INTRODUCTION TO RESIDENTIAL COASTAL CONSTRUCTION
INDEPENDENT STUDY

June 2001

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COURSE INTRODUCTION

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FEMA'S INDEPENDENT STUDY PROGRAM

The Federal Emergency Management Agency's (FEMA's) Independent Study Program is one of the delivery channels that the Emergency Management Institute (EMI) uses to provide training to the general public and specific audiences. This course is part of FEMA's Independent Study Program. In addition to this course, the Independent Study Program includes courses in floodplain management, radiological emergency management, the role of the emergency manager, hazardous materials, disaster assistance, the role of the Emergency Operations Center, an orientation to community disaster exercises, and many other topics.

FEMA's independent study courses are available at no charge and include a final examination. You may apply individually or through group enrollment. When enrolling for a course, you must include your name, mailing address, social security number, and the title of the course that you want to enroll in.

FOR ADDITIONAL INFORMATION

If you need assistance with enrollment, or if you have questions about how to enroll, contact the Independent Study Program at:

FEMA Independent Study Program
Administrative Office
Emergency Management Institute
16825 South Seton Avenue
Emmitsburg, MD 21727

Information about FEMA's Independent Study Program also is available on the Internet at:

http://www.fema.gov/emi/ishome.htm

Each request will be reviewed and directed to the appropriate course manager or program office for assistance.

SOCIAL SECURITY NUMBER

Your SSN is used as your student identification number, and is vital to maintaining an accurate student record on your behalf. See the privacy act statement on your answer sheet for details on how your SSN is used and managed. Disclosure of this information is voluntary: however, incomplete or missing names/addresses or social security numbers will cause delays in responding to requests for course materials and certificates of completion.

COMPLETION CERTIFICATES

You will receive an Independent Study certificate of completion if you score at least 75% on the final examination. Normally, you can expect to receive your certificate within 10 business days from the date your final examination is received at the ISP office. Any inquiries may be made in writing to: EMI Independent Study Program, 16825 South Seton Ave., Emmitsburg, MD 21727 or by email to: independent.study@fema.gov.

ABOUT THIS COURSE

Despite billions of dollars of losses resulting from coastal hazards to residential structures, U.S. coastal areas continue to appeal to thousands of people who are drawn to live along coastal waters. The explosion of coastal development has led to greater numbers of structures in areas that are at high risk. The risk to coastal residential development can be reduced by employing best practices in siting, design, and construction.

In an effort to ensure that residential structures built along coastal or lake-shore waters are well sited, designed, and constructed, the Federal Emergency Management Agency published an updated version of the *Coastal Construction Manual* (FEMA 55). Focusing on new residential structures, this multi-volume manual identifies best practices for improving the quality of construction and reducing the economic losses associated with coastal disasters.

This independent study course will introduce you to basic information about residential coastal construction, as presented in Volume I of the *Coastal Construction Manual*. Completing this course will prepare you for successful completion of the resident course entitled *Residential Coastal Construction.*

COURSE GOALS

Upon completing this course, you should be able to:

- Describe lessons learned from coastal flood disasters.
- Describe how Federal, State, and local regulations and building codes help reduce coastal damage.
- Interpret basic NFIP map information.
- Describe how coastal hazards—individually or together—can damage coastal residential structures.
- Identify sources of information that should be consulted before making siting decisions.
- Describe recommended practices for building siting.
- Identify the benefit and cost implications of siting, design, and construction decisions.

COURSE CONTENT The course content is presented in the nine units listed in the following table.

Unit	Title
I	Historical Perspective
II	Coastal Environment
III	Fundamentals
IV	Identifying and Evaluating Site Alternatives
V	Investigating Regulatory Requirements
VI	Identifying Hazards (Part I)
VII	Identifying Hazards (Part II)
VIII	Siting
IX	Financial and Insurance Implications

Appendix A contains a Glossary of Terms.
Appendix B contains the Final Examination.

HOW TO COMPLETE THIS COURSE

To help you identify course materials and track your progress in completing the course, each component (except the course pre-test and the final examination) is identified by an icon in the header at the top of the page. Icons are shown below with the component descriptions.

COURSE PRE-TEST Before beginning this course, complete the Course Pre-Test on pages vi-xi and check your answers against the Answer Key that follows. Taking the Course Pre-Test will help you identify areas in which you are proficient—and areas in which you need to concentrate as you complete this course.

COURSE CONTENT The nine course units contain all the information you will need to complete the course. Work through the course at a pace that is comfortable for you. You should resist the temptation to rush through the material, however. Take enough time with each unit to ensure that you have mastered its content before proceeding to the next. The entire course should take a total of approximately 15 hours of your time.

NOTE: If, after reading the unit introduction, you believe you have an advanced level of knowledge about the unit topic, you may wish to turn to the Unit Exercise and test your knowledge. If you answer all of the questions correctly, you may skip the unit. If you answer any questions incorrectly, you should review corresponding unit content before continuing.

SELF-CHECK REVIEWS

Content within the units is presented in short segments followed by Self-Check Reviews. These reviews check your comprehension of the material just read and provide opportunities for applying the knowledge you have gained.

The answers are provided on the page immediately following the questions. Check your answers before continuing to the next segment, and review the related unit content as needed to ensure that you have understood the material.

UNIT EXERCISES

To help you know when to proceed to the next unit, each unit is followed by a Unit Exercise that addresses the material contained in the entire unit.

The answers are provided immediately following the exercise. Check your answers before continuing to the next unit, and review the unit content as needed to ensure that you have understood the material. Do not continue to a new unit until you can answer all the questions correctly. It is up to you to review the information in each unit until you reach a comfortable level of understanding.

FINAL EXAMINATION

This course includes a written Final Examination, which you must complete and return to FEMA's Independent Study Office for scoring. To obtain credit for taking this course, you must successfully complete (75% correct) this examination regardless of whether you complete this course through self-instruction or through group instruction. You may take the Final Examination as many times as necessary.

When you have completed all the units, move on to the Final Examination (Appendix B). Take the Final Examination and send it to EMI at the address shown on page i of this Course Introduction. EMI will score your test and notify you of the results. You may also take the final exam online if you have access to the Internet. The web address is: www.fema.gov/emi/ishome.htm. Select "View Courses" and follow the instructions.

DEADLINE FOR COURSE COMPLETION

The course completion deadline for all FEMA Independent Study courses is one year from the date of enrollment. The date of enrollment is the date that the EMI Independent Study Office will use for completion of all required course work, including the Final Examination. If you do not complete this course, including the Final Examination, within that timeframe, your enrollment will be terminated.

PREREQUISITES

The *Introduction to Residential Coastal Construction* course has no prerequisites.

OTHER ICONS USED IN THIS COURSE

In addition to the icons used to identify course components, the following icons are used within the course content.

Definition — The meanings of selected technical and other special terms are given where appropriate. Definitions are also provided in Appendix A.

Warning — Warnings present critical information that will help you avoid mistakes that could result in dangerous conditions, violations of community ordinances or laws, and, possibly, delays and higher costs in a coastal construction project.

Note — Notes contain supplemental information that you may find helpful, including things to consider when undertaking a coastal construction project, suggestions that can expedite the project, and the titles and sources of other publications related to coastal construction.

Cost Consideration — Cost consideration notes discuss issues that can affect short-term and life-cycle costs associated with a coastal residential construction project.

COURSE PRE-TEST

Instructions: Use this pre-test to check your familiarity with the content of this course. When you have completed the pre-test, use the Answer Key that follows to determine in which areas you are proficient and where you need to concentrate as you complete this course.

1. Match the descriptions on the left with the terms on the right. Write one letter in each blank. (Note: There are more terms than descriptions.)

___ 1.1 More sediment transported into an area by coastal processes than is transported out.

___ 1.2 Flood elevation in communities that enforce floodplain management requirements more stringent than those of the NFIP.

___ 1.3 Measures taken to reduce, modify, offset, or share risks.

___ 1.4 Subject to wave effects, velocity flow, erosion, scour, but not as severe as in a coastal high hazard area.

___ 1.5 Area subject to inundation by a flood that has a 1% probability of being equaled or exceeded in any given year.

___ 1.6 Coastal high hazard area.

___ 1.7 Flood hazard area identified on the FIRM where the flood hazard is less than that in the SFHA.

___ 1.8 Increase in the stillwater surface near the shoreline because of the presence of breaking waves.

___ 1.9 Under the NFIP, flood elevation associated with the SFHA.

___ 1.10 Sustained action taken to reduce or eliminate long-term risk to people and property from hazards and their effects.

a. Base Flood Elevation (BFE)
b. Mitigation
c. Shoreline accretion
d. X zone
e. Risk management
f. Wave runup
g. Design Flood Elevation (DFE)
h. V zone
i. Shoreline erosion
j. Wave setup
k. Coastal A zone
l. Special Flood Hazard Area (SFHA)

2. Mark each statement true or false.

		True	False
2.1	Land use regulations may prohibit development in specified areas.		
2.2	Pre-FIRM buildings generally perform as well as or better than post-FIRM buildings during coastal flood and wind events.		
2.3	Failure to account for long-term erosion is one of the more common errors in siting coastal residential buildings.		
2.4	When assessing potential flood hazards, the effects of multiple storms should be discounted because the probability of major storms occurring close together is low.		
2.5	Siting a building atop a high bluff puts the building out of reach of coastal natural hazards.		
2.6	Meeting minimum A zone foundation and elevation requirements ensures that a building can resist coastal flood forces.		
2.7	FIRMs do not account for the future effects of long-term erosion.		
2.8	Siting a house close to a large high-rise building is one way to protect it from flood forces.		
2.9	Siting downdrift of a stabilized tidal inlet tends to protect a building from significant erosion.		
2.10	It is possible for a building to be both a structural success and a siting failure.		
2.11	It is unwise to incorporate freeboard in the design of a coastal building.		
2.12	Continuous perimeter wall foundations are best suited for V zones.		
2.13	Slab foundations in the SFHA are vulnerable to undermining by erosion and scour.		
2.14	Failure to provide a continuous load path from roof to foundation may lead to structural failure.		
2.15	Designers should maximize the use of breakaway wall enclosures below the BFE in V zones.		

		True	False
2.16	Inadequate embedment of foundation members leads to significant damage in coastal events.		
2.17	If more sediment is transported by coastal processes or human actions into a given area than is transported out, shoreline erosion results.		
2.18	Base Flood Elevations in coastal areas will be controlled by the wave crest elevation or the wave runup elevation—whichever is higher.		
2.19	FEMA's primary means of establishing Base Flood Elevations and distinguishing between V zones, A zones, and X zones is the wave height.		
2.20	In coastal areas, a building can be considered a success only if it is capable of resisting damage from coastal hazards and coastal processes over a period of decades.		
2.21	In a seismic event, a building that sustains significant damage but protects life and provides safety would be considered a building success.		
2.22	Safety factors are included in flood regulations but not wind regulations.		
2.23	Prudent siting and insurance are both risk management approaches.		
2.24	In identifying candidate coastal properties for development, past development practices in the area are one of the best indicators of potential success.		
2.25	Designers should ignore the effects of low-frequency, rare events when determining a site's potential vulnerability to hazards.		
2.26	The effects of high winds on a building are affected by the number and location of windows and the presence of shutters.		
2.27	Minor damage to the building envelope can lead to large economic losses.		
2.28	Because storms are short-lived, the amount of erosion induced by storms tends to be minor.		

3. Standards / building codes set forth requirements for the overall design of a building. (Circle one.)

4. Hydrostatic / hydrodynamic forces are imposed by standing or slowly moving water. (Circle one.)

5. To determine the probability that a building will be affected by a specific natural hazard event, the designer must know:

   a. Initial and long-term cost considerations.
   b. The owner's risk tolerance.
   c. Recurrence interval of the event and period of exposure.
   d. Federal, State, and local regulations and codes.

6. If a building is built to the minimum requirements for a flood event or a wind event, and a slightly more severe event occurs, which of the following statements best describes the damages?

   a. Most materials have some reserve capacity to resist wind loads. Wind damages are minimal.
   b. Flood damages are slightly less than wind. Only a minimal amount of damage occurs from a few inches of water in a house.
   c. The damages from wind and flood are similar and severe. When our design event is exceeded we should expect failure.
   d. We continue to see complete failure of buildings when the design wind speed is slightly exceeded. The wind damages far exceed any expected flood damages.

7. Which of the following is an example of a mitigation strategy?

   a. Buying insurance
   b. Building in a V zone rather than an A zone
   c. Enclosing the space below an elevated building
   d. Elevating a building above the minimum requirement

8. In evaluating a site's hazard vulnerability, _______________ may render simple extrapolation of historical patterns inaccurate.

   a. Effects of erosion
   b. Long-term trends
   c. Coincidence of storms with spring tides
   d. Outdated flood zone mapping

9. According to NFIP minimum requirements, newly constructed buildings in V zones must be elevated on pilings, posts, piers, or columns. The bottom of the lowest structural member must be:

   a. 3 feet above the BFE.
   b. At or above the BFE.
   c. Above the highest grade adjacent to the building by at least the depth of flooding.
   d. 1 foot above the 100-year stillwater depth.

10. According to recommended good practices for buildings in V zones and coastal A zones, the lowest horizontal structural member should be:

    a. 4 feet above the BFE and parallel to the expected wave runup.
    b. Above the highest grade adjacent to the building by twice the depth of flooding.
    c. Above the BFE and perpendicular to the expected wave crest.
    d. More than 1 foot above the 100-year stillwater depth.

11. The financial risk of building within a Coastal Barrier Resource Area is borne by:

    a. The developer.
    b. The homeowner.
    c. The NFIP.
    d. The taxpayers.

12. Which of the following causes the most severe flood damage to coastal buildings?

    a. Hydrostatic forces
    b. Wave runup
    c. Floodborne debris
    d. Breaking waves

13. Long-term erosion:

    a. Is a primary consideration in FIRM zone mapping.
    b. Shifts flood hazard zones landward.
    c. Is stopped by constructing jetties and similar structures.
    d. Will not be a threat to a building that complies with minimum State and local requirements.

