2. SUMMARY OF COASTAL FLOOD HAZARDS

2.1 Summary of Design Loads of Coastal Hazards

Since most major coastal flood events are associated with hurricanes, flood hazards in coastal areas occur as a result of storm surges and unusually high tides. Riverine flooding varies in character from coastal flooding due to the difference between current flow and wave action. Therefore the following explanation is specific to coastal flood loads.

In order to calculate coastal flood loads for a specific building and site, the Design Stillwater Depth needs to be determined. This is the vertical distance between the eroded ground elevation and the Stillwater Elevation associated with the design flood. This vertical dimension will help designers and engineers determine Design Flood Elevation (DFE), or the Design Flood Protection Depth, which is the height at which floodproof construction methods should be employed to resist flood-related damage to a building. The Design Stillwater Depth is used to determine the hydrostatic load, hydrodynamic load, flood velocity, design wave height, local scour depth, and debris impact loads. *(FEMA 55 2005)*

Local variables included in flood load calculations can be found in the Flood Insurance Study (FIS) Reports that are compiled to create the Flood Insurance Rate Map (FIRM) for a community. Chapter 11 of *FEMA 55: Coastal Construction Manual* provides extensive instructions on how to determine site-specific loads regarding coastal flood hazards. Additionally, *American Society of Engineers (ASCE) 7-98 Minimum Design Loads for Buildings and Other Structures* is an accepted reference to determine other loads, such as dead and live loads, to be used in combination with coastal flood loads to determine structural capacities of building components. Scott Sundberg, a structural engineer working on the Mississippi Gulf Coast, provided consultation services during the investigation of coastal flood hazards.

2.1.1 Flood-Related Loads

The following is a summary of forces acting on buildings as result of rising floodwaters during a flood event.

2.1.1.1 Hydrostatic forces

Hydrostatic loads result from vertical and lateral forces that act on a building from standing or slowly moving water. Lateral hydrostatic loads are applied to a building face at a point 2/3 below the depth of the Stillwater Elevation (Fig 2.1). Vertical hydrostatic loads (otherwise known as buoyant forces) act on a building from below the foundation structure. The Design Stillwater Depth is determined by the local FIS provided by the National Flood Insurance Program (NFIP). (*FEMA 55 2005*)

$$F_{STA} = [(1/2)\,\gamma\, d_s^{\,2}]\,(w)$$

where:

F_{STA} = lateral hydrostatic force on a structure (in lb)

γ = specific weight of water = 64.0 lb/ft^3 for saltwater

d_s = design stillwater flood depth

w = width of building (in ft)

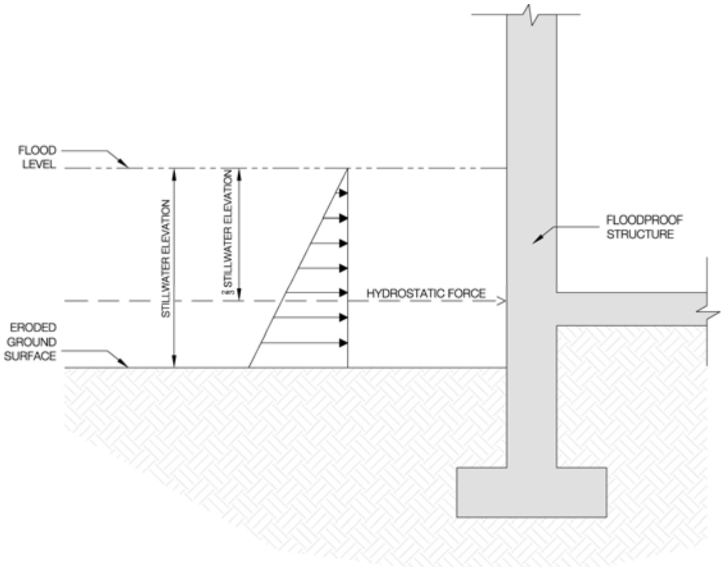


Fig. 2.1. DIAGRAM: Lateral hydrostatic force diagram.

These loads produce little damage to buildings when the flood depths on either side of a wall are similar, hence the requirement for flood vents and openings in foundation walls located below the BFE in A flood zones to equalize flood depths (Fig 2.1).

Fig. 2.2. PHOTO: Flood vent in foundation wall.

Dry floodproof buildings are designed to keep nearly all floodwater from entering the envelope of the building below and above the BFE (see definition of dry floodproof construction), and therefore need to be able to completely withstand the hydrostatic forces acting on the exterior walls. The photo below (Fig. 2.2) shows an example of a building failure due to lateral and vertical hydrostatic forces. In this case, the structure was detached from the foundation and moved during the flood event.

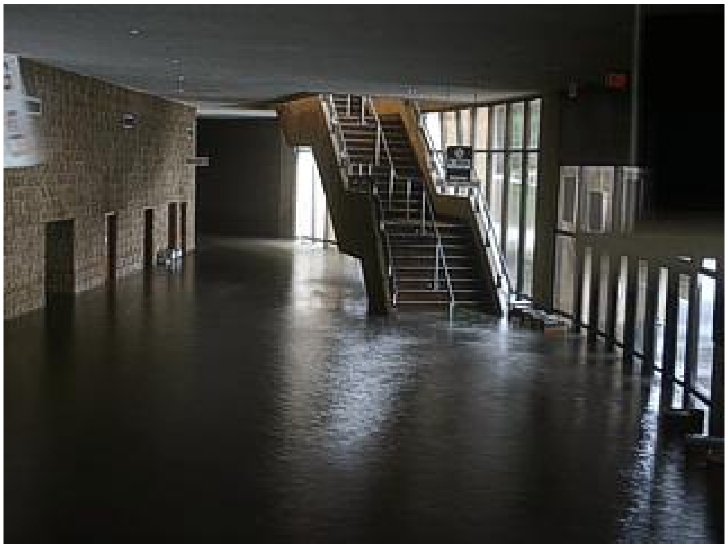


Fig. 2.3. PHOTO: Failure due to hydrostatic forces. (*Collura, 2005*)

2.1.1.2 Hydrodynamic forces

Hydrodynamic loads are forces which act on a structure due to moving water around exterior walls. These loads impact all sides of a building: directly to the seaward face (the exterior wall perpendicular to the flow of water), drag along the sides (the exterior walls parallel to the flow of water), and negative pressure (suction) on the downstream face (the exterior wall opposite of the seaward face) (Fig. 2.4).

