

Designing for Flood Levels Above the BFE



FEMA

HURRICANE KATRINA RECOVERY ADVISORY

Purpose: To recommend design and construction practices that reduce the likelihood of flood damage in the event that flood levels exceed the Base Flood Elevation (BFE).

Key Issues

- BFEs are established at a flood level, including wave effects, that has a 1-percent chance of being equaled or exceeded in any given year, also known as the 100-year flood or base flood. Floods more severe and less frequent than the 1-percent flood can occur in any year.
- Flood levels during some recent storms have exceeded BFEs depicted on the Flood Insurance Rate Maps (FIRMs), sometimes by several feet (see Figure 1). In many communities, flooding extended inland, well beyond the 100-year floodplain (Special Flood Hazard Area (SFHA)) shown on the FIRM (see Figure 2).
- Flood damage increases rapidly once the elevation of the flood extends above the lowest floor of a building, especially in areas subject to coastal waves. In a V Zone, a coastal flood with a wave crest 3 to 4 feet above the bottom of the floor beam (approximately 1 to 2 feet above the walking surface of the floor) will be sufficient to substantially damage or destroy most light-framed residential and commercial construction (see Figure 4).
- There are design and construction practices that can eliminate or minimize damage to buildings when flood levels exceed the BFE. The most common approach is to add freeboard to the design (i.e., to elevate the building higher than required by the FIRM).

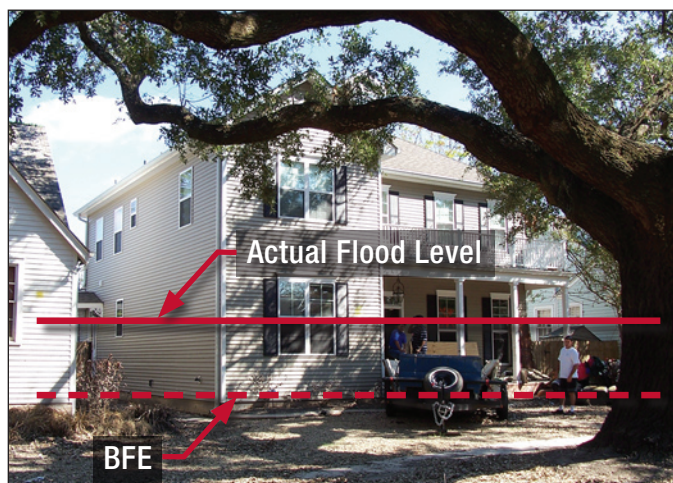


Figure 1. Levee failures and overtopping during Hurricanes Katrina and Rita (2005) resulted in flood levels (solid red line) several feet above the BFE (dashed red line) over large portions of the greater New Orleans area.

Figure 2. Map showing storm surge inundation by Hurricane Katrina at Long Beach (blue shading). Katrina flooding extended beyond the limits of the mapped 100-year floodplain (SFHA) (photo source: NOAA).



- There are other benefits of designing for flood levels above the BFE: reduced building damage and maintenance; longer building life; reduced flood insurance premiums; reduced displacement and dislocation of building occupants after floods (and need for temporary shelter and assistance); reduced job loss; and increased retention of tax base.

Flood Insurance Rate Maps and Flood Risk

Hurricanes Ivan (2004) and Katrina (2005) have demonstrated that constructing a building to the minimum National Flood Insurance Program (NFIP) requirements – or constructing a building outside the SFHA shown on the FIRMs – is no guarantee that the building will not be damaged by flooding. This is due to two factors: 1) flooding more severe than the base flood occurs, and 2) some FIRMs, particularly older FIRMs, may no longer depict the true base flood level and SFHA boundary.

The black line in Figure 3 shows the probability that the level of the flood will exceed the 100-year flood level during time periods between 1 year and 100 years; there is an 18-percent chance that the 100-year flood level will be exceeded in 20 years, a 39-percent chance it will be exceeded in 50 years, and a 51-percent chance it will be exceeded in 70 years. As the time period increases, the likelihood that the 100-year flood will be exceeded also increases.