14. Which of the following is a recommended siting practice for raw land development?

    a. Place a road close to the shoreline, and group small lots between it and the shoreline.
    b. Create flag-shaped lots to give direct shore access to more lots.
    c. Cluster development away from the shoreline.
    d. Align second-tier houses with the spaces between first-tier buildings.

15. Which of the following is an infill development practice to be avoided?

    a. Control pedestrian access to shoreline across dunes.
    b. Site the building farther landward than the minimum setback.
    c. Site the building immediately adjacent to an erosion-control structure or bulkhead.
    d. Design the building for easy relocation.

16. ___________ insurance is usually (but not always) part of the standard homeowner's insurance policy.

    a. Flood
    b. Wind
    c. Earthquake
    d. Comprehensive natural hazard

17. Which of the following would cause insurance for a coastal residence to be **less** costly?

    a. Including an enclosed basement in the design
    b. Siting the building in an VE zone rather than AE zone
    c. Constructing the lowest floor of an elevated building above the BFE
    d. Placing service equipment in the basement

18. Which of the following is FALSE?

    In coastal construction, exceeding code and regulatory minimums . . .
    a. Increases the homeowner's insurance premiums.
    b. Provides long-term benefits that will provide a positive lifecycle cost.
    c. Provides an added measure of safety.
    d. Adds to the cost of construction.

PRE-TEST ANSWER KEY

Instructions: Check your answers against the following answer key to determine in which areas you need to concentrate as you complete the course. Related units are listed to the right of the answers.

		Related Units								
Item	**Answer**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
1.										
1.1	**c**		x					x		
1.2	**g**	x				x				
1.3	**b**			x						x
1.4	**k**	x	x			x				
1.5	**l**	x	x			x				
1.6	**h**	x	x			x				
1.7	**d**	x	x			x				
1.8	**j**		x							
1.9	**a**	x	x			x				
1.10	**e**			x						
2.										
2.1	**T**					x				
2.2	**F**	x								
2.3	**T**				x			x		
2.4	**F**				x		x			
2.5	**F**	x			x		x			
2.6	**F**	x	x	x		x			x	
2.7	**T**	x	x					x		
2.8	**F**	x						x		
2.9	**F**	x						x		
2.10	**T**			x	x					
2.11	**F**	x		x		x				x
2.12	**F**					x				
2.13	**T**	x								
2.14	**T**	x								
2.15	**F**					x				x
2.16	**T**	x				x				
2.17	**F**		x					x		
2.18	**T**		x			x				
2.19	**T**		x			x				
2.20	**T**			x						
2.21	**T**			x						
2.22	**F**			x						
2.23	**T**			x	x				x	x
2.24	**F**				x					
2.25	**F**			x	x		x			

		Related Units								
Item	**Answer**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
2.26	**T**			x			x			
2.27	**T**						x			
2.28	**F**							x		
3.	**Building codes**					x				
4.	**Hydrostatic**						x			
5.	**c**			x						
6.	**a**			x						
7.	**d**			x		x				x
8.	**a**				x					
9.	**b**					x				
10.	**c**					x				
11.	**b**					x				
12.	**d**						x			
13.	**b**							x		
14.	**c**								x	
15.	**c**				x		x		x	
16.	**b**			x						x
17.	**c**									x
18.	**a**									x

UNIT I: HISTORICAL PERSPECTIVE

HISTORICAL PERSPECTIVE

INTRODUCTION

Through the years, FEMA and other agencies have documented and evaluated the effects of coastal flood events and the performance of coastal buildings during those events. These evaluations are useful because they provide a historical perspective on matters related to the siting, design, and construction of buildings along the Atlantic, Pacific, Gulf of Mexico, and Great Lakes coasts. They are useful also because they provide a baseline against which the impacts of later coastal flood events can be measured.

Within this context, several hurricanes, coastal storms, and other coastal flood events stand out as being especially important, either because of the nature and extent of the damage they caused or because of particular flaws they exposed in hazard identification, siting, design, construction, or maintenance practices. Many of these events—particularly the more recent ones—have been documented by FEMA in Flood Damage Assessment Reports and Building Performance Assessment Team (BPAT) reports.

This unit describes a few of the coastal flood and wind events that have affected the continental United States, Alaska, Hawaii, and U.S. Territories. Findings of post-event building performance and damage assessments are summarized, as are the lessons learned regarding factors that contribute to flood and wind damage.

UNIT OBJECTIVES

After completing this unit, you should be able to:

1.1 Define basic flood terminology.
1.2 Describe lessons learned from coastal flood disasters in relation to:
- Hazard identification.
- Siting.
- Design.
- Construction.
- Maintenance.

FLOOD TERMINOLOGY

To appreciate the lessons that can be learned from coastal flood disaster history, it is helpful to have an understanding of basic flood terminology. Some key terms are briefly explained below. More detailed discussions will be provided in later units.

NFIP, FIRM, and SFHA

FEMA's **National Flood Insurance Program (NFIP)** flood insurance zone designations shown on **Flood Insurance Rate Maps (FIRMs)** indicate the nature and magnitude of the flood hazard in a given area.

Communities who participate in the NFIP use these insurance zone designations to regulate construction in identified **Special Flood Hazard Areas (SFHAs)**—areas subject to inundation by a flood that has a one percent probability of being equaled or exceeded in any given year (also referred to as the *base flood*).

BFE and DFE

The flood elevation associated with the SFHA is termed the **Base Flood Elevation (BFE).** This course uses the term BFE when it discusses NFIP elevation requirements.

The term **Design Flood Elevation (DFE)** is used to account for situations where communities choose to enforce floodplain management requirements more stringent than those of the NFIP.

For example, many communities require **freeboard** above the BFE, and some regulate to more severe flood conditions. Where a community chooses to exceed NFIP minimum requirements, the DFE will be higher than the BFE. Where a community's requirements are the same as the NFIP requirements, the DFE and BFE will be identical.

def-a-

Under the NFIP, **freeboard** is a factor of safety, usually expressed in feet above flood level, that is applied for the purposes of floodplain management. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than those calculated for a selected flood, such as the base flood.

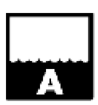
FLOOD ZONES

Currently, the NFIP uses two categories of zones to differentiate between flood hazards in SFHAs: **V zones** and **A zones**. The *Coastal Construction Manual* also describes a third zone within the SFHA: **coastal A zone.** Areas outside the SFHA appear as shaded or unshaded **X zones** (B or C zones on older FIRMs). The zone icons shown with the descriptions below are provided as visual guides throughout this course to help you find information specific to your needs.

V zone — The portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources. The V zone is also referred to as the **Coastal High Hazard Area.** The minimum NFIP regulatory requirements regarding construction in V zones are more stringent than those regarding A-zone construction. V-zone requirements account for the additional hazards associated with high-velocity wave action, such as the impact of waves and waterborne debris and the effects of severe scour and erosion.

Coastal A zone — The portion of the SFHA landward of a V zone or landward of an open coast without mapped V zones (e.g., the shorelines of the Great Lakes) in which the principal sources of flooding are astronomical tides, storm surges, seiches, or tsunamis, not riverine sources. Like the flood forces in V zones, those in coastal A zones are highly correlated with coastal winds or coastal seismic activity. Coastal A zones may therefore be subject to wave effects, velocity flows, erosion, scour, or combinations of these forces. The forces in coastal A zones are not as severe as those in V zones but are still capable of damaging or destroying buildings on inadequate foundations.

Although the NFIP regulations do not differentiate between coastal and non-coastal A zones, the *Coastal Construction Manual* recommends that buildings in coastal A zones be designed and constructed to be more resistant to flood forces—including wave effects, velocity flows, erosion, and scour—than buildings in non-coastal A zones.



Non-Coastal A zone — Portions of the SFHA in which the principal source of flooding is runoff from rainfall, snowmelt, or a combination of both. In non-coastal A zones, flood waters may move slowly or rapidly, but waves are usually not a significant threat to buildings. However, in extreme cases (e.g., the 1993 Midwest floods), long fetches and high winds have generated damaging waves in non-coastal A zones. Designers in non-coastal A zones subject to waves may wish to employ some of the methods described in the *Coastal Construction Manual*.

WARNING

Areas outside the SFHA can still be subject to flooding and erosion. Designers should not ignore potential flooding and erosion hazards in areas labeled Zone X, Zone B, or Zone C.

X zone — Areas where the flood hazard is less than that in the SFHA. Shaded X zones shown on recent FIRMs (B zones on older FIRMs) designate areas subject to inundation by the flood with a 0.2 percent annual probability of being equaled or exceeded (the 500-year flood). Unshaded X zones (C zones on older FIRMs) designate areas where the annual exceedance probability of flooding is less than 0.2 percent.

SELF-CHECK REVIEW: FLOOD TERMINOLOGY

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any question incorrectly, you should review the related material before continuing.

1. Some States and communities require that buildings be elevated <u>above</u> the BFE. This additional elevation is called:

   ____

2. Base Flood Elevation (BFE) is: (mark the correct answer)

   _____ The flood elevation associated with a Special Flood Hazard Area.

   _____ The flood elevation used by communities that exceed NFIP minimum requirements.

   _____ The flood elevation with a factor of safety added for floodplain management purposes.

3. Which of the following flood hazard zones has the most stringent NFIP regulatory requirements?

   _____ Coastal A zone

   _____ V zone

   _____ X zone

   _____ Non-coastal A zone

4. The flood forces in a _____________________ or ________________________ zone are highly correlated with coastal winds or coastal seismic activity.

ANSWER KEY

1. Some States and communities require that buildings be elevated above the BFE. This additional elevation is called **freeboard.**

2. Base Flood Elevation (BFE) is:

   ✓ **The flood elevation associated with a Special Flood Hazard Area.**
   The flood elevation used by communities that exceed NFIP minimum requirements (i.e., that has an added factor of safety) is termed Design Flood Elevation (DFE).

3. Which of the following flood hazard zones has the most stringent NFIP regulatory requirements?

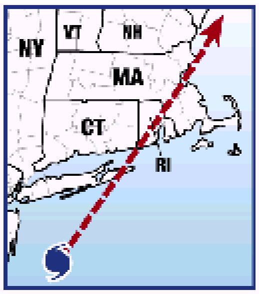
   ✓ **V zone**.
   (Note: NFIP requirements do not currently distinguish between coastal and non-coastal A zones.)

4. The flood forces in a **V zone** or **coastal A zone** are highly correlated with coastal winds or coastal seismic activity.

COASTAL FLOOD AND WIND EVENTS

NORTHEAST ATLANTIC COAST — *Hurricane Bob — Buzzards Bay Area, Massachusetts August 19, 1991*

Figure 1-1.
Track of Hurricane Bob



Hurricane Bob, a Category 2 hurricane, followed the track shown in Figure 1-1. Although undistinguished by its intensity (not even ranking in the 65 most intense hurricanes to strike the United States during the 20th century), it caused $1.75 billion in damage (1996 dollars), ranking 18th in terms of damage (see Fig. 1-2).

NOTE

Hurricane categories reported in this course should be interpreted cautiously. Storm categorization based on wind speed may differ from that based on barometric pressure or storm surge. Also, storm effects vary geographically—only the area near the point of landfall will experience effects associated with the reported storm category.

A FEMA Flood Damage Assessment Report documented damage in the Buzzards Bay area. The wind speeds during Hurricane Bob were below the design wind speed and the storm tide (corresponding to a 15-year tide) was at least 5 feet below the Base Flood Elevation (BFE). Nevertheless the results of the storm allowed an evaluation of the performance of different foundation types.

Figure 1-2.
Hurricane Bob (1991) destroyed 29 homes along this reach of Mattapoisett, MA.

Post-hurricane findings regarding foundations included:

- Many buildings in the area had been elevated on a variety of foundations, either in response to Hurricane Carol (1954) or the 1978 northeaster, or as a result of community-enforced National Flood Insurance Program (NFIP) requirements.

- Buildings constructed before the date of the Flood Insurance Rate Map (FIRM) for each community—referred to as ***pre*-FIRM buildings—that had not been elevated, or that had not been elevated sufficiently, suffered major damage or complete destruction;** some destroyed buildings appeared to have had **insufficient foundation embedment**.

- Post-FIRM buildings (i.e., built after the date of the FIRM) and pre-FIRM **buildings with sufficient elevation performed well** during the storm. Where water was able to pass below buildings unobstructed by enclosed foundations, damage was limited to loss of decks and stairs.

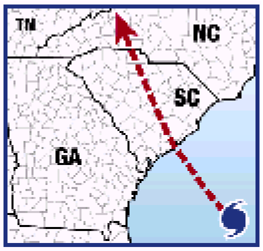
- Foundation types that appeared to survive the storm without structural damage included the following:
  - Cast-in-place concrete columns, at least 10 inches in diameter.
  - Masonry block columns with adequate embedment depth.
  - 10-inch-thick shear walls with a flow-through configuration (open ends) or modified to include garage doors at each end of the building (intended to be open during a storm).

SOUTHEAST ATLANTIC COAST AND CARIBBEAN

Hurricane Hugo — South Carolina, 1989

Hurricane Hugo was one of the strongest hurricanes known to have struck South Carolina. Widespread damage resulted from a number of factors: flooding, waves, erosion, debris, and wind. In addition, building and contents damage caused by rainfall penetration into damaged buildings, several days after the hurricane itself, often exceeded the value of direct hurricane damage.

Figure 1-3.
Track of Hurricane Hugo



Damage from, and repairs following, Hugo were documented in a FEMA Flood Damage Assessment Report and a Follow-Up Investigation Report. The reports concluded the following:

- Post-FIRM buildings that were both properly constructed and elevated survived the storm (see Fig. 1-4). These buildings stood out in sharp contrast to pre-FIRM buildings and to post-FIRM buildings that were poorly designed or constructed.

Figure 1-4.
Hurricane Hugo (1989), Garden City Beach, SC. House on pilings survived while others did not.