Fig. 2.4. PHOTO: Failure due to hydrodynamic forces. (*FEMA 549 2006*)

Hydrodynamic loads are a function of expected flood velocities, which are subject to high uncertainty. For flow velocities less than 10 ft/sec, the hydrodynamic load can be converted to a hydrostatic load. For buildings within an A flood zone, flood velocities are expected to be less than 10ft/sec. Buildings within V, VE, or Coastal A zones are subject to hydrodynamic forces (Fig. 2.5). The hydrodynamic load can impact a building at localized points when the flow velocity is increased unevenly around a building. This happens when the flow is obstructed and more water is forced through smaller openings (i.e. between two buildings that are close to each other). (*FEMA 55 2005*)

$$F_{dyn} = \{\gamma d_s[(1/2)C_d V^2/g]\}w$$

where:

F_{dyn} = lateral hydrostatic force in lb acting at the point 2/3 below the stillwater elevation

γ = specific weight of saltwater (64.0lb/ft^3)

d_s = design stillwater flood depth

C_d = drag coefficient for width to depth ratio

V = velocity of water in ft/sec

g = acceleration due to gravity (32.2ft/sec^2)

w = width of structure in feet

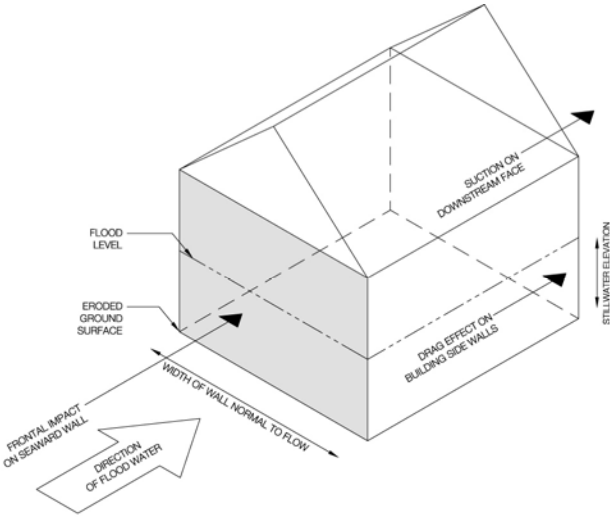


Fig. 2.5. DIAGRAM: Hydrodynamic forces.

The most common means of mitigating hydrodynamic forces in building design is to elevate the floor of the structure so that it is above the expected Design Flood Elevation (DFE), and anchor it properly to an open foundation (driven piles, concrete piers with deep footings). If portions of the enclosure are to be built below the DFE in an area subject to flow velocities higher than 10 ft/sec, the enclosure needs to be built as a breakaway wall, so that it does not damage the primary structure above it in a flood event (Fig. 2.6) See *FEMA Technical Bulletin 5: Free of Obstruction Requirements* for prescriptive information on design and installation of structures below the DFE.

Fig. 2.6. PHOTO: Damage as a result of non-breakaway stair design. (*FEMA TB-5 2008*)

2.1.1.3 Wave action

Wave loads are forces acting on the seaward face of a building at the Design Stillwater Elevation, as a result of four types of wave forces: non-breaking waves, breaking waves, broken waves, and uplift (as a result of wave run up on vertical or sloping surfaces, or waves peaking under protruding horizontal surfaces). Because breaking waves produce the highest load acting on a building, they are used to calculate the design wave load (Fig. 2.7). Wave loads affect buildings in all types of flood zones, but their impact is greatest in V, VE, and Coastal A zones, where the height of the cresting waves are expected to be higher than in other flood zones. (*FEMA 55 2005*)

$$F_{brkw} = [1.1C_p \gamma d_s^2 + 2.41\gamma d_s^2](w)$$

where:

F_{brkw} = wave load per unit length of wall acting at the stillwater level

C_p = dynamic pressure coefficient (as a Function of Probability of Exceedance, Walton et al. 1989) = 3.2

γ = specific weight of water = 64.0 lb/ft^3 for saltwater

d_s = design stillwater flood depth in feet

w = width of wall normal to flow of flood water

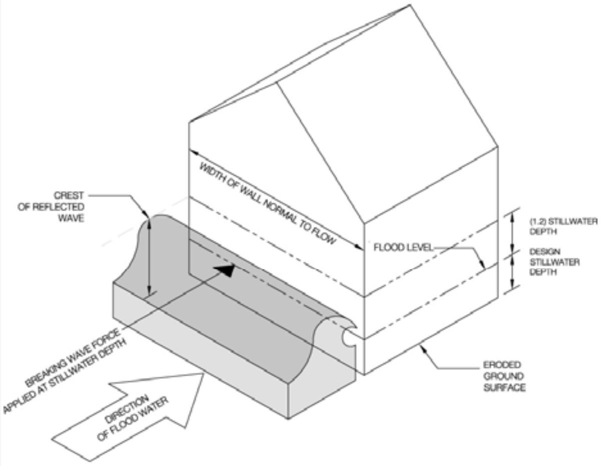


Fig. 2.7. DIAGRAM: Breaking wave forces.

Because breaking wave loads are associated with hydrodynamic forces, mitigation strategies are similar. Elevating the structure above the DFE, choosing durable materials and installing them with proper anchorage, and using open foundations with breakaway structures below the DFE are all common methods used to decrease damage to buildings in flood zones that experience high wave loads. The photo in Fig. 2.8 demonstrates extensive damage to a building due to high breaking wave forces.

Fig. 2.8. PHOTO: Damage as a result of breaking waves. (*FEMA 490 2005*)

2.1.1.4 Localized scour

Scour is the erosion of soil adjacent to a building as a result of turbulence from floodwater moving toward and against the foundation structure of a building. The removal of this soil can affect the bearing capacity and the anchoring resistance of the remaining soil around the foundation (Fig. 2.9).