Figure 3 also shows the probabilities that floods of other severities will be exceeded. For example, taking a 30-year time period where there is a 26-percent chance that the 100-year flood level will be exceeded, there is an 18-percent chance that the 150-year flood will be exceeded, a 14-percent chance that the 200-year flood will be exceeded, and a 6-percent chance that a flood more severe than the 500-year flood will occur.

FIRMs depict the limits of flooding, flood elevations, and flood hazard zones during the base flood. As seen in Figure 3, buildings elevated only to the BFEs shown on the FIRMs have a significant chance of being flooded over a period of decades. Users should also be aware that the flood limits, flood elevations, and flood hazard zones shown on the FIRM reflect ground elevations, development, and flood conditions at the time of the Flood Insurance Study (FIS).¹

Consequences of Flood Levels Exceeding the BFE

Buildings are designed to resist most environmental hazards (e.g., wind, seismic, snow, etc.), but are generally designed to avoid flooding by elevating the building above the anticipated flood elevation. The difference in design approach is a result of the sudden onset of damage when a flood exceeds the lowest floor elevation of a building. Unlike wind – where exposure to a wind speed slightly above the design speed does not generally lead to severe building damage – occurrence of a flood level even a few inches above the lowest floor elevation generally leads to significant flood damage, therefore, the recommendation to add freeboard.

This is especially true in cases where waves accompany coastal flooding. Figure 4 illustrates the expected flood damage (expressed as a percent of a building's pre-damage market value) versus flood depth above the bottom of the lowest

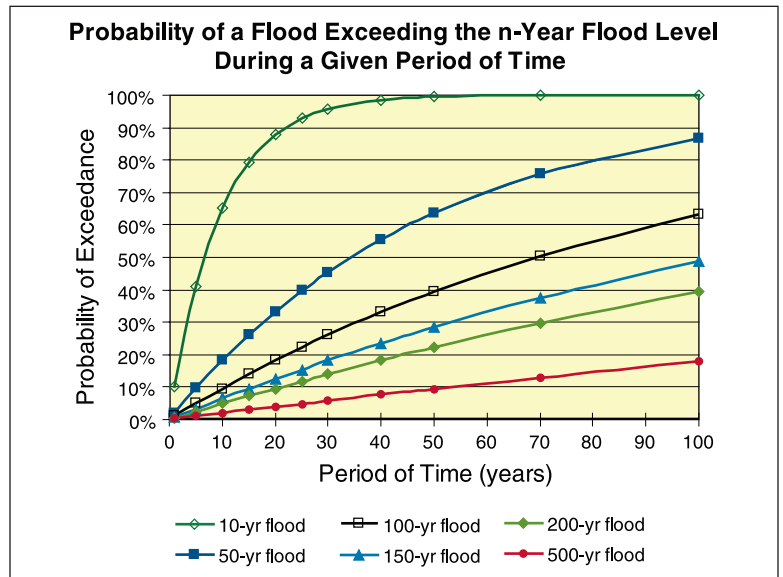


Figure 3. Probability that a flood will exceed the n-year flood level over a given period of time (Note: this analysis assumes no shoreline erosion, and no increase in sea level or storm frequency/severity over time).

FIRMs do not account for the following:

- Shoreline erosion, wetland loss, subsidence, and relative sea level rise
- Upland development or topographic changes
- Degradation or settlement of levees and floodwalls
- Changes in storm climatology (frequency and severity)
- The effects of multiple storm events

Thus, what was once an accurate depiction of the 100-year floodplain and flood elevations may no longer be so.