- Many **buildings elevated on masonry or reinforced concrete columns supported by shallow footings** failed. In some instances, the columns were undermined; in others, the columns failed as a result of poor construction (see Fig. 1-5).

**Figure 1-5.
Hurricane Hugo (1989), South Carolina. Failure of reinforced masonry column.**

- Several pile-supported buildings **not elevated entirely above the wave crest** showed damage or destruction of floor beams, floor joists, floors, and exterior walls.

- Some of the most severely damaged buildings were in the second, third, and fourth rows back from the shoreline, in **areas mapped as A zones on the FIRMs** for the affected communities. Consideration should be given to more stringent design standards for coastal A zones.

- The storm exposed many **deficiencies in residential roofing practices:** improper flashing, lack of weather-resistant ridge vents, improper shingle attachment, and failure to replace aging roofing materials.

Hurricane Andrew — Dade County, Florida
August 24, 1992

Figure 1-6.
Track of Hurricane Andrew

Hurricane Andrew was a strong Category 4 hurricane when it made landfall in southern Dade County (see Fig. 1-6) and caused over $26 billion in damage. The storm was the third most intense hurricane to strike the United States in the 20th century and remains the most costly natural disaster to date.

The storm surge and wave effects of Andrew were localized and minor when compared with the damage from wind. A FEMA Building Performance Assessment Team (BPAT) evaluated damage to one- to two-story wood-frame and/or masonry residential construction in Dade County. In its report, the team concluded the following:

- Buildings designed and constructed with components and connections that transferred loads from the envelope to the foundation performed well. When these critical "**load transfer paths**" were not in evidence, damage ranged from considerable to total, depending on the type of architecture and construction.

- Catastrophic **failures of light wood-frame buildings** were observed more frequently than catastrophic failures of other types of buildings constructed on site. Catastrophic failures resulted from a number of factors:

  - Lack of bracing and load path continuity at wood-frame gable ends.
  - Poor fastening and subsequent separation of roof sheathing from roof trusses.
  - Inadequate roof truss bracing or bridging (see Fig. 1-7).
  - Improper sillplate-to-foundation or sillplate-to-masonry connections.

Figure 1-7.
Hurricane Andrew (1992). Roof structure failure from inadequate bracing.

- **Failures in masonry wall buildings** were usually attributable to one or more of the following:

  - Lack of or inadequate vertical wall reinforcing.
  - Poor mortar joints between masonry walls and monolithic slab pours.
  - Lack of or inadequate tie beams, horizontal reinforcement, tie columns, and tie anchors.
  - Missing or misplaced hurricane straps between the walls and roof structure.

- **Composite shingle and tile** (extruded concrete and clay) **roofing systems** sustained major damage during the storm. Failures usually resulted from improper attachment, impacts of windborne debris, or mechanical failure of the roof covering itself.

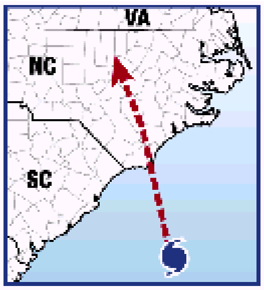
- **Loss of roof sheathing** and consequent rainfall penetration through the roof magnified damage by a factor of five over that suffered by buildings whose roofs remained intact or suffered only minor damage.

- **Exterior wall opening failures** (particularly garage doors, sliding glass doors, French doors, and double doors) frequently led to internal pressurization and structural damage. Storm shutters and the covering of windows and other openings reduced such failures significantly.

- **Quality of workmanship** played a major role in building performance. Many well-constructed buildings survived the storm intact, even though they were adjacent to or near other buildings that were totally destroyed by wind effects.

Hurricane Fran — Southeastern North Carolina September 5, 1996

Figure 1-8.
Track of Hurricane Fran



Hurricane Fran, a Category 3 hurricane, made landfall near Cape Fear, North Carolina (see Figure 1-8). Erosion and surge damage to coastal construction were exacerbated by the previous effects of a weaker storm, Hurricane Bertha, which struck 2 months earlier. A FEMA BPAT reviewed building failures and successes and concluded the following:

- Many buildings in **mapped A zones were exposed to conditions associated with V zones**, which resulted in building damage and failure from the effects of erosion, high-velocity flow, and waves. Remapping of flood hazard zones after the storm, based on analyses that accounted for wave runup, wave setup, and dune erosion, resulted in a significant landward expansion of V zones.

- Hundreds of oceanfront houses were destroyed by the storm, mostly as a result of **insufficient pile embedment and wave effects.** Most of the destroyed buildings had been constructed under an older building code provision that required that piling foundations extend only 8 feet below the original ground elevation. Erosion around the destroyed oceanfront foundations was typically 5–8 feet. In contrast, foundation failures were rare in similar, piling-supported buildings located farther from the ocean and not subject to erosion.

- A significant reduction in building losses was observed in similarly sized oceanfront buildings constructed after the North Carolina Building Code was amended in 1986 to require a minimum embedment to –5.0 feet National Geodetic Vertical Datum (NGVD) or 16 feet below the original ground elevation (which is shallower) for pilings near the ocean.

  A study of Topsail Island found that 98 percent of post-1986 oceanfront houses (200 of 205) remained after the hurricane. Ninety-two percent of the total displayed no significant damage to the integrity of the piling foundation. However, five percent (11) were found to have **leaning foundations** (see Figure 1-9). A nondestructive test used to measure piling length in a partial sample of the leaning buildings revealed that none of the leaning pilings tested met the required piling embedment standard. Many were much shorter. However, given the uncertainty of predicting future erosion, the BPAT recommended that consideration be given to a piling embedment standard of –10.0 feet NGVD.

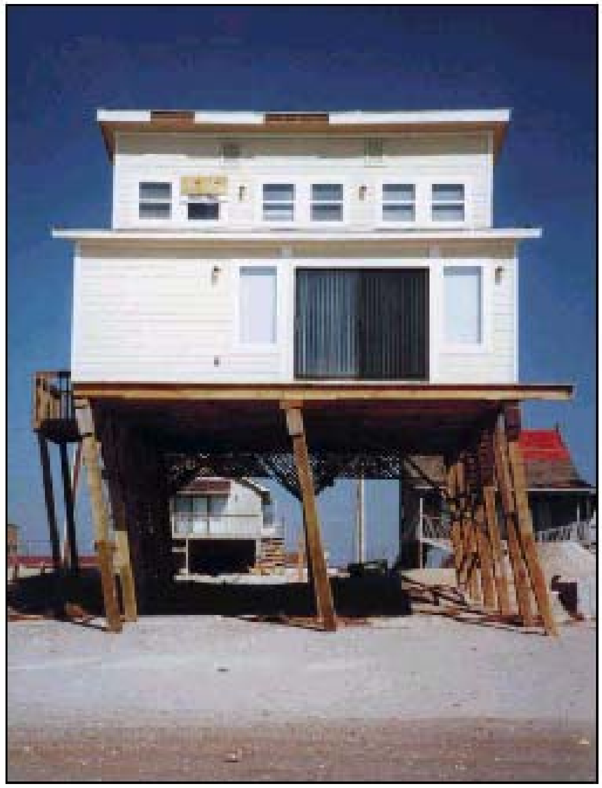


Figure 1-9. Hurricane Fran (1996). Many oceanfront houses built before the enactment of the 1986 North Carolina State Code were found to be leaning or destroyed.

- The BPAT noted a prevalence of **multi-story decks and roofs supported by posts resting on elevated decks;** these decks, in turn, were often supported by posts or piles with only 2–6 feet of embedment. Buildings with such deck and roof structures often sustained extensive damage when flood forces caused the deck to separate from the main structure or caused the loss of posts or piles and left roofs unsupported.

- Design or construction flaws were often found in **breakaway walls.** These flaws included:

  - Excessive connections between breakaway panels and the building foundation (however, the panels were observed generally to have failed as intended).

  - Placement of breakaway wall sections immediately seaward of foundation cross-bracing.

  - Attachment of utility lines to breakaway wall panels.

- Wind damage to **poorly connected porch roofs** and **large roof overhangs** was frequently observed.

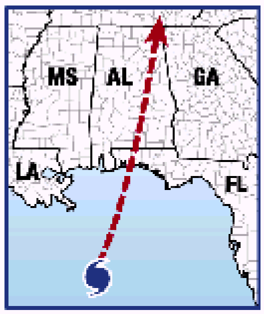
- **Corrosion of galvanized metal connectors** (e.g., hurricane straps and clips) may have contributed to the observed wind damage to elevated buildings.

- As has been observed time and time again following coastal storms, properly designed and constructed coastal residential buildings generally perform well. Damage to well-designed, well-constructed buildings usually results from the effects of **long-term erosion, multiple storms, large debris loads** (e.g., parts of damaged adjacent houses), or **storm-induced inlet formation/modification.**

GULF OF MEXICO COAST

Hurricane Opal — Florida Panhandle, October 4, 1995

Figure 1-10.
Track of Hurricane Opal



Hurricane Opal was one of the most damaging hurricanes to ever affect Florida. In fact, the State concluded that more coastal buildings were damaged or destroyed by the effects of flooding and erosion during Opal than in all other coastal storms affecting Florida in the previous 20 years combined. Erosion and structural damage were exacerbated by the previous effects of Hurricane Erin, which hit the same area just one month earlier.

The Florida Bureau of Beaches and Coastal Systems (FBBCS) conducted a post-storm survey to assess structural damage to major residential and commercial buildings constructed seaward of the Florida Coastal Construction Control Line (CCCL). The survey revealed that out of 1,942 existing buildings, 651 had sustained some amount of structural damage. None of these damaged buildings had been permitted by FBBCS (all pre-dated CCCL permit requirements). Among the 576 buildings for which FBBCS had issued permits, only two sustained structural damage as a result of Opal, and those two did not meet the State's currently implemented standards.

A FEMA BPAT evaluated damage in the affected area and concluded the following:

- Damaged buildings generally fell into one of the following four categories:
  - Pre-FIRM buildings founded on **slabs or shallow footings** and located in mapped V zones.
  - Post-FIRM buildings outside mapped V zones and on slab or shallow footing foundations, but subject to high-velocity wave action, high-velocity flows, erosion, impact by floodborne debris, and/or overwash.
  - **Poorly designed or constructed** post-FIRM elevated buildings.
  - Pre-FIRM and post-FIRM buildings dependent on **failed seawalls or bulkheads** for protection and foundation support.

- Oceanfront foundations were exposed to 3–7 feet of vertical erosion in many locations (see Figure 1-11). **Lack of foundation embedment**, especially in the case of older elevated buildings, was a significant contributor to building loss.

Figure 1-11. Hurricane Opal (1995), Bay County, Florida. Building damage from erosion and undermining.

- Two communities enforced **freeboard and V zone foundation requirements in coastal A zones.** In these communities, the performance of buildings subject to these requirements was excellent.

- State-mandated elevation, foundation, and construction requirements seaward of the CCCL **exceeded minimum NFIP requirements** and undoubtedly reduced storm damage.

The National Association of Home Builders (NAHB) Research Center also conducted a survey of damaged houses. In general, the survey revealed that newer wood-frame construction built to varying degrees of compliance with the requirements of the *Standard for Hurricane Resistant Residential Construction SSTD 10-93*, or similar construction requirements, performed very well overall, with virtually no wind damage. In addition, the Research Center found that even older houses not on the immediate coastline performed well, partly because the generally wooded terrain helped shield these houses from the wind.

PACIFIC COAST *Winter Coastal Storms — California, Oregon, and Washington, 1982–83*

A series of El Nino-driven coastal storms caused widespread and significant damage to beaches, cliffs, and buildings along the coast between Baja California and Washington. These storms were responsible for more coastal erosion and property damage from wave action than had occurred since the winter of 1940–41. One assessment of winter storm damage in the Malibu, California, area found the following storm effects:

- Many beaches were stripped of their sand, resulting in 8–12 feet of vertical **erosion**.
- Bulkheads failed when **scour** exceeded the depth of embedment and backfill was lost.
- Many oceanfront houses were damaged or destroyed, particularly older houses.
- **Sewage disposal systems that relied on sand for effluent filtration** were damaged or destroyed.
- Battering by **floating and wave-driven debris** (pilings and timbers from damaged piers, bulkheads, and houses) caused further damage to coastal development.

A 1985 conference on coastal erosion, storm effects, siting, and construction practices was organized largely as a result of the 1982–83 storms. The proceedings highlighted many of the issues and problems associated with construction along California's coast:

- The need for high-quality data on coastal erosion and storm effects.
- The vulnerability of houses constructed atop coastal bluffs, out of mapped floodplains, but subject to destruction by erosion or collapse of the bluffs.
- The benefits, adverse impacts, and costs associated with various forms of bluff stabilization, erosion control, and beach nourishment.
- The need for rational siting standards in coastal areas subject to erosion, wave effects, or bluff collapse.

Winter Coastal Storms — California and Oregon, 1997–98

Another series of severe El Nino-driven coastal storms battered the Pacific coast. The distinguishing feature of the 1997–98 event was rainfall. The California Coastal Commission reported widespread soil saturation, which resulted in thousands of incidents of debris flows, landslides, and bluff collapse (see Figure 1-12).

Figure 1-12.
Winter Coastal storms, California and Oregon (1997–1998). House in Pacifica, CA, undermined by bluff erosion.

Alaska Tsunami — March 27, 1964

This tsunami, generated by the 1964 Good Friday earthquake, affected parts of Washington, Oregon, California, and Hawaii; however, the most severe effects were near the earthquake epicenter in Prince William Sound, southeast of Anchorage, Alaska.

The tsunami flooded entire towns and caused extensive damage to waterfront and upland buildings (see Figure 1-13). Tsunami runup reached approximately 20 feet above sea level in places, despite the fact that the main tsunami struck near the time of low tide. Also, liquefaction of coastal bluffs in Anchorage resulted in the loss of buildings.

Figure 1-13. 1964 Good Friday earthquake. Damage in Kodiak City, Alaska, caused by the tsunami of the 1964 Alaskan earthquake.