Fig. 2.9. PHOTO: Damage as a result of localized scour. (*FEMA 549 2006*)

Scour depths are influenced by the flood depth, flood velocity, soil characteristics and the Flow Angle of Attack (the angle of the floodwater in relation to the building). The design scour depth is calculated using the maximum variables, such as the upper bound flow velocity and the highest impact Flow Angle of Attack, which is 60 degrees to normal (Fig. 2.10). Choosing a foundation type that is installed well below the anticipated scour depth is the most effective way to mitigate against damage from scour during a flood event. (*FEMA 55 2005*)

$$S_{max} = d_s\{2.2(a/d_s)^{0.65}[V/(gd_s)^{0.50}]^{0.43}\}K$$

where:

S_{max} = max. localized scour depth (in feet)

d_s = design stillwater flood depth (in feet)

a = half the width of the foundation perpendicular to the flow of water

V = velocity of water in ft/sec (upper bound)

g = gravitational constant (32.2 ft/sec^2)

K = factor applied for Flow Angle of Attack

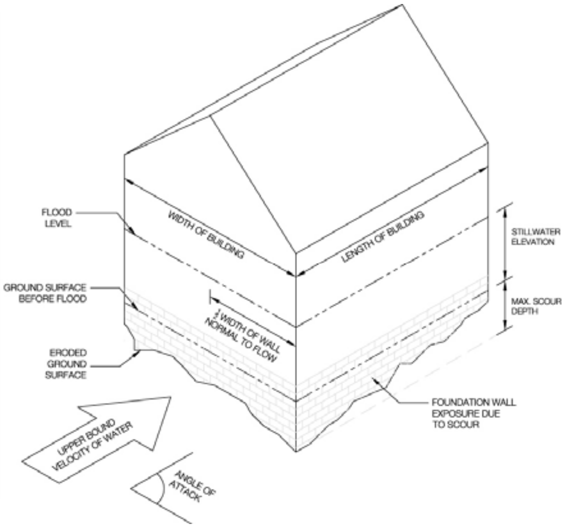


Fig. 2.10. DIAGRAM: Localized maximum scour diagram.

2.1.1.5 Debris impact

Debris impact loads are lateral forces that act on a building as a result of debris floating in floodwater and colliding with the face of a building (Fig. 2.11). The magnitude of this load is extremely difficult to predict, as it is a function of the weight of the debris and the velocity at which it is travelling. Additionally, the type of debris cannot be accurately predicted for a flood event. Here, it is assumed that the design object weighs 1,000lbs and is moving at the Design Floodwater Velocity.

$$F_i = wV/gt$$

where:

F_i = impact force, in lbs, acting at the stillwater level

w = weight of the debris object
= 1,000lbs

V = velocity of floodwater in ft/sec = $(gd_s)^{0.5}$;

g = gravitational constantat 32.2 ft/sec^2

t = duration of impact (in seconds)
= 0.1 for reinforced concrete

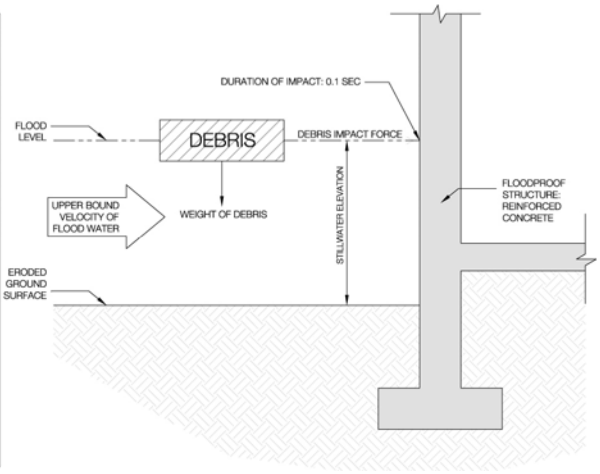


Fig. 2.11. DIAGRAM: Debris impact.

Also, the duration of impact of the debris is influenced by the "rigidity" of the building materials. The City of Honolulu building code has determined this by the type of construction method employed. Subsequently, FEMA has adopted this method for determining the design duration of impact of debris. (*FEMA 55 2005*)

Table 1. Duration of impact

	Duration (t) of Impact (sec)	
Type of Construction	**Wall**	**Pile**
Wood	0.7-1.1	0.5-1.0
Steel	n/a	0.2-0.4
Reinforced Concrete	0.2-0.4	0.3-0.6
Concrete Masonry	0.3-0.6	0.3-0.6

Because debris impact is extremely difficult to predict, mitigation strategies are somewhat limited. Choosing building materials that can withstand higher impact loads, elevating the structure above the DFE, limiting the amount of obstructions in the structure below the DFE, and removing or anchoring large objects around the structure prior to a flood event are ways to decrease the risk of damage due to debris impact. Below (Fig. 2.12), damage was recorded to a building due to debris that traveled over two miles during Hurricane Opal in Pensacola Beach, Florida.

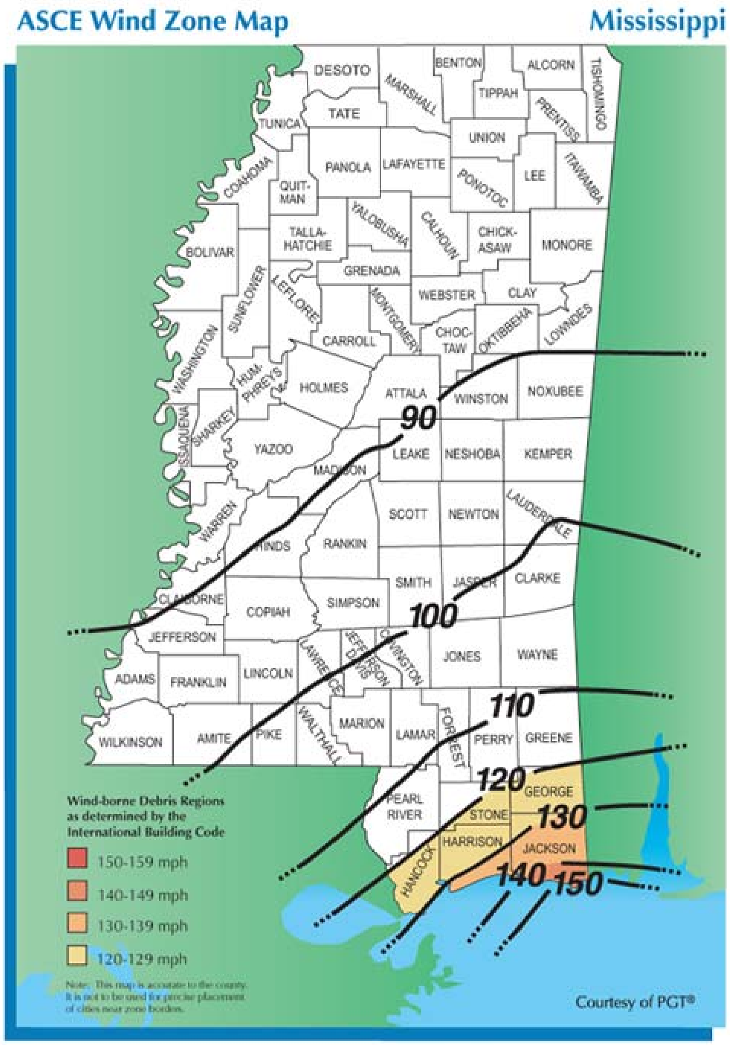
Fig. 2.12. PHOTO: Damage as a result of debris impact. (*FEMA 55 2005*)

2.1.2 Wind-Related Loads

The following is a summary of forces acting in conjunction with flood hazards as result of a high-wind event, such as a hurricane.