¹ Sections 7.8.1.3 and 7.9 of FEMA's *Coastal Construction Manual* (FEMA 55, 2000 ed.) provide guidance on evaluating a FIRM to determine whether it still provides an accurate depiction of base flood conditions, or whether it is obsolete.

horizontal structural member supporting the lowest floor (e.g., bottom of the floor beam), for a V Zone building and for a riverine A Zone building.²

One striking difference between the two curves is that a V Zone flood depth (wave crest elevation) 3 to 4 feet above the bottom of the floor beam (or approximately 1 to 2 feet above the top of the floor) is sufficient to cause substantial (>50 percent) damage to a building. In contrast, A Zone riverine flooding (without waves and high velocity) can submerge a structure without causing substantial damage. This difference in building damage is a direct result of the energy contained in coastal waves striking buildings – something obvious to those who saw the wave damage that Hurricane Katrina caused in Mississippi and Louisiana (see Figure 5).

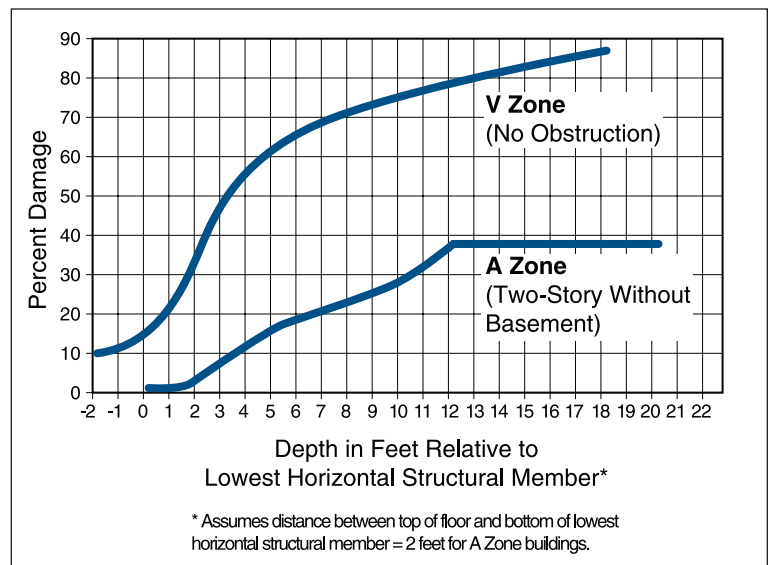


Figure 4. Flood depth versus building damage curves for V Zones and riverine A Zones (Source: FEMA 55, Coastal Construction Manual).



Figure 5. Hurricane Katrina damage to buildings in coastal Mississippi. The upper left, upper right, and lower left photos are of buildings that were close to the Gulf shoreline and subjected to storm surge above the floor and large waves striking the building walls. The lower right photo is of a building almost 1 mile from the Gulf, and subjected to storm surge flooding only.

² Since the normal floor reference for A Zone buildings is the top of the lowest floor, the A Zone curve was shifted for comparison with the V Zone curve.

In cases where buildings are situated behind levees, a levee failure can result in rapid flooding of the area. Buildings near a levee breach may be exposed to high velocity flows, and damages to those buildings will likely be characterized by the V Zone damage curve in Figure 4. Damages to buildings farther away from the breach will be a result of inundation by floodwaters, and will likely resemble the A Zone curve in Figure 4.

General Recommendations

The goal of this Advisory is to provide methods to minimize damage to buildings in the event that coastal flood levels rise above the BFE. Achieving this goal will require adherence to one or more of the following general recommendations:

- In all areas where flooding is a concern, inside and outside the SFHA, elevate the lowest floor so that the bottom of the lowest horizontal structural member is at or above the Design Flood Elevation (DFE). Do not place the top of the lowest floor at the DFE, since this guarantees flood damage to wood floor systems, wood floors, floor coverings, and lower walls during the design flood, and may lead to mold/contamination damage (see Figure 6).
- In flood Zones V and A, use a DFE that results in freeboard (elevate the lowest floor above the BFE) (see Figure 7).
- In flood Zones V and A, calculate design loads and conditions (hydrostatic loads, hydrodynamic loads, wave loads, floating debris loads, and erosion and scour) under the assumption that the flood level will exceed the BFE.
- In an A Zone subject to waves and erosion (i.e., a Coastal A Zone), use a pile or column foundation (see Figure 7).
- Outside the SFHA (in flood Zones B, C, and X), adopt flood-resistant design and construction practices if historical evidence or a review of the available flood data shows the building could be damaged by a flood more severe than the base flood (see Figure 8).
- Design and construct buildings using the latest model building code, ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures* and ASCE 24-05 *Standard for Flood Resistant Design and Construction*.
- Follow the recommendations in FEMA 499, *Home Builder's Guide to Coastal Construction Technical Fact Sheets Series* (available at http://www.fema.gov/rebuild/mat/mat_fema499.shtm).
- Use the pre-engineered foundations shown in FEMA 550, *Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations*.