The 1968 report provided recommendations for land and waterfront buildings, including the following:

- Buildings on exposed land should have deep foundations of reinforced concrete or of the beam-and-rafter type, to resist scour and undermining.
- Buildings should be oriented, if possible, to expose their shorter sides to potential wave inundation.
- Reinforced concrete or steel-frame buildings with shearwalls are desirable.
- Wood-frame buildings should be located in the lee of more substantial buildings.

- Wood-frame buildings should be well secured to their foundations and have corner bracing at ceiling level.

- Wood-frame buildings in very exposed, low-lying areas should be designed so that the ground floor area may be considered expendable, because wetting damage would be inevitable. Elevated “stilt” designs of aesthetic quality should be considered.

- Tree screening should be considered as a buffer zone against the sea and for its aesthetic value.

SELF-CHECK REVIEW: COASTAL FLOOD AND WIND EVENTS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any questions incorrectly, you should review the related material before continuing.

1. Pre-FIRM buildings generally perform as well as or better than post-FIRM buildings during coastal flood and wind events.

   True False

2. Damage to well designed, well constructed buildings usually results from the effects of long-term erosion, multiple storms, large debris loads, or storm-induced inlet formation/modification.

   True False

3. What are some of the most common design/construction problems that have resulted in major building damage and destruction during hurricanes? Name at least three.

4. Why have buildings in mapped A zones often sustained significant damage during coastal events?

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Your answers to questions 3 and 4 may be slightly different, but they should include the same main points.

1. Pre-FIRM buildings generally perform as well as or better than post-FIRM buildings during coastal flood and wind events.

   False

2. Damage to well-designed, well-constructed buildings usually results from the effects of long-term erosion, multiple storms, large debris loads, or storm-induced inlet formation/modification.

   True

3. What are some of the most common design/construction problems that have resulted in major building damage and destruction during hurricanes? Name at least three.

   Your answer should have included at least three of the following:
   - **Insufficient foundation embedment**
   - **Insufficient elevation**
   - **Failure to create a continuous load transfer path**
   - **Poor quality of workmanship or failure of the building envelope**
   - **Building on slab foundations or on concrete columns with shallow footings**
   - **Deficiencies in residential roofing practices**
   - **Design or construction flaws in breakaway walls**
   - **Dependence on seawalls or bulkheads for protection and foundation support**

4. Why have buildings in mapped A zones often sustained significant damage during coastal events?

   Significant damage occurred because these buildings were exposed to conditions associated with V zones, including erosion, high-velocity flow, and waves.

LESSONS LEARNED

Although flood events and physiographic features vary throughout the coastal areas of the United States, post-event damage reports show that the nature and extent of damage caused by coastal flood events are remarkably similar. Moreover, review of these reports shows that the types of damage experienced today are, in many ways, similar to those experienced decades ago. It is clear that although we have improved many aspects of coastal construction over the years, we make many of the same mistakes over and over.

NOTE

Although there is no statistical basis for the conclusions presented in this section, they are based on numerous post-event damage assessments, which serve as a valuable source of information on building performance and coastal development practices.

The conclusions of post-event assessments can be classified according to those factors that contribute to both building damage and successful building performance:

- Hazard identification
- Siting
- Design
- Construction
- Maintenance

Reduction of building damages in coastal areas will require attention to these conclusions and coordination between owners, designers, buildings, and local officials.

Conclusions related to these five factors are presented in the tables that follow.

LESSONS RELATED TO HAZARD IDENTIFICATION

The following table summarizes lessons learned from coastal flood and wind events with regard to hazard identification issues.

ISSUE	CONCLUSION
Multiple Flood Hazards	Flood damage can result from the effects of short- and long-term increases in water levels (storm surge, tsunami, seiche, sea-level rise), wave action, high-velocity flows, erosion, and debris. Addressing all potential flood hazards at a site will help reduce the likelihood of building damage or loss.
Multiple Events	Failure to consider the effects of multiple storms or flood events may lead to an underestimation of flood hazards in coastal areas. Coastal buildings left intact by one storm may be vulnerable to damage or destruction by a second storm.
Long-Term Erosion	Long-term erosion can increase coastal flood hazards through time, causing loss of protective beaches, dunes, and bluffs, and soils supporting building foundations. Failure to account for long-term erosion is one of the more common errors made by those siting and designing coastal residential buildings.
Coastal A Zones	Flood hazards in areas mapped as A zones on coastal FIRMs can be much greater than flood hazards in riverine A zones. There are two reasons for this situation: 1. Waves 2–3 feet high (i.e., too small for an area to be classified as a V zone, but still capable of causing structural damage and erosion) will occur during base flood conditions in many coastal A zones. 2. Aging FIRMs may fail to keep pace with changing site conditions (e.g., long-term erosion, loss of dunes during previous storms) and revised flood hazard mapping procedures. Therefore, minimum A-zone foundation and elevation requirements should not be assumed adequate to resist coastal flood forces without a review of actual flood hazards. The concept of a “coastal A zone” with elevation and foundation requirements closer to those of V zones should be considered. **WARNING** FIRMs do not account for future effects of long-term erosion. Users are cautioned that all mapped flood hazard zones (V, A, and X) in areas subject to long-term erosion will likely underestimate the extent and magnitude of actual flood hazards that a coastal building will experience over its lifetime.

ISSUE	CONCLUSION
Effects of Topography on Wind Speeds	Failure to consider the effects of topography (and changes in topography—e.g., bluff erosion) on wind speeds can lead to underestimation of wind speeds that will be experienced during the design event. Siting buildings on high bluffs or near high-relief topography requires special attention by the designer.
Slope Stability	In coastal bluff areas, consideration of the potential effects of surface and subsurface drainage, removal of vegetation, and site development activities can help reduce the likelihood of problems resulting from slope stability hazards and landslides.
Septic Systems	Drainage from septic systems on coastal land can destabilize coastal bluffs and banks, accelerate erosion, and increase the risk of damage and loss to coastal buildings.
Groundwater in Bluffs	Vertical cracks in the soils of some cohesive bluffs cause a rapid rise of groundwater in the bluffs during extremely heavy and prolonged precipitation events and rapidly decrease the stability of such bluffs.
Seismic Hazards	Some coastal areas are also susceptible to seismic hazards. Although the likelihood of flood and seismic hazards acting simultaneously is small, each hazard should be identified carefully and factored into siting, design, and construction practices.

SELF-CHECK REVIEW: HAZARD IDENTIFICATION LESSONS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any questions incorrectly, you should review the related material before continuing.

1. When siting atop high coastal bluffs, what hazards should receive special attention? Name at least two.

2. Addressing all potential ______________________________ at a site will help reduce the likelihood of building damage or loss.

3. _____________________________________ over time can cause loss of protective beaches, dunes, and bluffs and soil supporting building foundations.

4. Meeting minimum A zone foundation and elevation requirements is generally adequate to resist coastal flood forces.

   True False

5. FIRMs do not account for the future effects of long-term erosion.

   True False

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. When siting atop high coastal bluffs, what hazards should receive special attention? Name at least two.

   Your answer should have included at least two of the following:
   - **Effects of topography on wind speeds**
   - **Potential effects on slope stability of surface and subsurface drainage, removal of vegetation, and site development activities**
   - **Drainage from septic systems**
   - **Vertical cracks that can cause rapid rise of groundwater**

2. Addressing all potential **hazards** at a site will help reduce the likelihood of building damage or loss.

3. **Long-term erosion** over time can cause loss of protective beaches, dunes, and bluffs and soil supporting building foundations.

4. Meeting minimum A zone foundation and elevation requirements is generally adequate to resist coastal flood forces.

   False.
   Minimum A-zone foundation and elevation requirements should not be assumed adequate to resist coastal flood forces without a review of actual flood hazards.

5. FIRMs do not account for the future effects of long-term erosion.

   True.
   All mapped flood hazard zones (V, A, and X) in areas subject to long-term erosion will likely underestimate the extent and magnitude of actual flood hazards that a coastal building will experience over its lifetime.

LESSONS RELATED TO SITING

The following table summarizes lessons learned from coastal flood and wind events with regard to siting issues.

ISSUE	CONCLUSION
Building Close to the Shoreline	Building close to the shoreline is a common, but possibly poor, siting practice. It may render a building more vulnerable to wave, flood, and erosion effects; may remove any margin of safety against multiple storms or erosion events; and may require moving, protecting, or demolishing the building if flood hazards increase over time.
Poor Siting of Elevated Buildings	In coastal areas subject to long-term or episodic erosion, poor siting often results in otherwise well-built elevated buildings standing on the active beach. While a structural success, such buildings are generally uninhabitable (because of the loss of utilities and access). This situation can also lead to conflicts over beach use and increase pressure to armor or renourish beaches (controversial and expensive measures).
Building Close to Other Structures	Building close to other structures may increase the potential for damage from flood, wind, debris, and erosion hazards. Of particular concern is the siting of homes or other small buildings adjacent to large, engineered high-rise structures. The larger structures can redirect and concentrate flood, wave, and wind forces and have been observed to increase flood and wind forces as well as scour and erosion.
Siting Too Close to Protective Structures	Depending on erosion or flood protection structures often leads to building damage or destruction. Seawalls, revetments, berms, and other structures may not afford the required protection during a design event and may themselves be vulnerable as a result of erosion and scour or other prior storm impacts. Siting too close to these structures may also preclude or make difficult any maintenance of the protective structure.
Siting on Top of Erodible Dunes and Bluffs	Siting buildings on the tops of erodible dunes and bluffs renders those buildings vulnerable to damage caused by the undermining of foundations and the loss of supporting soil around vertical foundation members.
Siting Downdrift of Stabilized Tidal Inlets	Siting buildings on the downdrift shoreline of an inlet whose location has been fixed by jetties often places the buildings in an area subject to increased erosion rates.
Depending on Barrier Islands	Siting along shorelines protected against wave attack by barrier islands or other land masses does not guarantee protection against flooding. In fact, storm surge elevations along low-lying shorelines in embayments are often higher than storm surge elevations on open coast shorelines.

SELF-CHECK REVIEW: SITING LESSONS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any questions incorrectly, you should review the related material before continuing.

1. Building close to ____________________________ may require moving, protecting, or demolishing the building if flood hazards increase over time.

2. Give an example of a situation in which a building would be considered a structural success but a siting failure.

3. Why is it unwise to site buildings close to protective structures?

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Your answers may be slightly different, but they should include the same main points.

1. Building close to **the shoreline** may require moving, protecting, or demolishing the building if flood hazards increase over time.

2. Give an example of a situation in which a building would be considered a structural success but a siting failure.

   A structurally sound elevated building sited too close to the shoreline will be a siting failure if erosion leaves it standing on the active beach without access or utilities.

3. Why is it unwise to site buildings close to protective structures?

   - **Seawalls, revetments, berms, and other structures may not provide the needed protection during a design event.**
   - **The structures themselves may become vulnerable as a result of erosion, scour, or other prior storm impacts.**
   - **Siting too close to the structure may also interfere with maintenance of the structure.**

LESSONS RELATED TO DESIGN

The following table summarizes lessons learned from coastal flood and wind events with regard to design issues.

ISSUE	CONCLUSION
Shallow Spread Footing and Slab Foundations	Use of shallow spread footing and slab foundations in areas subject to wave impact and/or erosion can result in building collapse, even during minor flood or erosion events. Because of the potential for undermining by erosion and scour, these foundations may not be appropriate for some coastal A zones and some coastal bluff areas outside the mapped floodplain.
Continuous Perimeter Wall Foundations	In areas subject to wave impact and/or erosion, the use of continuous perimeter wall foundations, such as crawlspace foundations (especially those constructed of unreinforced masonry) may result in building damage, collapse, or total loss.
Inadequate Embedment	Inadequate depth of foundation members (e.g., pilings not embedded deeply enough, shallow footings supporting masonry and concrete walls and columns) is a common cause of failure in elevated one- to four-family residential buildings.
Lack of Freeboard	Elevating a building sufficiently will help protect the superstructure from damaging wave forces. Designs should incorporate freeboard above the required elevation of the lowest floor or bottom of lowest horizontal member.
Non-Corrosion-Resistant Connectors	Failure to use corrosion-resistant structural connectors (e.g., wooden connectors, stainless steel connectors, or galvanized connectors made of heavier gauge metal or with thicker galvanizing) can compromise structural integrity and may lead to building failures under less than design conditions.

ISSUE	CONCLUSION
Corrosion of Metal Building Components	Corrosion of metal building components is accelerated by salt spray and breaking waves. Nails, screws, sheet-metal connector straps, and truss plates are the most likely to be threatened by corrosion.
Lack of a Continuous Load Path	Failure to provide a continuous load path using adequate connections between all parts of the building, from roof to foundation, may lead to structural failure.
Multi-Story Decks/Roofs	Multi-story decks/roofs supported by inadequately embedded vertical members can lead to major structural damage, even during minor flood and erosion events. Either roof overhangs should be designed to remain intact without vertical supports, or supports should be designed to the same standards as the main foundation. Decks must be designed to withstand all design loads or should be designed so that they do not cause damage to the main building when they fail.
Porch Roofs and Overhangs	Failure to adequate connect porch roofs and to limit the size of roof overhangs can lead to extensive damage to the building envelope.
Low-Slope Roofs	Many coastal communities have building height restrictions that, when coupled with building owners' desires to maximize building size and areas, encourage the use of low-slope roofs. These roofs can be more susceptible to wind damage and water penetration problems.
Unbraced Gable Ends and Wide Overhangs	Roof designs that incorporate gable ends (especially unbraced gable ends) and wide overhangs are susceptible to failure unless adequately designed and constructed for the expected loads. Alternative designs that are more resistant to wind effects should be used in coastal areas.
Roof Sheathing and Roof Coverings	Many commonly used residential roofing techniques, systems, and materials are susceptible to damage from wind and windborne debris. Designs should pay special attention to the selection and attachment of roof sheathing and roof coverings in coastal areas.