2.1.2.1 Wind load

Wind pressures are forces acting in various directions on a building as a result of heavy wind events (hurricanes, thunderstorms, or tornadoes). Lateral and vertical (uplift) forces can cause damage if buildings are not properly designed or constructed to meet or exceed the wind load. FEMA's accepted standard for determining wind force is the *ASCE 7-02 Minimum Design Loads for Buildings and Other Structures.* Fig. 2.13 shows the ASCE Wind Zone map used to determine design wind speeds for Mississippi.



SOURCE: ASCE MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES

Fig. 2.13. MAP: ASCE Wind Zone Map for Mississippi. (*ASCE 7 1998*)

Wind pressures are calculated both for the capacity of the structural frame--known as the Main Wind Force Resisting System (MWFRS)--consisting of the foundation, floor supports, columns, roof rafters or trusses, bracing, walls, and any diaphragms assisting in transferring loads), and also for the capacity of building components and cladding (elements not directly related to the structure, such as roof sheathing, coverings, exterior siding, windows, doors, soffits, fascia).

The following factors influence the impact of wind forces:

a) Wind speed (Fig. 2.13)
b) Size and shape of the building (height above the ground, proportion of length to width, the exposed faces in relation to the wind direction)
c) Strength of the structure and envelope (including the number and sizes of openings), along with the strength of components and their connections
d) Measures taken to protect the building, such as shutters, site topography and orientation, and vegetation

During a high-wind event, an enclosed building will experience high pressures on the exterior of the building envelope. When even a small piece of cladding becomes detached, and wind and rain are allowed to enter the building, the building can fail substantially because of the uncontrolled forces acting upon the interior walls (Fig. 2.14). (*FEMA 55 2005*)

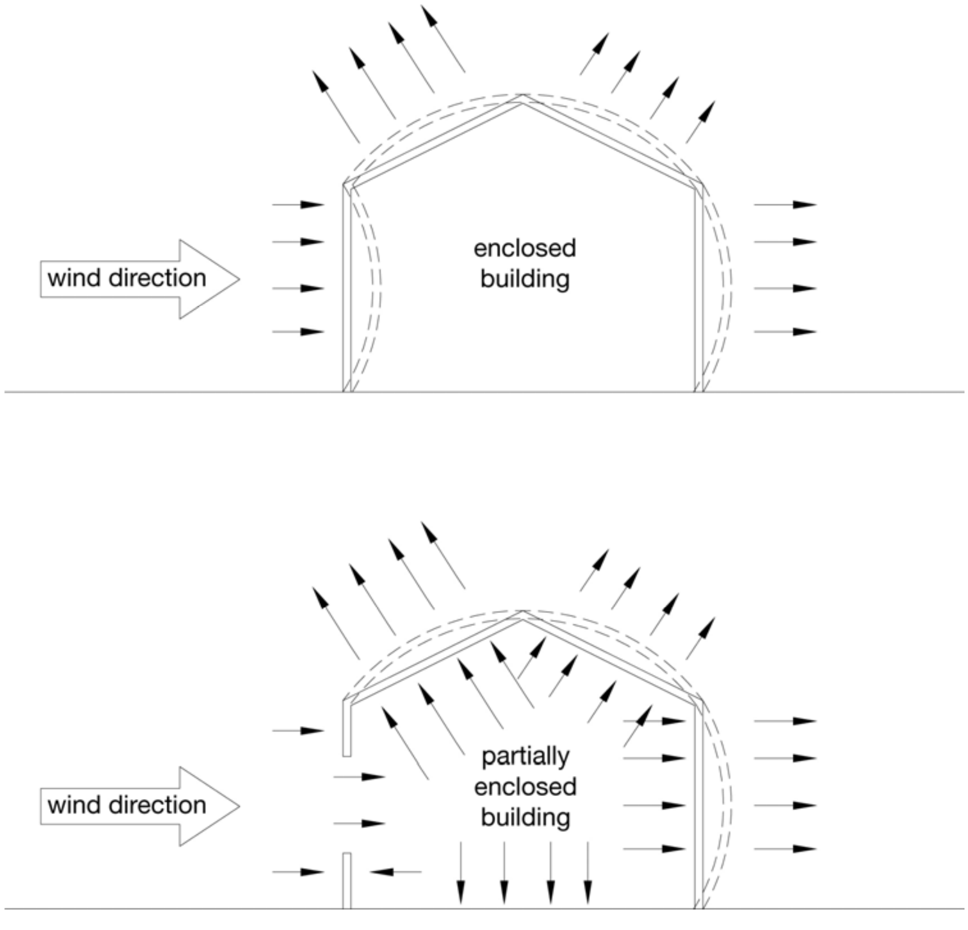


Fig. 2.14. DIAGRAM: Wind loads. (*FEMA 55 2005*)

Mitigation strategies used to decrease the risk of damage to buildings located in areas prone to high wind speeds are: using building materials and components that meet wind speed requirements, using correct fastening and anchoring systems (and also using fasteners that will not corrode if exposed to water such as stainless steel or galvanized coated), designing appropriately shaped buildings to meet wind loads, using impact-resistant windows and doors, placing shutters or protective panels over openings in walls, and refraining from using light-weight cladding systems. Fig. 2.15 shows how a building with vinyl siding (a light-weight cladding system) was damaged when wind entered the attic of the building through a failure in the porch soffit, and 'blew out' the gable end wall.

Fig. 2.15. PHOTO: Damage as a result of pressure differences. (*FEMA 549 2006*)

2.1.2.2 Missile impact (windborne debris)

Windborne debris colliding with a building during a high wind event can puncture the envelope and components, leading to differentials in wind pressure between the exterior and interior of the building. Additionally, punctures in the building envelope lead to damage to interior finishes and the structure due to rainfall and wind-driven rain entering the building envelope unintended. Since high wind events in coastal areas are generally associated with hurricanes, water damage as a result of missile impacts can produce damage up to nine times the dollar amount of damage produced by missile impacts alone (*FEMA 55 2005*). Fig. 2.16 demonstrates how the glazing on a New Orleans building was damaged heavily during Hurricane Katrina when aggregate from a nearby roofing system was blown off, puncturing the building envelope.