Figure 6. Other concerns when flood levels rise above the lowest floor are mold and biological/chemical contamination. These may render an otherwise repairable building unrepairable, or will at least make the cleanup, restoration, and repairs much more expensive and time-consuming.

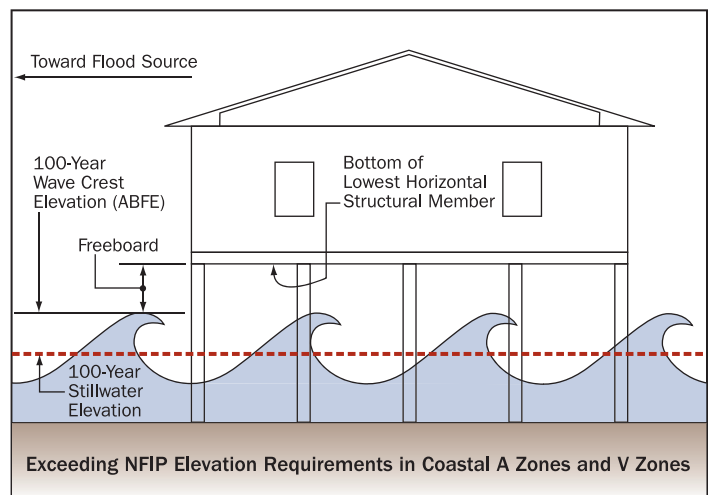


Figure 7. Recommended construction in Coastal A Zones and V Zones.

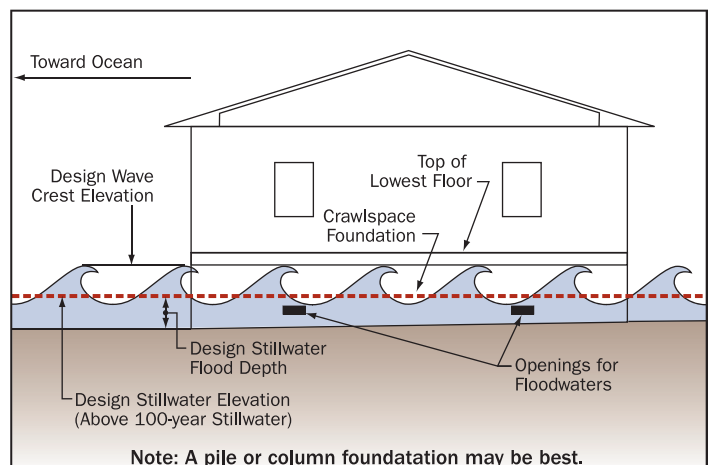


Figure 8. Recommended construction in Zones B, C, and X.

- Use **strong connections between the foundation and the elevated building** to prevent the building from floating or washing off the foundation, in the event that flood levels do rise above the lowest floor.
- Use **flood damage resistant building materials and methods** above the lowest floor. For example, consider using drainable, dryable interior wall assemblies (see Figure 9). This allows interior walls to be opened up and dried after a flood above the lowest floor, minimizing damage to the structure. For cavity and mass wall assemblies, the methods and materials in Figures 10 and 11 are recommended.