ISSUE	CONCLUSION
Protection of Building Envelope	Protection of the entire building envelope is necessary in high-wind areas. Therefore, proper specification of windows, doors, and their attachment to the structural frame is essential. Protecting openings with temporary or permanent storm shutters and the use of impact-resistant (e.g., laminated) glass will help protect the building envelope and reduce damage caused by wind, windborne debris, and rainfall penetration.
Treatment of Below-BFE Areas	Designs should maximize the use of lattice and screening below the BFE and minimize the use of breakaway wall enclosures in V zones and solid wall enclosures in A zones. Post-construction conversion of enclosures to habitable space remains a common violation of floodplain management requirements and is difficult for communities and States to control.
Swimming Pools	The design and placement of swimming pools can affect the performance of adjacent buildings. Pools should not be structurally attached to buildings, because an attached pool can transfer flood loads to the building. Building foundation designs should also account for increased flow velocities, wave ramping, wave deflection, and scour that can result from the redirection of flow by an adjacent pool.

SELF-CHECK REVIEW: DESIGN LESSONS

Instructions: Answer the following question. Then turn the page to check your answers. If you answered incorrectly, you should review the related material before continuing.

1. Place a check mark next to design alternatives that should generally be AVOIDED in coastal areas subject to wave impact.

   _____ Shallow spread footings

   _____ Slab foundations

   _____ Elevation on pilings

   _____ Corrosion-resistant connectors

   _____ Continuous-perimeter wall foundations

   _____ Deck supports designed to the same standards as the main foundation

   _____ Continuous load path from roof to foundation

   _____ Extensive use of breakaway wall enclosures below the BFE

   _____ Attachment of a swimming pool to the building

   _____ Shutters and impact-resistant glass on wall openings

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

1. Place a check mark next to design alternatives that should generally be AVOIDED in coastal areas subject to wave impact.

   ✓ **Shallow spread footings**

   ✓ **Slab foundations**

   _____ Elevation on pilings

   _____ Corrosion-resistant connectors

   ✓ **Continuous-perimeter wall foundations**

   _____ Deck supports designed to the same standards as the main foundation

   _____ Continuous load path from roof to foundation

   ✓ **Extensive use of breakaway wall enclosures below the BFE**

   ✓ **Attachment of a swimming pool to the building**

   _____ Shutters and impact-resistant glass on wall openings

LESSONS RELATED TO CONSTRUCTION

The following table summarizes lessons learned from coastal flood and wind events with regard to construction issues.

ISSUE	CONCLUSION
Poorly Made Structural Connections	Poorly made structural connections, particularly in wood-frame and masonry structures (e.g., pile/pier/column to beam, joist to beam) have been observed to cause the failure of residential structures throughout the coastal areas of the United States.
Fastener Selection	Connections must be made with the appropriate fastener for the design structural capacity to be attained. For example, post-event investigations have revealed many inadequate connections (e.g., made with the wrong size nails) that either failed during the event or could have failed if the design loads had been realized at the connection.
Use of Nail and Staple Guns	Nail and staple guns, which are used frequently to speed construction, have disadvantages that can lead to connections with reduced capacity. These guns can easily overdrive nails or staples, or drive them at an angle. In addition, it is often difficult for the nail gun operator to determine whether a nail has penetrated an unexposed wood member (such as a rafter or truss below roof sheathing) as intended.
Inadequate Embedment	Failure to achieve the pile or foundation embedment specified by building plans or local/State requirements will render an otherwise properly constructed building vulnerable to flood, erosion, and scour damage.
Improperly Constructed Breakaway Walls	Improperly constructed breakaway walls (e.g., improperly fastened wall panels, panels constructed immediately seaward of foundation cross-bracing) can cause preventable damage to the main structure. Lack of knowledge or inattention by contractors can cause unnecessary damage.
Utility Systems	Improperly installed utility system components (e.g., plumbing and electrical components attached to breakaway walls or on the waterward side of vertical foundation members; unelevated or insufficiently elevated heat pumps, air conditioning compressors, and ductwork) will fail during a flood event. They can also cause damage to the main structure that otherwise might not have occurred.

ISSUE	CONCLUSION
Roofs and Walls	Bracing and fastening roofs and walls can help prevent building envelope failures in high-wind events.
Roofing Connections	Lack of or inadequate connections between shingles and roof sheathing and between sheathing and roof framing (e.g., nails that fail to penetrate roof truss members or rafters) can cause roof failures and subsequent building failures.
Inspection	Communities often have insufficient resources to inspect buildings frequently during construction. Although contractors are responsible for following plans and satisfying code requirements, infrequent inspections may result in failure to find and remedy construction deficiencies.

LESSONS RELATED TO MAINTENANCE

The following table summarizes lessons learned from coastal flood and wind events with regard to maintenance issues.

ISSUE	CONCLUSION
Deterioration Repair and Replacement	Repairing and replacing structural elements, connectors, and building envelope components that have deteriorated over time, because of decay or corrosion, will help maintain the building's resistance to natural hazards. Maintenance of building components in coastal areas should be a constant and ongoing process. The ultimate costs of deferred maintenance in coastal areas can be high when natural disasters strike.
Damage Repair	Failure to inspect and repair damage caused by a wind, flood, erosion, or other event will make the building even more vulnerable during the next event.
Maintenance of Erosion Control and Flood Protection Structures	Failure to maintain erosion control or coastal flood protection structures will lead to increased vulnerability of those structures and the buildings behind them.

SELF-CHECK REVIEW: CONSTRUCTION AND MAINTENANCE LESSONS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any questions incorrectly, you should review the related material before continuing.

1. Bracing and fastening roofs and walls can help prevent building envelope failures in high wind events.

   True False

2. Inadequate connections between shingles and roof sheathing, or between sheathing and roof framing, can lead to roof failures.

   True False

3. The best schedule for inspecting and maintaining building components in coastal areas is once every 5 years and after storm damage.

   True False

4. Nail guns are highly recommended for coastal construction because of the uniformity they provide.

   True False

ANSWER KEY

1. Bracing and fastening roofs and walls can help prevent building envelope failures in high wind events.

   True

2. Inadequate connections between shingles and roof sheathing, or between sheathing and roof framing, can lead to roof failures.

   True

3. The best schedule for inspecting and maintaining building components in coastal areas is once every 5 years and after storm damage.

   False.
   Maintenance should be a constant and ongoing process, and buildings should be inspected following any wind, flood, erosion, or other event that could cause damage. The ultimate costs of deferred maintenance in coastal areas can be high when natural disasters strike.

4. Nail guns are highly recommended for coastal construction because of the uniformity they provide.

   False.
   Nail guns can overdrive nails or drive them at an angle. It may also be difficult to determine whether a nail has adequately penetrated an underlying wood member.

UNIT I EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit I. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit II.

1. Which of the following terms is used to describe flood elevation in communities that enforce floodplain management requirements more stringent than those of the NFIP?

   _____ Base Flood Elevation (BFE)

   _____ Design Flood Elevation (DFE)

2. Areas that are subject to inundation by a flood that has a one percent probability of being equaled or exceeded in any given year are called:

   ____

3. The portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources is called:

   ____

4. On Flood Insurance Rate Maps, the portion of the SFHA that is inland of the V zone is:

   ____

5. What have past coastal flood and wind events taught us about multiple events?

6. When siting a building on a coastal bluff, failure to consider the effects of __________________ on wind speeds can lead to underestimation of wind speeds that will be experienced during the design event.

7. What have past coastal flood and wind events taught us about building close to the shoreline?

8. A builder wants to build homes on a shoreline that is protected from the open ocean by barrier islands. What would you tell this person, based past coastal flood and wind events?

9. What lesson about freeboard can designers derive from past coastal flood and wind events?

10. What is the most common foundation problem that leads to significant building damage in coastal events?

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT I EXERCISE — ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Which of the following terms is used to describe flood elevation in communities that enforce floodplain management requirements more stringent than those of the NFIP?

   __✓__ **Design Flood Elevation (DFE)**

2. Areas that are subject to inundation by a flood that has a one percent probability of being equaled or exceeded in any given year are called:

   Special Flood Hazard Areas (SFHAs).

3. The portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources is called:

   The V zone. (The V zone is also referred to as the Coastal High Hazard Area).

4. On Flood Insurance Rate Maps, the portion of the SFHA that is inland of the V zone is:

   The A zone (the Coastal A zone designation is not currently used on FIRMS).

5. What have past coastal flood and wind events taught us about multiple events?

   Coastal buildings left intact by one storm may be vulnerable to damage or destruction by a second storm. Failure to consider the effects of multiple storms or flood events may lead to an underestimation of flood hazards in coastal areas.

6. When siting a building on a coastal bluff, failure to consider the effects of <u>**topography**</u> on wind speeds can lead to underestimation of wind speeds that will be experienced during the design event.

7. What have past coastal flood and wind events taught us about building close to the shoreline?

   Building close to the shoreline is a common, but possibly poor, siting practice. It may render a building more vulnerable to wave, flood, and erosion effects. It may remove any margin of safety against multiple storms or erosion events. It may require moving, protecting, or demolishing the building if flood hazards increase over time.

8. A builder wants to build homes on a shoreline that is protected from the open ocean by barrier islands. What would you tell this person, based past coastal flood and wind events?

   Siting along shorelines protected against wave attack by barrier islands or other land masses does not guarantee protection against flooding. In fact, storm surge elevations along low-lying shorelines in embayments are often higher than storm surge elevations on open coast shorelines.

9. What lesson about freeboard can designers derive from past coastal flood and wind events?

   Elevating a building sufficiently will help protect the superstructure from damaging wave forces. Designs should incorporate freeboard above the required elevation of the lowest floor or the bottom of the lowest horizontal member.

10. What is the most common foundation problem that leads to significant building damage in coastal events?

    Inadequate embedment of foundation members (e.g., pilings not embedded deeply enough, shallow footings supporting masonry and concrete walls and columns).

UNIT II: COASTAL ENVIRONMENT

COASTAL ENVIRONMENT

INTRODUCTION

Planning, siting, design, and construction of coastal residential buildings require an understanding of the coastal environment—including a basic understanding of coastal geology, coastal processes, regional variations in coastline characteristics, and coastal sediment budgets. This unit will briefly discuss each of these topics.

UNIT OBJECTIVES

After completing this unit, you should be able to:

2.1 Explain the concept of coastal sediment budget.
2.2 Identify characteristics of major divisions of the U.S. coastlines.
2.3 Interpret basic NFIP map information.
2.4 Define key terms related to Base Flood Elevation (BFE).

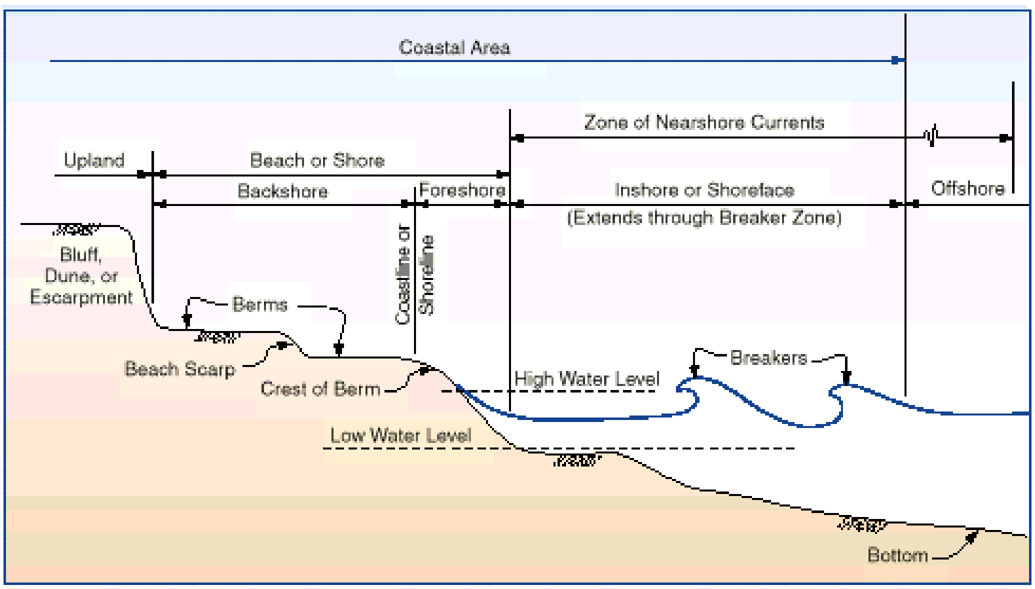
COASTAL REGION TERMINOLOGY

COASTAL GEOLOGY

Coastal geology refers to the origin, structure, and characteristics of the sediments that make up the coastal region, from the uplands to the nearshore region (see Fig. 2-1). The sediments can vary from small particles of silt or sand (a few thousandths or hundredths of an inch across), to larger particles of gravel and cobble (up to several inches across), to formations of consolidated sediments and rock.

The sediments can be easily erodible and transportable by water and wind, as in the case of silts and sands, or can be highly resistant to erosion. The sediments and geology that compose a particular coastline will be the product of physical and chemical processes that take place over thousands of years.

Figure 2-1. Coastal region terminology



COASTAL PROCESSES

Coastal processes refers to those physical processes that act upon and shape the coastline. These processes, which influence the configuration, orientation, and movement of the coast, include:

- Tides and fluctuating water levels.
- Waves.
- Currents (usually generated by tides or waves).
- Winds.

Coastal processes interact with the local coastal geology and sediment supply to form and modify the physical features that will be referred to frequently in this course: beaches, dunes, bluffs, and upland areas. Water levels, waves, currents, and winds will vary with time at a given location (sometimes according to short-term, seasonal, or longer-term patterns) and will vary geographically at any point in time.

A good analogy is weather: weather conditions at a given location undergo significant variability over time but tend to follow seasonal and other patterns. Further, weather conditions can differ substantially from one location to another at the same point in time.

REGIONAL VARIATIONS IN COASTLINES

Regional variations in coastlines will be the product of variations in coastal processes and coastal geology. These variations can be quite substantial, as you will see later in this unit. Thus, shoreline siting and design practices appropriate to one area of the coastline may not be suitable for another.