Fig. 2.16. PHOTO: Damage as a result of missile impact. (*FEMA 549 2006*)

Damage caused by windborne debris is a function of the size, shape, and weight of the missile, the velocity at which it is travelling, and the strength of the building that it collides with. The *2009 International Building Code* specifies that openings in buildings located in high wind areas need to be protected by impact resistant products that meet American Society for Testing and Materials (ASTM) E1886 and ASTM E1996 (*IBC 2009*). Wood structural panels may be used to protect openings that do not already meet these requirements, if local building codes permit.

2.2 Summary of Dry Floodproof Regulatory Requirements

In order to understand the breadth of regulatory publications of floodproof construction in the United States, it was necessary to follow the influential documents through networks of research, design, and governance. Pivotal sources for floodproof-related standards, developed by federal agencies, industry groups, and academic research organizations have informed the research presented in this report. The GCCDS created a diagram showing the choronology of floodproof construction publications (Fig 2.17) in order to map relationships within existing research with reference to important flood events in history. The regulations that are enforced at a local level for floodproof design and construction projects have been influenced through a number of publications presented within this diagram. This map was intended to be used as a working document during the research phases of this project, and does not represent all publications and research related to the topic of floodproof construction.

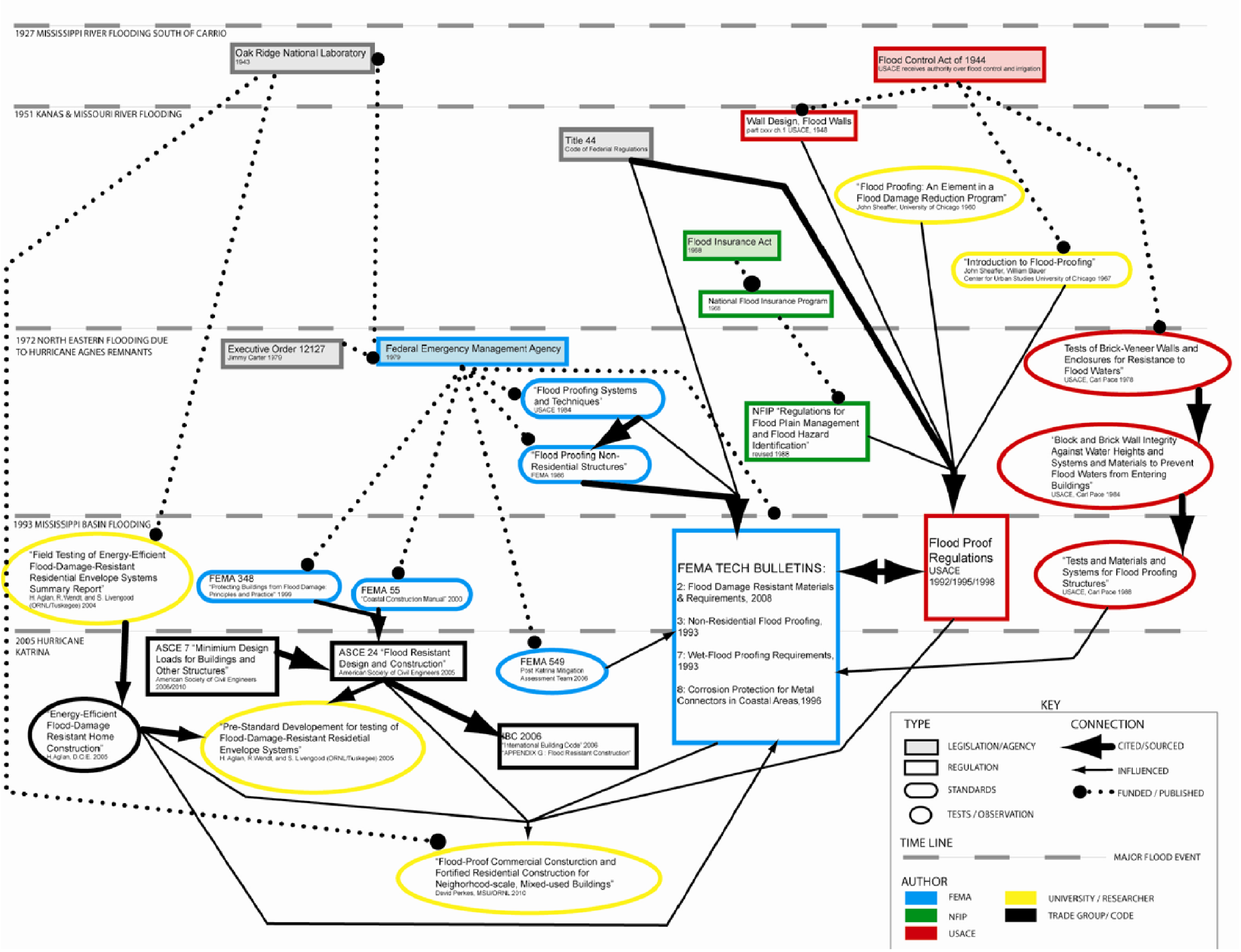


Fig 2.17. DIAGRAM: Chronology of floodproof construction research publications.

2.2.1 National Flood Insurance Program (NFIP) Requirements

Communities participating in the NFIP must implement a floodplain management ordinance. This ordinance establishes certain standards that must be met in order for the community to receive favorable flood insurance rates under the NFIP. Community Floodplain requirements are based on NFIP regulations, in addition to state and regional building code regulations. Fig. 2.18 shows the relationships between the agencies and the documents that inform flood zone regulation.