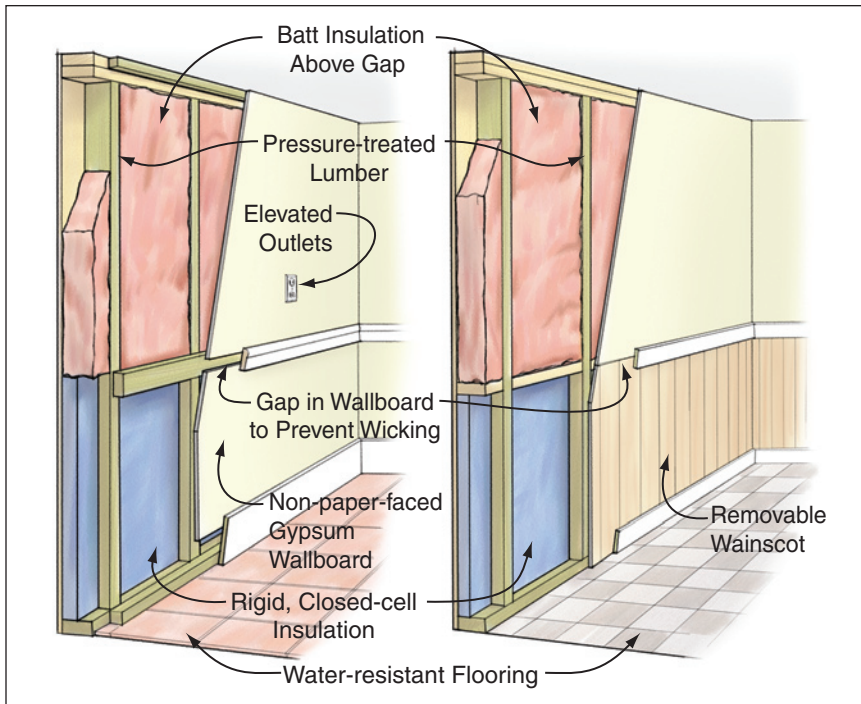


Figure 9. Recommended wet floodproofing techniques for interior wall construction. The following flood damage resistant materials and methods will prevent wicking and limit flood damage: 1) construct walls with horizontal gaps in wallboard; 2) use non-paper-faced gypsum wallboard below gap, painted with latex paint; 3) use rigid, closed-cell insulation in lower portion of walls; 4) use water-resistant flooring with waterproof adhesive; and 5) use pressure treated wood framing (Source: LSU AgCenter and Coastal Contractor Magazine).