COASTAL SEDIMENT BUDGETS

Coastal sediment budget refers to the identification of sediment sources and sinks, and the quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

Sediment budgets are used by coastal engineers and geologists to analyze and explain shoreline changes and to project future shoreline behavior.

NOTE

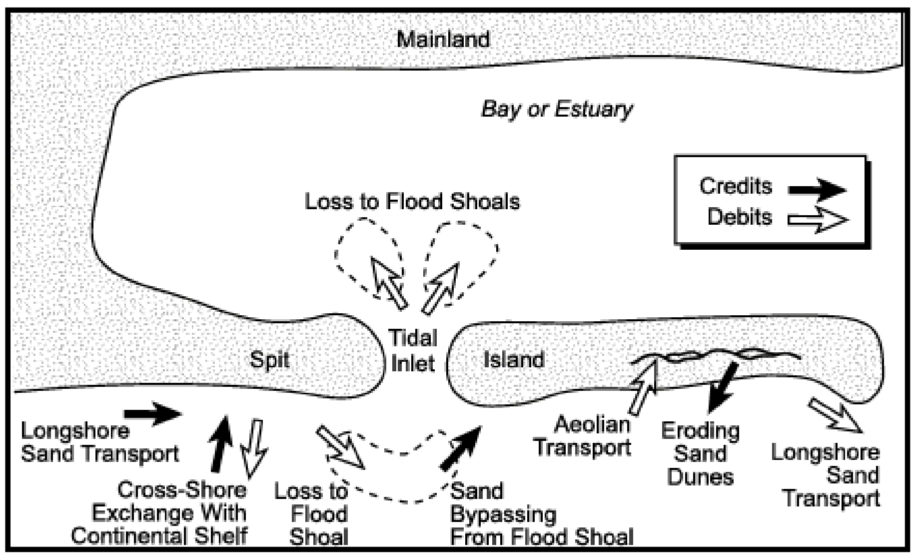
The premise behind a *coastal sediment budget* is simple: if more sediment is transported by coastal processes or human actions into a given area than is transported out, **shoreline accretion** results. If more sediment is transported out of an area than is transported in, **shoreline erosion** results.

While the calculation of sediment budgets is beyond the scope of typical planning and design studies for coastal residential structures, it is useful to consider the basic concept and to review the principal components that make up a sediment budget. Moreover, sediment budgets may have been calculated by others for the shoreline segment containing a proposed building site.

Figures 2-2 and 2-3 illustrate the principal components of sediment budgets for the majority of U.S. coastline types.

Note that there may be other locally important sediment sources and sinks that are not shown in the figures. For example, the addition of sand to a beach through **beach nourishment** could be considered a significant source in some communities. The loss of sediment through storm-generated **overwash** could represent an important loss in some areas.

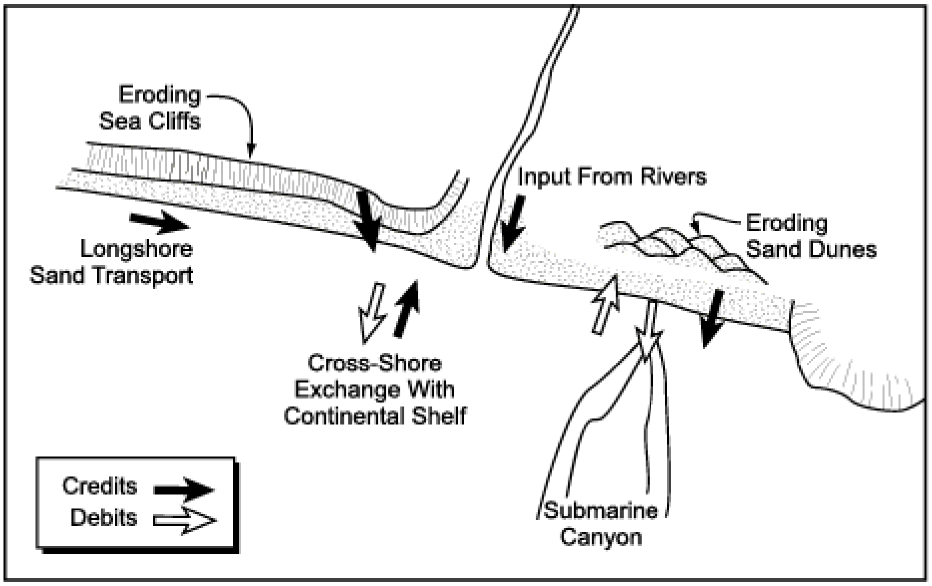
Figure 2-2.
Principal components of a typical sediment budget for a barrier island and barrier spit shoreline.



Flood shoals are sediment deposits formed just inside a tidal inlet by flood tidal currents (also called flood tidal delta).

Ebb shoals are sediment deposits formed by ebb tidal currents just offshore of a tidal inlet (also called ebb tidal delta).

Figure 2-3.
Principal components of a typical sediment budget for a mainland shoreline backed by bluffs and dunes.



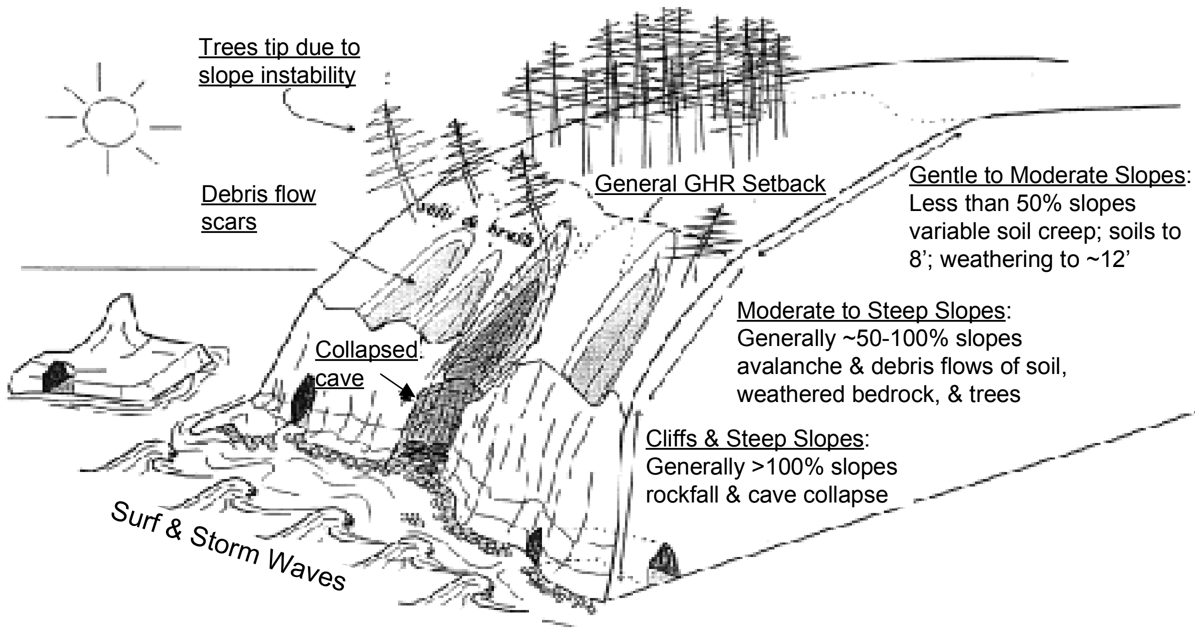
Longshore sand transport is wave- and/or tide-generated movement of shallow-water coastal sediments parallel to the shoreline.

Cross-shore sand transport is wave- and/or tide-generated movement of shallow-water coastal sediments toward or away from the shoreline.

Note that Figures 2-2 and 2-3 do not characterize all coastlines, particularly those rocky coastlines that are generally resistant to erosion and whose existence does not depend upon littoral sediments transport by coastal processes.

Rocky coastlines typical of many Pacific, Great Lakes, New England, and Caribbean areas are better represented by Figure 2-4, which illustrates the slow process by which rocky coasts erode in response to elevated water levels, waves, and storms.

Figure 2-4. Generalized depiction of erosion process along a rocky coastline.



Breakers erode base of cliff, forming caves in cones of weakness; caves eventually form arches, then stacks; some caves collapse. Weathering causes rockfall on cliff face. Debris flows and avalanches on steeper slopes are triggered by seismicity, heavy soil saturation, and loss of tree root strength.

SELF-CHECK REVIEW: COASTAL REGION TERMINOLOGY

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any questions incorrectly, you should review the related material before continuing.

1. ___________________ refers to the origin, structure, and characteristics of the sediments that make up the coastal region.

   a. Coastal sediment budget
   b. Coastal geology
   c. Longshore sand transport
   d. Cross-shore sand transport

2. ___________________ refers to the identification of sediment sources and sinks, and the quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

   a. Coastal sediment budget
   b. Coastal geology
   c. Longshore sand transport
   d. Cross-shore sand transport

3. ___________________ refers to wave- and/or tide-generated movement of shallow-water coastal sediments toward or away from the shoreline.

   a. Coastal sediment budget
   b. Coastal geology
   c. Longshore sand transport
   d. Cross-shore sand transport

4. ___________________ refers to wave- and/or tide-generated movement of shallow-water coastal sediments parallel to the shoreline.

   a. Coastal sediment budget
   b. Coastal geology
   c. Longshore sand transport
   d. Cross-shore sand transport

5. If more sediment is transported by coastal processes or human actions into a given area than is transported out, shoreline erosion results.

   True False

ANSWER KEY

1. ____________________ refers to the origin, structure, and characteristics of the sediments that make up the coastal region.

   b. Coastal geology

2. ____________________ refers to the identification of sediment sources and sinks, and the quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

   a. Coastal sediment budget

3. ____________________ refers to wave- and/or tide-generated movement of shallow-water coastal sediments toward or away from the shoreline.

   d. Cross-shore sand transport

4. ____________________ refers to wave- and/or tide-generated movement of shallow-water coastal sediments parallel to the shoreline.

   c. Longshore sand transport

5. If more sediment is transported by coastal processes or human actions into a given area than is transported out, shoreline erosion results.

   False.
   In this situation, shoreline accretion results.

UNITED STATES COASTLINE CHARACTERISTICS

The coastline of the United States can be divided into seven major segments and smaller segments, as shown in Figure 2-5. Each of the subsegments generally describes coastlines of similar origin, characteristics, and hazards.

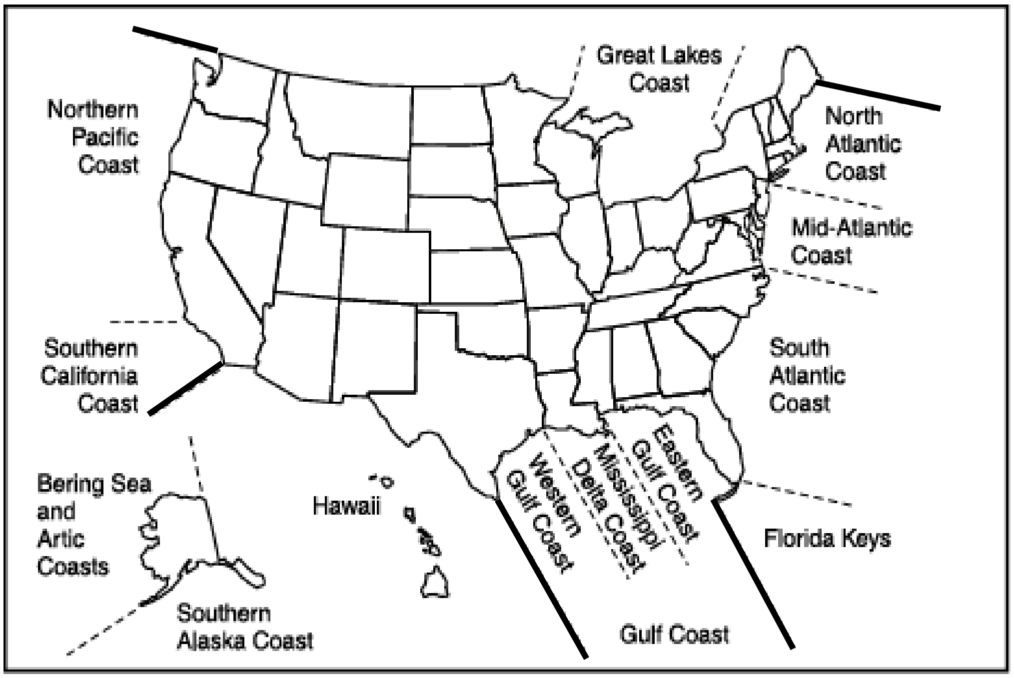


Figure 2-5. The United States coastline

SECTIONS AND SUBSECTIONS

1) **Atlantic coast.** The Atlantic coast is divided into:

- **North Atlantic** coast—from Maine to Long Island, New York.
- **Mid-Atlantic** coast—from New Jersey to Virginia.
- **South Atlantic** coast—from North Carolina to South Florida.
- **Florida Keys**.

2) **Gulf of Mexico coast.** The Gulf coast is divided into:

- **Eastern Gulf** coast—from southwest Florida to Mississippi.
- **Mississippi Delta** coast of southeast Louisiana.
- **Western Gulf** coast of Louisiana and Texas.

3) **Pacific coast.** The Pacific coast is divided into:

- **Southern California** coast—from San Diego County to Point Conception (Santa Barbara County), California.
- **North Pacific** coast—from Point Conception, California, to Washington.

4) **Great Lakes coast**, which extends from Minnesota to New York.

5) **Coast of Alaska**.

6) **Coast of Hawaii** and **Pacific Territories**.

7) **Coast of Puerto Rico** and the **U.S. Virgin Islands**.

The U.S. Army Corps of Engineers in 1971 estimated the total shoreline length of the continental United States, Alaska, and Hawaii at 84,240 miles, including 34,520 miles of exposed shoreline and 49,720 miles of sheltered shoreline. The shoreline length of the continental United States alone was put at 36,010 miles (13,370 miles exposed, 22,640 miles sheltered).