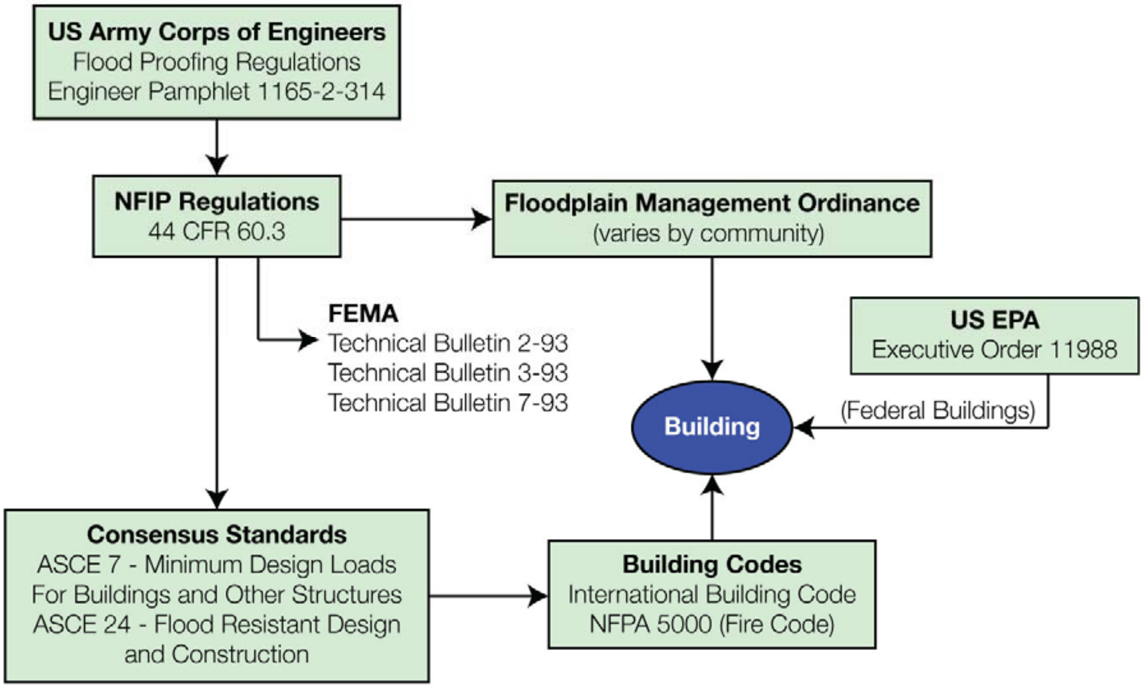


Fig. 2.18. DIAGRAM: Flow chart of flood regulation influence on building design. (*Jones 2009*)

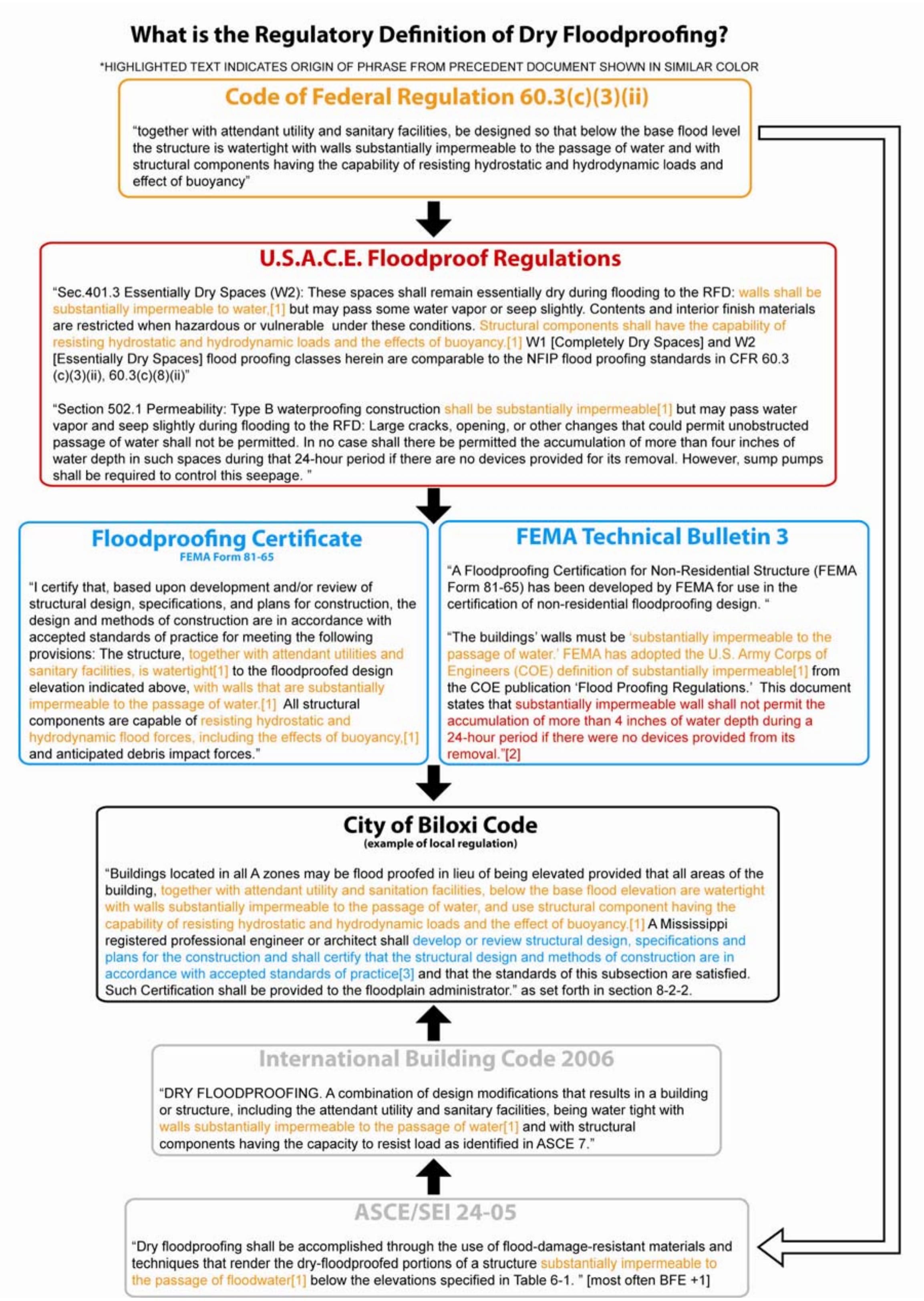
Floodplain management ordinances are designed to mitigate hazards associated with flooding, such as: direct damage from inundation, high velocity flow, waves, erosion, sedimentation and/or floodborne debris, degradation of building materials and contamination of the building due to floodborne substances or mold. (*Jones 2009*) Preferred mitigation techniques in flood zones vary; the most common techniques are the relocation of buildings outside of the flood hazard area or the elevation of buildings' FFE above the BFE. Non-residential buildings may be permitted to have a FFE below the BFE, if dry floodproof construction methods are allowed and applied correctly according to the floodplain management ordinance. A dry floodproof building should be materially and structurally resistant to damages from flooding in all areas of the building below the BFE. Residential uses below the BFE are strictly forbidden under the NFIP; the chance of injury or death to a person inhabiting a building during flood event is too high.