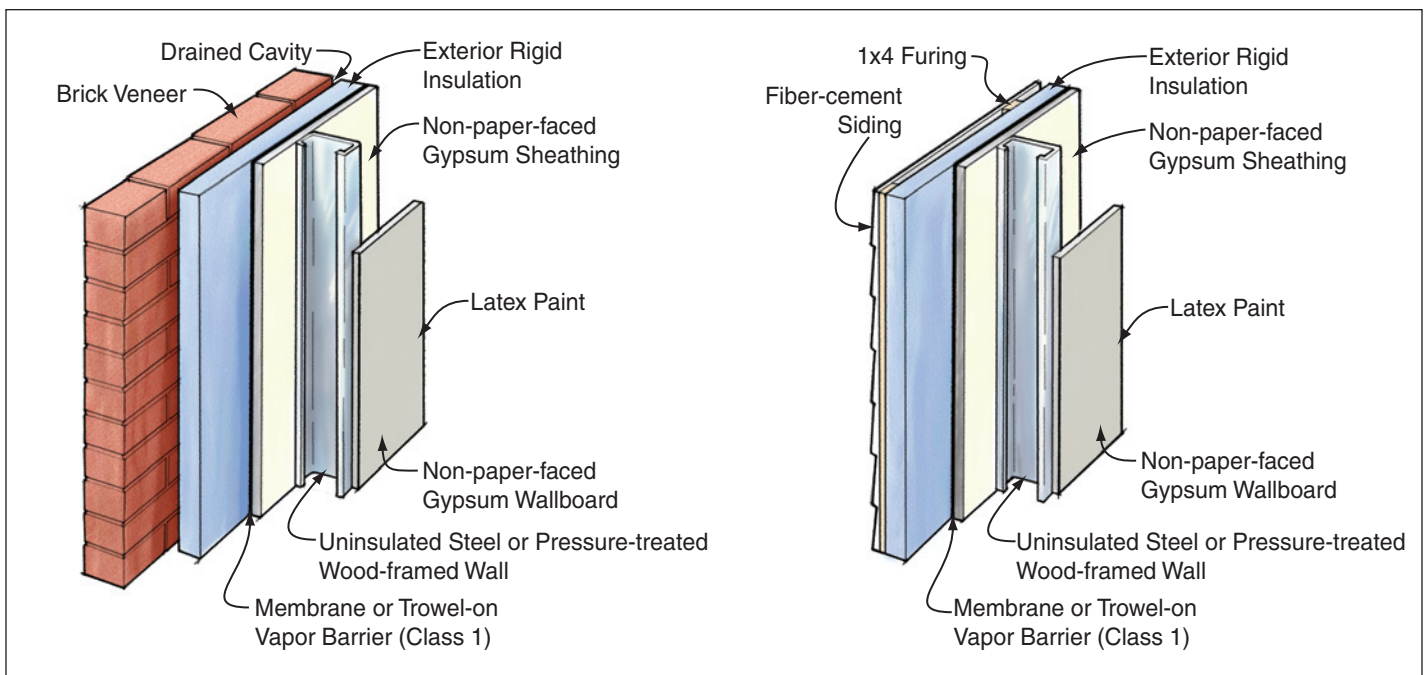


Figure 10. Recommended flood-resistant exterior cavity wall construction. The following materials and methods will limit flood damage to exterior cavity walls: 1) use brick veneer or fiber-cement siding, with non-paper-faced gypsum sheathing (vinyl siding is also flood-resistant but is less resistant to wind damage); 2) provide cavity for drainage; 3) use rigid, closed-cell insulation; 4) use steel or pressure treated wood studs and framing; and 5) use non-paper-faced gypsum wallboard painted with latex paint (Source: Coastal Contractor Magazine and Building Science Corporation).

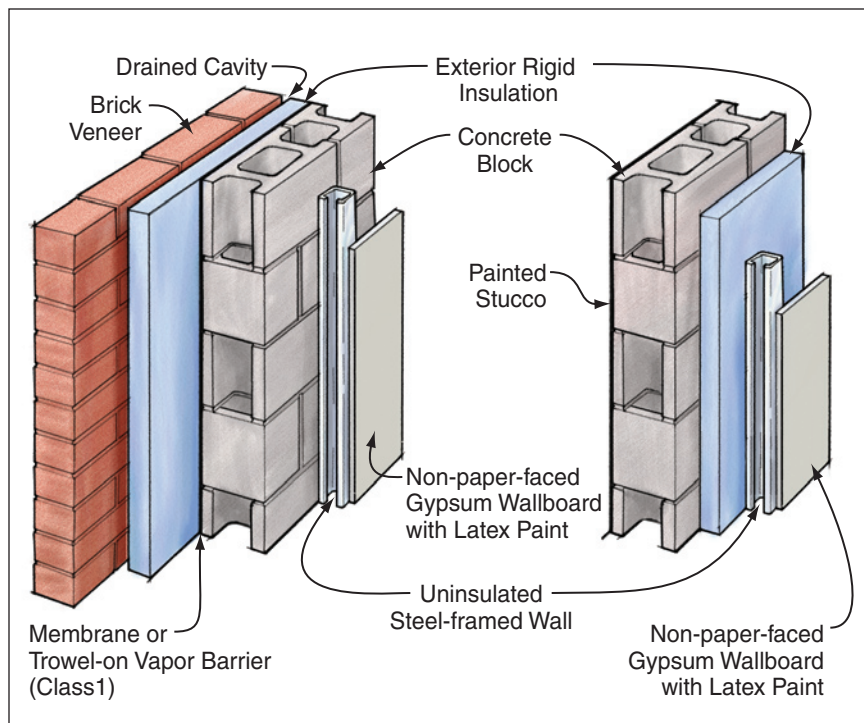


Figure 11. Recommended flood-resistant exterior mass wall construction. The following materials and methods will limit flood damage to exterior mass walls: 1) use concrete masonry with stucco or brick veneer (provide drainage cavity if brick veneer is used); 2) use rigid, closed-cell insulation; 3) use steel framing; and 4) use non-paper-faced gypsum wallboard painted with latex paint (Source: Coastal Contractor Magazine and Building Science Corporation).