ATLANTIC COAST

The **North Atlantic** coast is glacial in origin. It is highly irregular, with erosion-resistant rocky headlands and pocket beaches in northern New England, and erodible bluffs and sandy barrier islands in southern New England and along Long Island, New York.

The **Mid-Atlantic** coast extends from New Jersey to Virginia and includes two of the largest estuaries in the United States—Delaware Bay and Chesapeake Bay. The open coast shoreline is generally composed of long barrier islands separated by tidal inlets and bay entrances.

The **South Atlantic** coast consists of three regions:

- The North Carolina and northern South Carolina shoreline—composed of long barrier and mainland beaches (including the Outer Banks and the South Carolina Grand Strand region).

- The region extending from Charleston, South Carolina, to the St. Johns River entrance at Jacksonville, Florida—a tide-dominated coast composed of numerous short barrier islands, separated by large tidal inlets and backed by wide expanses of tidal marsh.

- The east coast of Florida—composed of barrier and mainland beaches backed by narrow bays and rivers.

The **Florida Keys** are a series of low-relief islands formed by limestone and reef rock, with narrow, intermittent carbonate beaches.

Vulnerability: The entire Atlantic coast is subject to high storm surges from hurricanes and/or northeasters. Wave runup on steeply sloping beaches and shorelines in New England is also a common source of coastal flooding.

GULF OF MEXICO COAST

Cheniers are Mississippi Delta sediments transported westward to form sandy ridges atop mud plains.

The Gulf of Mexico coast can be divided into three regions:

- The eastern Gulf coast from southwest Florida to Mississippi—composed of low-lying sandy barrier islands south of Tarpon Springs, Florida, and west of St. Marks, Florida, with a marsh-dominated coast in between in the Big Bend area of Florida.

- The Mississippi Delta region—characterized by wide, marshy areas and a low-lying coastal plain.

- The western Gulf of Mexico coast, including the **cheniers** of southwest Louisiana, and the long, sandy barrier islands of Texas.

Vulnerability: The entire Gulf coast is vulnerable to high storm surges from hurricanes. Some areas (e.g., the Big Bend area of Florida) are especially vulnerable because of a wide, shallow continental shelf and low-lying upland areas.

PACIFIC COAST

The Pacific coast can be divided into two regions:

- The southern California reach—dominated by long, sandy beaches and coastal bluffs.

- The northern Pacific reach—characterized by rocky cliffs, pocket beaches, and occasional long sandy barriers near river mouths.

Vulnerability: Open coast storm surges along the Pacific shoreline are generally small (less than 2 feet) because of the narrow continental shelf and deep water close to shore. However, storm wave conditions along the Pacific shoreline are very severe, and the resulting wave runup can be very destructive. In some areas of the Pacific coast, tsunami flood elevations can be much higher than flood elevations associated with coastal storms.

GREAT LAKES COAST

The shorelines of the Great Lakes are highly variable and include wetlands, low and high cohesive bluffs, low sandy banks, and lofty sand dunes perched on bluffs (200 feet or more above lake level).

Vulnerability: Storm surges along the Great Lakes are generally less than 2 feet except in embayments (2–4 feet) and on Lake Erie (up to 8 feet). Periods of active erosion are triggered by heavy precipitation events, storm waves, rising lake levels, and changes in groundwater outflow along the coast.

COAST OF ALASKA

The coast of Alaska can be divided into two areas:

- The southern coast, dominated by steep mountainous islands indented by deep fjords.
- The Bering Sea and arctic coasts, backed by a coastal plain dotted with lakes and drained by numerous streams and rivers.

Vulnerability: The climate of Alaska and the action of ice along the shorelines set it apart from most other coastal areas of the United States.

COAST OF HAWAII AND PACIFIC TERRITORIES

The islands that make up Hawaii are submerged volcanoes; thus, the coast of Hawaii is formed by rocky cliffs and intermittent sandy beaches. Coastlines along the Pacific Territories are generally similar to those of Hawaii.

Vulnerability: Coastal flooding can result from two sources: storm surges from hurricanes or cyclones, and wave runup from tsunamis.

COAST OF PUERTO RICO AND THE U.S. VIRGIN ISLANDS

Like the Hawaiian Islands and Pacific Territories, the islands of Puerto Rico and the Virgin Islands are the products of ancient volcanic activity. The coastal lowlands of Puerto Rico, which occupy nearly one-third of the island's area, contain sediment eroded and transported from the steep, inland mountains by rivers and streams. Ocean currents and wave activity rework the sediments on pocket beaches around each island.

Vulnerability: Coastal flooding is usually caused by hurricanes, although tsunami events are not unknown to the Caribbean.

SELF-CHECK REVIEW: U.S. COASTLINE CHARACTERISTICS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

For each item on the left, find the phrase on the right that best applies to it. Write the letter of the phrase in the blank.

1.	___ North Atlantic coast	a.	Rocky cliffs
2.	___ Gulf of Mexico coast	b.	Two of the largest estuaries in the U.S.
3.	___ Southern Pacific coast	c.	Erodible bluffs and sandy barrier islands
4.	___ Coast of Alaska	d.	Long, sandy beaches and coastal bluffs
5.	___ Mid-Atlantic coast	e.	Action of ice along the shoreline
6.	___ South Atlantic coast	f.	Marshy coast, low-lying coastal plain, cheniers
7.	___ Northern Pacific coast	g.	Barrier islands, mainland beaches, large tidal inlets

Circle True or False.

8. The entire Atlantic coast is subject to high storm surges from hurricanes and/or northeasters.

   True False

9. The entire Gulf coast is vulnerable to storm surges from hurricanes or cyclones, and wave runup from tsunamis.

   True False

10. In some areas of the Pacific coast, tsunami flood elevations can be much higher than flood elevations associated with coastal storms.

   True False

ANSWER KEY

1. **c** North Atlantic coast		a.	Rocky cliffs
2. **f** Gulf of Mexico coast		b.	Two of the largest estuaries in the U.S.
3. **d** Southern Pacific coast		c.	Erodible bluffs and sandy barrier islands
4. **e** Coast of Alaska		d.	Long, sandy beaches and coastal bluffs
5. **b** Mid-Atlantic coast		e.	Action of ice along the shoreline
6. **g** South Atlantic coast		f.	Marshy coast, low-lying coastal plain, cheniers
7. **a** Northern Pacific coast		g.	Barrier islands, mainland beaches, large tidal inlets

8. The entire Atlantic coast is subject to high storm surges from hurricanes and/or northeasters.

   True

9. The entire Gulf coast is vulnerable to storm surges from hurricanes or cyclones, and wave runup from tsunamis.

   False.
   The Gulf coast is vulnerable to high storm surges from hurricanes, but there is no particular risk of tsunamis in this region.

10. In some areas of the Pacific coast, tsunami flood elevations can be much higher than flood elevations associated with coastal storms.

    True

COASTAL FLOOD HAZARDS

Coastal flood hazards at a site will depend upon several factors:

- The elevation and topography of the site.
- The erodibility of the site.
- The nature and intensity of coastal flood events affecting the site.

FEMA has developed procedures for estimating and mapping coastal flood hazards that take the above factors into account. This section describes some of the underlying concepts and mapping issues.

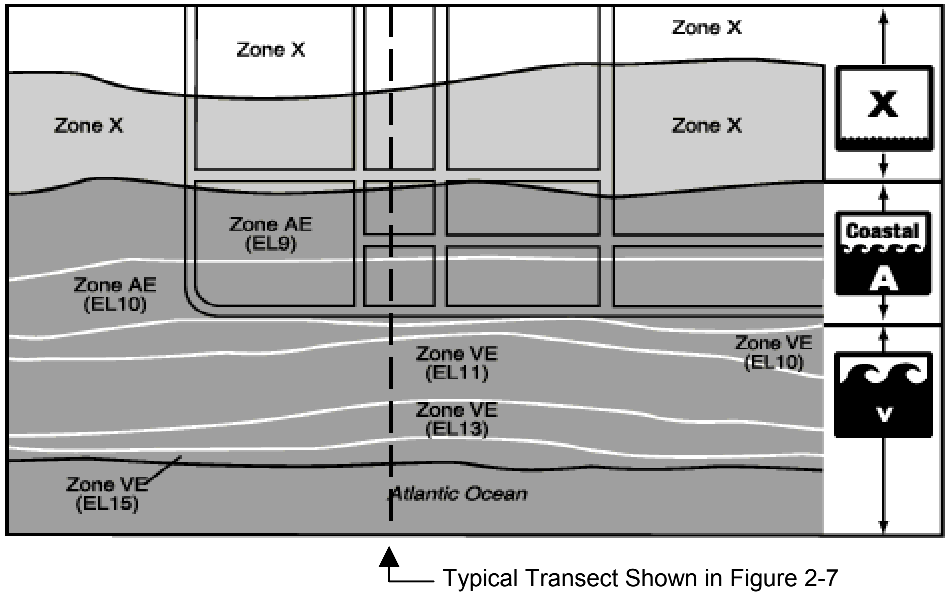
Figure 2-6 shows a portion of a typical Flood Insurance Rate Map (FIRM) that a designer is likely to encounter for a coastal area. Three flood hazard zones have been mapped: V zones, A zones, and X zones. The V zone is the most hazardous of the three areas because structures there will be exposed to the most severe flood and wind forces, including wave action, high-velocity flow, and erosion. **The A zone shown on the map should be thought of as a coastal A zone.**

NOTE

As noted earlier, the *Coastal Construction Manual* introduces the concept of the **coastal A zone** to differentiate A zones in coastal areas from those in inland areas. Coastal A zones are not currently mapped or regulated by FEMA any differently than inland A zones; however, post-disaster damage inspections consistently show the need for such a distinction. Flood hazards in coastal A zones, like those in V zones, can include the effects of waves, velocity flow, and erosion (although the magnitude of these effects will be less in coastal A zones than in V zones).

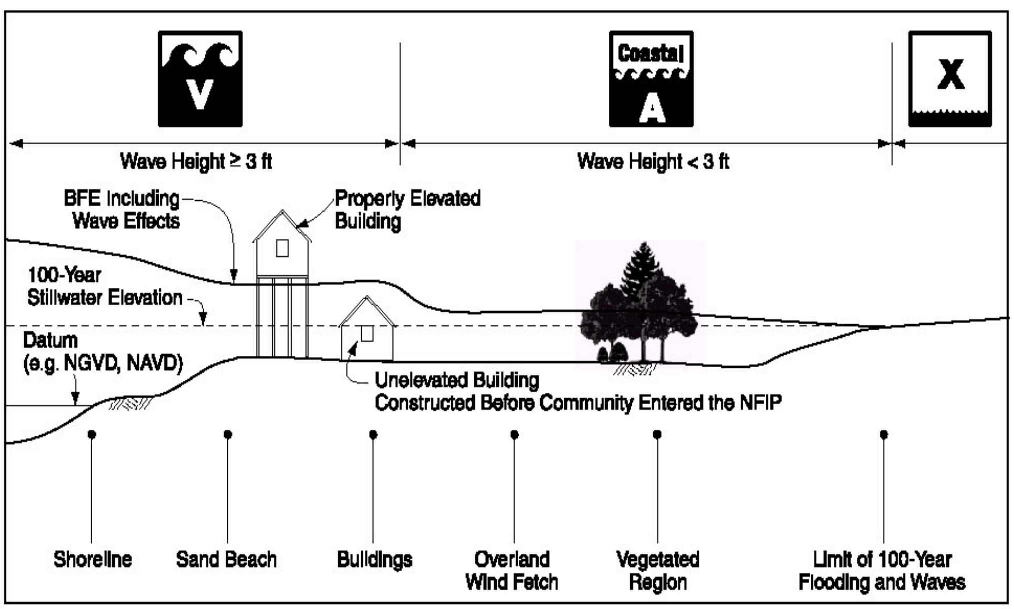
FEMA's flood mapping procedures show the area designated as Zone X on the map has less than a one percent probability of flooding in any year.

Figure 2-6. Portion of a FIRM



- Dark gray = coastal Special Flood Hazard Area (SFHA)
- Light gray = 500-year flood hazard area.
- Numbers in parentheses = Coastal BFEs.
- Flood insurance rate zones: AE and VE = SFHA; VE = Coastal High Hazard Area; X = areas outside the SFHA

Figure 2-7. Typical shoreline-perpendicular transect used in the analysis of stillwater and wave crest elevations



STILLWATER ELEVATION

A FIRM is the product of a **Flood Insurance Study** (FIS) conducted for a community under FEMA's National Flood Insurance Program. A coastal FIS is completed with specified techniques and procedures to determine stillwater and wave elevations along transects drawn perpendicular to the shoreline (see Figures 2-6 and 2-7).

The determination of the 100-year stillwater elevation (and stillwater elevations associated with other return periods) is usually accomplished through the statistical analysis of historical tide and water level data, or by the use of a numerical storm surge model.

Wave heights and elevations are computed from stillwater and topographic data with established procedures and models that account for wave dissipation by obstructions (e.g., sand dunes, buildings, vegetation) and wave regeneration across overland fetches.

Several factors can contribute to the 100-year stillwater elevation in a coastal area. The most important factors include:

- Offshore bathymetry.
- Astronomical tide.
- Wind setup (rise in water surface as strong winds blow water toward the shore).
- Pressure setup (rise in water surface from low atmospheric pressure).
- Wave setup (rise in water surface inside the surf zone from the presence of breaking waves).
- Seiches and long-term changes in lake levels (in the case of the Great Lakes).

NOTE

Base Flood Elevations (BFEs) in coastal areas will be controlled by the higher of the wave crest elevation or the wave runup elevation.

WAVE HEIGHTS AND WAVE CREST ELEVATIONS

FEMA's primary means of establishing Base Flood Elevations (BFEs) and distinguishing between V zones, (coastal) A zones, and X zones is the **wave height**. The wave height is simply the vertical distance between the crest and trough of a wave propagating over the water surface. BFEs in coastal areas are usually set at the crest of the wave as it propagates inland.