2.2.1.1 44 CFR 60.3 Floodplain management criteria for flood-prone areas

The federal precedent for the NFIP requirements for dry floodproof construction is *44 Code of Federal Regulations (CFR) 60.3 Flood plain management criteria for flood-prone areas*. This code defines the following requirements for dry floodproof construction below the BFE:

a) Must be a non-residential structure
b) Restricted to Zones A1-30, AE and AH zones on the community's FIRM
c) The structure below the BFE is to be watertight with "walls substantially impermeable to the passage of water with structural components having the capability of resisting hydrostatic and hydrodynamic load and effects of buoyancy"
d) A registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction and shall certify that the design and methods of construction are in accordance with accepted standards set forth for dry floodproof buildings
e) A record of certification of the building should be maintained with the floodplain manager

Exact prescriptive requirements for dry floodproof construction vary based on location and local interpretation of regulation. A series of documents citing federal code and best practices contribute to the floodplain regulations enforced at the local level through the floodplain management ordinance. Fig. 2.19 demonstrates the influence of federal codes in the City of Biloxi (case study area) code for dry floodproof construction.



What is the Regulatory Definition of Dry Floodproofing?

*HIGHLIGHTED TEXT INDICATES ORIGIN OF PHRASE FROM PRECEDENT DOCUMENT SHOWN IN SIMILAR COLOR

Code of Federal Regulation 60.3(c)(3)(ii)

"together with attendant utility and sanitary facilities, be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effect of buoyancy"

U.S.A.C.E. Floodproof Regulations

"Sec.401.3 Essentially Dry Spaces (W2): These spaces shall remain essentially dry during flooding to the RFD: walls shall be substantially impermeable to water,[1] but may pass some water vapor or seep slightly. Contents and interior finish materials are restricted when hazardous or vulnerable under these conditions. Structural components shall have the capability of resisting hydrostatic and hydrodynamic loads and the effects of buoyancy.[1] W1 [Completely Dry Spaces] and W2 [Essentially Dry Spaces] flood proofing classes herein are comparable to the NFIP flood proofing standards in CFR 60.3 (c)(3)(ii), 60.3(c)(8)(ii)"

"Section 502.1 Permeability: Type B waterproofing construction shall be substantially impermeable[1] but may pass water vapor and seep slightly during flooding to the RFD: Large cracks, opening, or other changes that could permit unobstructed passage of water shall not be permitted. In no case shall there be permitted the accumulation of more than four inches of water depth in such spaces during that 24-hour period if there are no devices provided for its removal. However, sump pumps shall be required to control this seepage. "

Floodproofing Certificate

FEMA Form 81-65

"I certify that, based upon development and/or review of structural design, specifications, and plans for construction, the design and methods of construction are in accordance with accepted standards of practice for meeting the following provisions: The structure, together with attendant utilities and sanitary facilities, is watertight[1] to the floodproofed design elevation indicated above, with walls that are substantially impermeable to the passage of water.[1] All structural components are capable of resisting hydrostatic and hydrodynamic flood forces, including the effects of buoyancy,[1] and anticipated debris impact forces."

FEMA Technical Bulletin 3

"A Floodproofing Certification for Non-Residential Structure (FEMA Form 81-65) has been developed by FEMA for use in the certification of non-residential floodproofing design. "

"The buildings' walls must be 'substantially impermeable to the passage of water.' FEMA has adopted the U.S. Army Corps of Engineers (COE) definition of substantially impermeable[1] from the COE publication 'Flood Proofing Regulations.' This document states that substantially impermeable wall shall not permit the accumulation of more than 4 inches of water depth during a 24-hour period if there were no devices provided from its removal."[2]

City of Biloxi Code

(example of local regulation)

"Buildings located in all A zones may be flood proofed in lieu of being elevated provided that all areas of the building, together with attendant utility and sanitation facilities, below the base flood elevation are watertight with walls substantially impermeable to the passage of water, and use structural component having the capability of resisting hydrostatic and hydrodynamic loads and the effect of buoyancy.[1] A Mississippi registered professional engineer or architect shall develop or review structural design, specifications and plans for the construction and shall certify that the structural design and methods of construction are in accordance with accepted standards of practice[3] and that the standards of this subsection are satisfied. Such Certification shall be provided to the floodplain administrator." as set forth in section 8-2-2.

International Building Code 2006

"DRY FLOODPROOFING. A combination of design modifications that results in a building or structure, including the attendant utility and sanitary facilities, being water tight with walls substantially impermeable to the passage of water[1] and with structural components having the capacity to resist load as identified in ASCE 7."

ASCE/SEI 24-05

"Dry floodproofing shall be accomplished through the use of flood-damage-resistant materials and techniques that render the dry-floodproofed portions of a structure substantially impermeable to the passage of floodwater[1] below the elevations specified in Table 6-1. " [most often BFE +1]

Fig. 2.19 DIAGRAM: Federal regulatory influence on definition of dry floodproofing.

2.2.1.2 Engineering Pamphlet 1165-2-314

Within *44 CFR 60.3*, the term "substantially impermeable" is used to describe the structure of a dry floodproof building without providing a clear definition within the document. The USACE document *Engineering Pamphlet 1165-2-314* states that waterproof construction shall be "permitted the accumulation of [no] more than four inches of water depth in such a space during a 24-hour period if there are no devices provided for its removal…" This definition is used throughout the NFIP regulations and is also found in FEMA publications.

2.2.1.3 Technical Bulletin 3-93 Non-Residential Floodproofing

FEMA Technical Bulletin (TB) 3-93 Non-Residential Floodproofing—Requirements and Certification provides guidance for complying with the NFIP regulations for dry floodproof construction. Key requirements from *FEMA TB 3-93* include:

a) "The building must be watertight to the floodproof design elevation, which is further defined as being at least the BFE." However, "to receive a flood insurance rate based on 100-year flood protection, the structure must be dry floodproofed to an elevation of at leat one foot above the BFE."
b) A watertight building must be "substantially impermeable" to the passage of water" as defined by the USACE in *Engineering Pamphlet 1165-2-314*.
c) Hydrostatic and hydrodynamic loads, buoyancy, and debris impact forces must be calculated for the site based on the FIS formulas defined in the requirements. (Guidelines for these calculations can be found in *FEMA TB 3-93*)
d) "Where human intervention is required to implement floodproofing measures, such as the installation of flood gates or flood shields, a Flood emergency Operation Plan is required. This plan must be produced by the design professional to ensure that floodproofing measures can be implemented in a safe and timely fashion."
e) "A Floodproofing Certificate is required for all non-residential buildings to be floodproofed and is to be completed by the design professional."
f) "Like all construction that falls under NFIP regulations, the building must meet the requirements of all applicable portions of local and State building codes, including the provisions of the ADA, life-safety codes for ingress/egress and clearing; and venting and combustion requirements."