- **New and replacement manufactured homes should be installed in accordance with the provisions of the 2005 edition of NEPA 225, Model Manufactured Home Installation Standard (<http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=225&cookie%5Ftest=1>).** The standard provides flood, wind, and seismic resistant installation procedures. It also calls for elevating A Zone manufactured homes with the bottom of the main chassis frame beam at or above the BFE, not with the top of the floor at the BFE.

How High Above the BFE Should a Building be Elevated?

Ultimately, the building elevation will depend on several factors, all of which must be considered before a final determination is made:

- **The accuracy of the BFE shown on the FIRM:** If the BFE is suspect, it is probably best to elevate several feet above the BFE; if the BFE is deemed accurate, it may only be necessary to elevate a couple of feet above the BFE.
- **Availability of Advisory Base Flood Elevations (ABFEs):** ABFEs have been produced for coastal areas following Hurricanes Ivan, Katrina, and Rita. These elevations are intended to be interim recommendations until new FISs can be completed. Some communities have adopted ABFEs, but not all (see the Hurricane Katrina Recovery Advisory posted at http://www.fema.gov/pdf/rebuild/mat/reconst_guidance.pdf).
- **Future conditions:** Since the FIRM reflects conditions at the time of the FIS, some owners or jurisdictions may wish to consider future conditions (such as sea level rise, wetland loss, shoreline erosion, increased storm frequency/intensity, and levee settlement/failure) when they decide how high to elevate.
- **State or local requirements:** The state or local jurisdiction may require a minimum freeboard through its floodplain management regulations.
- **Building code requirements:** The International Building Code (IBC) requires buildings be designed and constructed in accordance with ASCE 24 (*Standard for Flood Resistant Design and Construction*). ASCE 24 requires between 0 and 2 feet of freeboard, depending on the building importance and the edition of ASCE 24 referenced.³
- **Critical and essential facilities:** Given the importance of these facilities, some of which must remain operational during a hurricane, they should be elevated higher than most commercial and residential buildings.

³The 1998 edition of ASCE 24 is referenced by the 2003 edition of the IBC, and requires between 0 and 1 feet of freeboard. The 2005 edition of ASCE 24 is referenced by the 2006 edition of the IBC, and requires between 0 and 2 feet of freeboard.

- **Building owner tolerance for damage, displacement, and downtime:** Some building owners may wish to avoid building damage and disruption, and may choose to elevate far above the BFE (see Figures 12 and 13).



Figure 12. Ocean Springs, Mississippi, home elevated approximately 14 feet above the BFE. Katrina flooding was 4 feet below the elevated floor (photo taken after the storm surge had dropped several feet. Courtesy of Ocean Springs, Mississippi, fire chief).

Figure 13. Pass Christian, Mississippi, home elevated on reinforced concrete columns in Zone A, with the bottom of the floor beam elevated approximately 9 feet above the BFE. Although Katrina flooding was approximately 4 feet above the top of the lowest elevated floor, the home sustained no structural damage. All other buildings in the vicinity were destroyed.



The *Hurricane Katrina Summary Report on Building Performance* (FEMA 548) recommends that critical and essential facilities be elevated to the 500-year flood elevation or based on the requirements of ASCE 24-05, whichever is higher. This recommendation may also be appropriate for residential and commercial structures, as well.

