding of the building's envelop system.

5.2. Use Strong Connections

A building's continuous load path resists loads acting on the building such as wind, seismic, and flood. The continuous load path starts at the location where loads are applied, moves through the building, continues to the foundation, and terminates where the loads are transferred to the soils that support the building. To be effective, each link in the load path chain must be strong enough to transfer loads without breaking.

[17] Hurricane-prone regions are defined in FEMA P-804, *Wind Retrofit Guide for Residential Buildings: In Hurricane-Prone Regions* (2023), Section 2.1.

Where flooding is present, additional consideration must be given to the connections between the foundations and the elevated building. The connections must be strong enough to prevent the building from floating or washing off the foundation if flood levels, including waves, reach the lowest horizontal member supporting the lowest floor. 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; refer also to Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings* (2013), for additional information on connections and resources.

Additionally, using connections that minimize corrosion over time is critical. NFIP Technical Bulletin 8, *Corrosion Protection for Metal Connectors and Fasteners in Coastal Areas* (FEMA 2019), provides guidance on selecting corrosion-resistant connectors. Annual inspection and maintenance should also be performed to ensure connectors remain corrosion free and are replaced as needed to maintain proper structural connections.

5.3. Use Flood Damage–Resistant Materials

Flood damage–resistant building materials and methods should be used below the higher of the BFE or the lowest floor, and also for wall construction and floor finishes sitting directly on the lowest floor. For new construction, repair of substantially damaged buildings, and substantial improvement of existing buildings in SFHAs, all construction below the BFE must consist of flood damage-resistant building materials for NFIP compliance.

Flood damage resistant materials should also be used when wet floodproofing is implemented as a voluntary retrofit measure. Where compliance is not required (i.e., building is not substantially improved/damaged), wet floodproofing may be implemented to reduce flood damage by enabling the equalization of hydrostatic loads. Wet floodproofing cannot be implemented to bring a non-elevated building into compliance, but owners of compliant elevated buildings may elect to wet floodproof above a lowest floor to reduce the chances of flood damage in the event that flood levels rise above the lowest floor. Refer to NFIP Technical Bulletin 7, *Wet Floodproofing Requirements and Limitations* (FEMA 2022), for additional guidance on wet floodproofing.

For example, consider using drainable, dryable interior wall assemblies. This allows interior walls to be opened up and dried after a flood that rises above the lowest floor. To prevent wicking and limit flood damage, building owners can use the following flood damage–resistant methods and materials:

- 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

Refer to NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (FEMA 2008), for additional guidance on flood damage–resistant materials.

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