2.2.2 Regional Building Codes

Building code requirements relating to dry floodproof construction can be found withinin the IBC and the NFPA 5000. These codes pertain to the use and safety of components within a dry floodproof building. These code requirements are drawn largely from standards developed by the ASCE. The ASCE provides relevant standards in *ASCE 7 Minimum Design Loads for Buildings and Other Structures* and *ASCE 24 Flood Resistant Design and Construction*. The standards within *ASCE 24* are similar to the NFIP standards. However, *ASCE 24* is “more restrictive than the NFIP regulations with respect to the identification of flood hazard areas subject to damaging wave action and some other areas.” (*ASCE 24 2005*)

2.2.2.1 ASCE 24 Flood Resistant Design and Construction

The requirements within *ASCE 24* state that “dry floodproofing of non-residential structures and non-residential areas of mixed-use structures shall not be allowed unless such structures are located outside of High Risk Flood Hazard Areas, Coastal High Hazard Areas, and Coastal A Zones.” Coastal A zones are not specifically marked on FIRMs, nor do NFIP regulations differentiate between Coastal A zones and A zones. Coastal A zones are located between the Limit of Moderate Wave Action (LiMWA)—where the potential for breaking wave heights is greater than or equal to 1.5 feet—and a velocity zone. Fig 2.20 shows the floodplain delineations for East Biloxi, Mississippi, per the 2009 adopted FIRM.

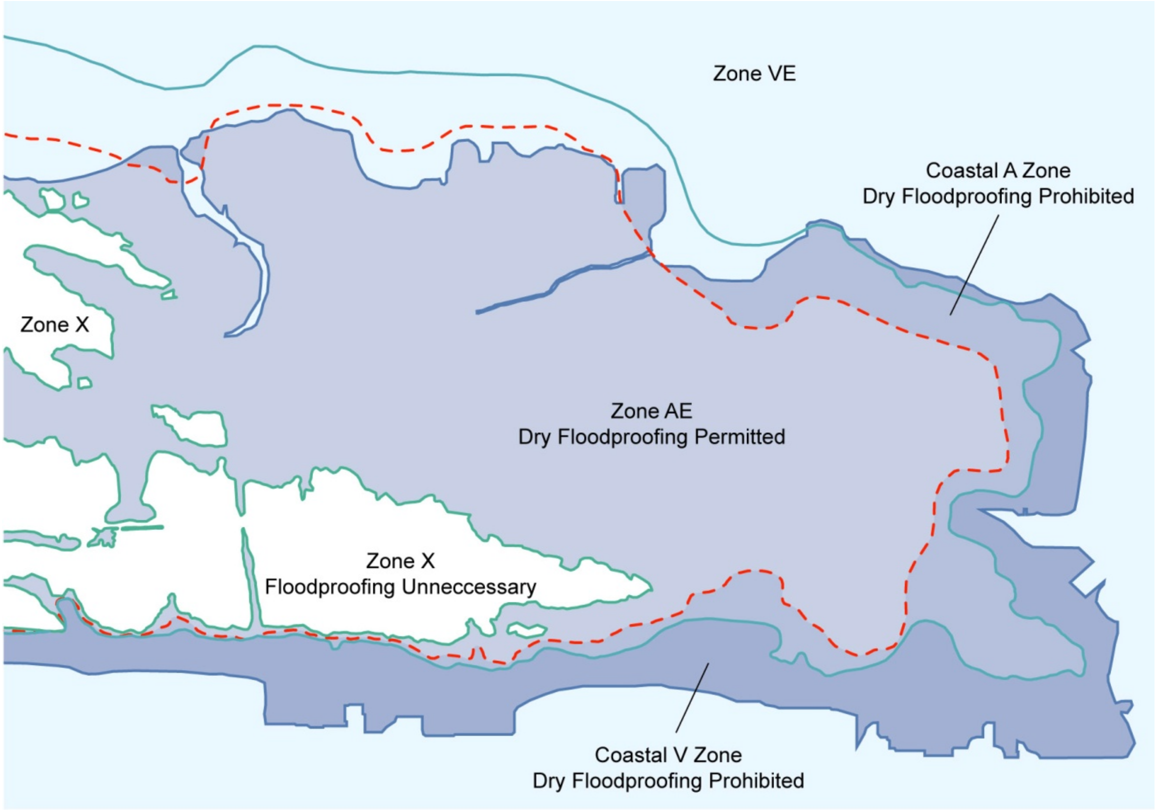


Fig. 2.20 MAP: East Biloxi flood zones.

Additionally, *ASCE 24* limits dry floodproof projects to areas “where flood velocities adjacent to the structure are less than or equal to 5 ft/sec during the design flood”. *ASCE 24* also sets standards for flood warning time within human intervention plans in *Section 6.0 Dry and Wet Floodproofing.* In nearly all cases, *ASCE 24* requires at least one exit door at or above the DFE, which must be capable of providing ingress and egress during design flood conditions. The majority of the remaining requirements within *ASCE 24* reiterate those found within FEMA, NFIP and USACE documents.

2.2.3 Biloxi, Mississippi

In Biloxi, Mississippi, where this research was conducted, the *Code of Ordinances, City of Biloxi, Mississippi* states that a certified dry floodproof building has been certified by an engineer or architect to be watertight with walls substantially impermeable to the passage of water and structurally capable of resisting hydrostatic, hydrodynamic and buoyancy forces. The FFE of the floodproof building must be no more than three feet below the BFE with floodproofing construction details extending a foot above the BFE. Additional floodproof construction requirements found in the City of Biloxi Code of Ordinances are drawn directly from the NFIP regulations listed earlier in Section 2.2.1.1 of this report, as well as drawn from the *ASCE 24* regulations listed in Section 2.2.2.1 of this report. (*City of Biloxi 2011*)

2.2.4 Conclusions

Dry floodproofing is a viable flood protection technique for non-residential spaces in areas subject to low to moderate flood elevation, floodwater velocity, and wave action. Municipalities are responsible for the regulation of dry floodproof construction through building codes and floodplain management ordinances. However, the challenge of designing and certifying a dry floodproof building is the responsibility of the professional engineer or architect.