The 500-year elevation can be approximated as 1.5 times the 500-year stillwater depth (500-year stillwater elevation minus the ground elevation) added to the ground elevation. This procedure is similar to the procedure used to calculate ABFEs, but with a different stillwater level.

If the 500-year stillwater elevation (feet North American Vertical Datum of 1988 [NAVD] or feet National Geodetic Vertical Datum of 1929 [NGVD]) is not available, a rule of thumb can be used to approximate it as 1.25 times the 100-year stillwater elevation (feet NAVD or feet NGVD).

Coastal A Zones

The Coastal A Zone is the area where wave heights between 1.5 and 3.0 feet are expected during the base flood. It is recommended that buildings in this area, with a few exceptions, be designed and constructed similar to V Zone buildings. See the Hurricane Katrina Recovery Advisory at http://www.fema.gov/pdf/rebuild/mat/coastal_a_zones.pdf for details.

Other Considerations

As previously stated, in addition to reduced building damage, there are other reasons to design for flood levels above the BFE:

- Reduced building maintenance and longer building life
- Reduced flood insurance premiums
- Reduced displacement and dislocation of building occupants after floods (and need for temporary shelter and assistance)
- Reduced job loss
- Increased retention of tax base

Until flooded, many homeowners and communities don't think about these benefits. However, one of the most persuasive (to homeowners) arguments for elevating homes above the BFE is the reduction in annual flood insurance premiums. In most cases, flood premiums can be cut in half by elevating a home 2 feet above the BFE, saving several hundred dollars per year in A Zones, and \$2,000 or more per year in V Zones. In V Zones, savings continue to increase with added freeboard.

Flood Insurance Premium Reductions Can Be Significant

Example 1: V Zone building, supported on piles or piers, no below-BFE enclosure or obstruction. \$250,000 building coverage, \$100,000 contents coverage.		Example 2: A Zone building, slab or crawlspace foundation (no basement). \$200,000 building coverage, \$75,000 contents coverage.	
Floor Elevation above BFE	Reduction in Annual Flood Premium*	Floor Elevation above BFE	Reduction in Annual Flood Premium*
1 foot	25%	1 foot	39%
2 feet	50%	2 feet	48%
3 feet	62%	3 feet	48%
4 feet	67%	4 feet	48%

* Compared to flood premium with lowest floor at BFE

References

ASCE. 2005. *Minimum Design Loads for Buildings and Other Structures*. ASCE 7-05.

ASCE. 2005. *Standard for Flood Resistant Design and Construction*. ASCE 24-05.

Building Science Corporation. 2006. (relevant articles and publications are available at <http://www.buildingscience.com>).

Coastal Contractor. July 2006. *Low Country Rx: Wet Floodproofing. Drainable, dryable assemblies made with water-tolerant materials help speed recovery from deeper than-expected floods*, by Ted Cushman. (available at <http://www.coastalcontractor.net/cgi-bin/issue.pl?issue=9>).

FEMA. 2000. *Coastal Construction Manual*. FEMA-55 (ordering information at http://www.fema.gov/pdf/plan/prevent/nhp/nhp_fema55.pdf).

FEMA. 2005. *Home Builder's Guide to Coastal Construction Fact Sheets Series*. FEMA 499 (available at http://www.fema.gov/rebuild/mat/mat_fema499.shtm).

FEMA. 2006. *Hurricane Katrina Summary Report*. FEMA-548 (available at http://www.fema.gov/pdf/rebuild/mat/fema548/548_SumRprt0329fnl.pdf).

FEMA. 2006. *Recommended Residential Construction for the Gulf Coast, Building on Strong and Safe Foundations*. FEMA-550.

LSU AgCenter. 1999. *Wet Floodproofing. Reducing Damage from Floods*. Publication 2771. (available at <http://www.louisianafloods.org/NR/rdonlyres/2AEAF3E7-F068-40E6-A4CD-C4B6901F4307/26120/pub2771Wet6.pdf>).

NFPA. 2005. *Model Manufactured Home Installation Standard*. NFPA 225. (available at <http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=225&cookie%5Ftest=1>).