The maximum **wave crest elevation** (used to establish the BFE) is determined by the maximum wave height, which depends largely on the 100-year stillwater depth (d_{100}). This depth is the difference between the 100-year stillwater elevation (E_{100}) and the ground elevation (GS).

(Note that GS is ***not*** the existing ground elevation; it is the ground elevation that will result from the amount of erosion expected to occur during the 100-year flood.)

Wave height is the vertical distance between the wave crest and wave trough (see Fig. 2-8).

Wave crest elevation is the elevation of the crest of a wave, referenced to the NGVD or other datum.

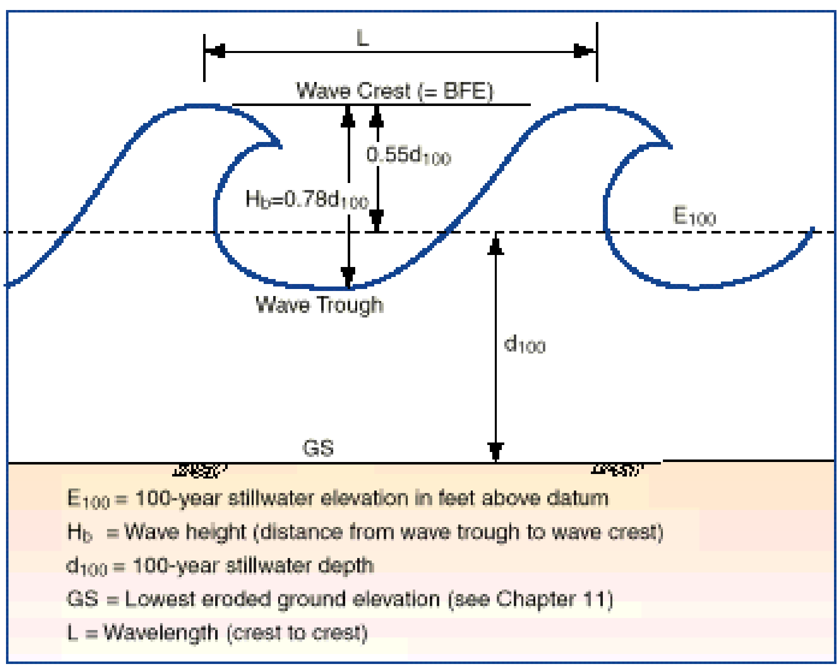


Figure 2-8. Determination of BFE in coastal flood hazard areas where wave crest elevations exceed wave runup elevations (zones A and V). Note that BFE = $E_{100} + 0.55d_{100}$.

Wave setup is an increase in the stillwater surface near the shoreline, because of the presence of breaking waves. Wave setup typically adds 1.5 to 2.5 feet to the 100-year stillwater flood elevation.

In relatively shallow waters, such as those in coastal areas of the United States, the maximum height of a breaking wave (H_b) is determined by the equation $\mathbf{H_b = 0.78d_{sw}}$, where d_{sw} is the stillwater depth.

The maximum height of a breaking wave above the stillwater elevation is equal to $0.55d_{100}$ (see Fig. 2-8). Note that for wind-driven waves, water depth is only one of three parameters that determine actual wave height at a particular site (wind speed and fetch length are the other two). In some instances, actual wave heights may be below the computed maximum height.

For a coastal flood hazard area where the ground is gently sloping, the BFE shown on the FIRM is equal to the ground elevation (referenced to the NGVD or other datum) plus the 100-year stillwater depth (d_{100}) plus $0.55d_{100}$.

> Example: Where the ground elevation is 4 feet NGVD and d_{100} is 6 feet, the BFE is equal to 4 feet plus 6 feet plus 3.3 feet, or 13.3 feet NGVD.

WAVE RUNUP

On steeply sloped shorelines, the rush of water up the surface of the natural beach, including dunes and bluffs, or the surface of a manmade structure, such as a revetment or vertical wall, can result in flood elevations higher than those of the crests of wind-driven waves.

Wave runup is the rush of water up a slope or structure.

Wave runup elevation is the elevation reached by wave runup, referenced to the NGVD or other datum.

Wave runup depth at any point is equal to the maximum wave runup elevation minus the lowest eroded ground elevation at that point.

For a coastal flood hazard area where this situation occurs, the BFE shown on the FIRM is equal to the highest elevation reached by the water (see Fig. 2-9). The methodology adopted by FEMA for the computation of wave runup elevations includes the determination of wave heights. Where the wave runup elevations are lower than the wave height elevations, the BFE equals the wave height elevation.

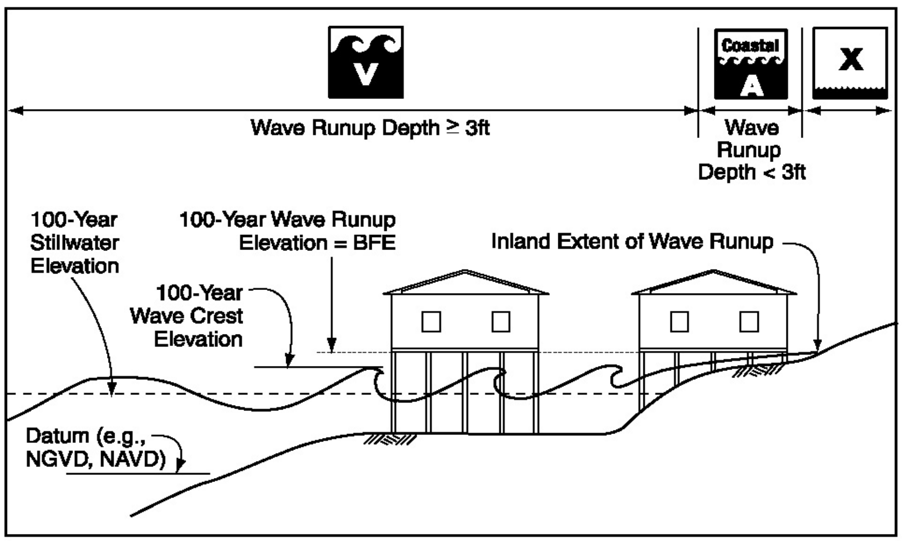


Figure 2-9.
Where wave runup elevations exceed wave crest elevations, the BFE is equal to the runup elevation.

EROSION CONSIDERATIONS AND FLOOD HAZARD MAPPING

Current FIS procedures account for the potential loss of protective dunes during the 100-year flood. However, this factor was not considered in the preparations of many older coastal FIRMs, which delineated V zones without any consideration for storm-induced erosion. V-zone boundaries were often drawn at the crest of the dune solely on the basis of the elevation of the ground and without regard for the erosion that would occur during a storm.

Designers, property owners, and floodplain managers should be careful not to assume that flood hazard zones shown on FIRMs accurately reflect current flood hazards. For example, flood hazard restudies completed after Hurricanes Opal (1995—Florida Panhandle) and Fran (1966—Topsail Island, North Carolina) have produced FIRMs that are dramatically different from the FIRMs in effect prior to the storms.

Figure 2-10 compares pre- and post-storm FIRMs for Surf City, North Carolina. The map changes are attributable to two factors:

- Pre-storm FIRMs did not show the effects of erosion that had occurred since the FIRMs were published and did not meet technical standards currently in place.

- Hurricane Fran caused significant changes to the topography of the barrier island.

Not all coastal FIRMs would be expected to undergo such drastic revisions after a flood restudy; however, many FIRMs may be in need of updating, and designers should be aware that FIRMs may not reflect present flood hazards at a site.

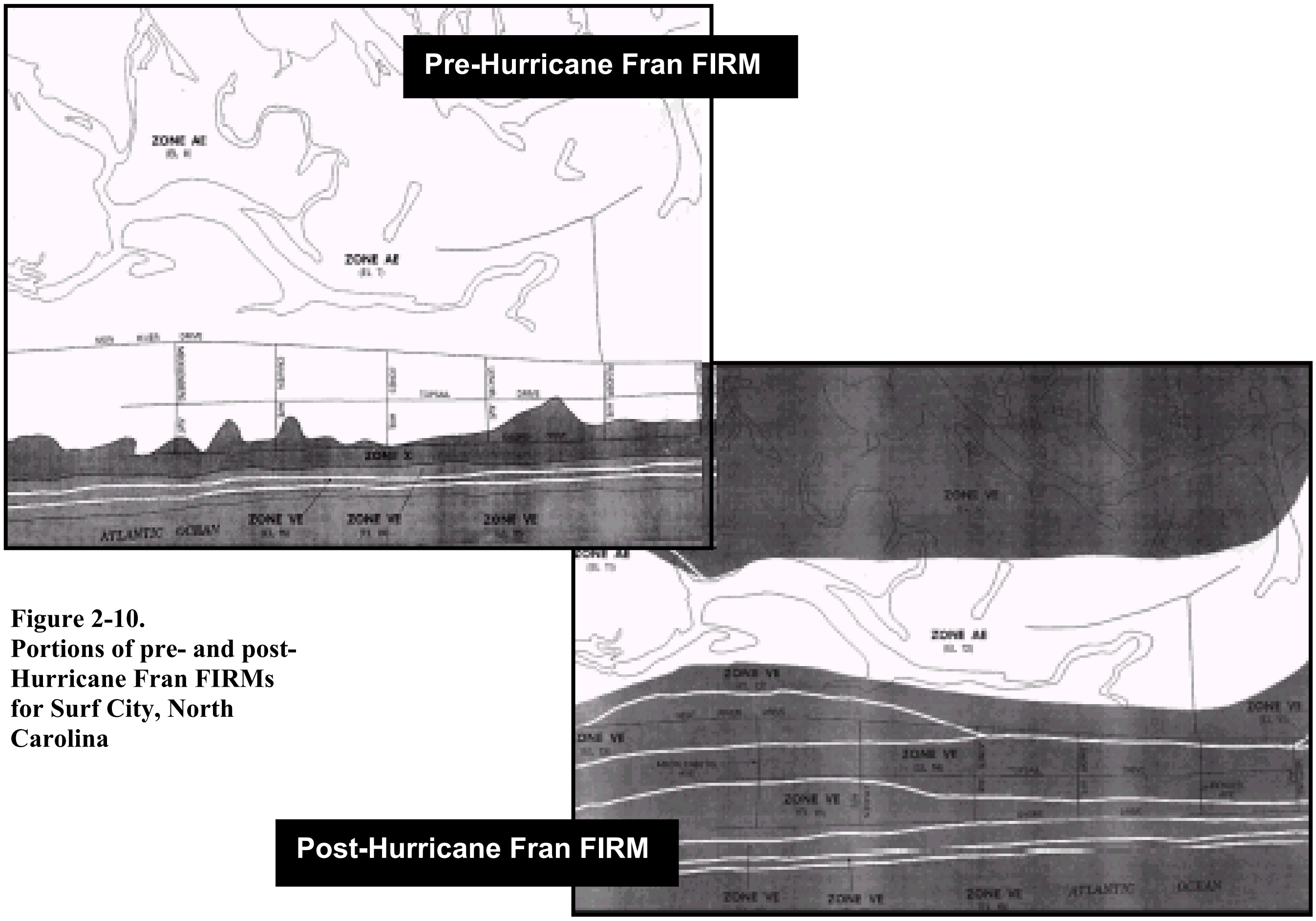


Figure 2-10.
Portions of pre- and post-Hurricane Fran FIRMs for Surf City, North Carolina

SELF-CHECK REVIEW: COASTAL FLOOD HAZARDS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. In the portion of a FIRM shown below,

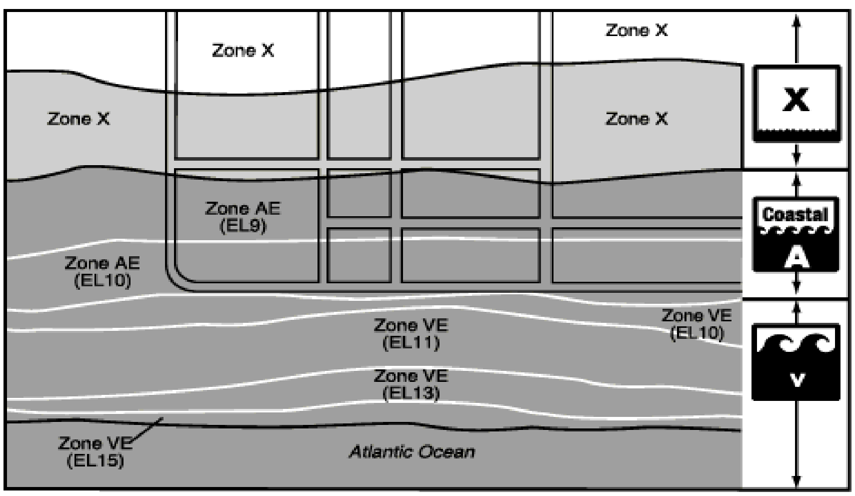
   a. The SFHA is shown as dark/light gray. (Circle one)

   b. The 500-year flood hazard area is shown as dark/light gray. (Circle one)

   c. The numbers in parentheses are ____.

   d. What is the zone of highest flood hazard? _____________________________________.

   e. What is the zone of lowest flood hazard? _____________________________________.



2. ______________________ is the vertical distance between the wave crest and wave trough.

3. ______________________ is the rush of water up a slope or structure.

4. ______________________ is an increase in the stillwater surface near the shoreline, because of the presence of breaking waves.

5. Why is it unwise to assume that flood hazard zones shown on FIRMs accurately reflect current flood hazards?

ANSWER KEY

1. a. The SFHA is shown as **dark** gray.

   b. The 500-year flood hazard area is shown as **light** gray.

   c. The numbers in parentheses are **Base Flood Elevations (BFEs).**

   d. What is the zone of highest flood hazard? **the V zone.**

   e. What is the zone of lowest flood hazard? **the X zone.**

2. **<u>Wave height</u>** is the vertical distance between the wave crest and wave trough.

3. **<u>Wave runup</u>** is the rush of water up a slope or structure.

4. **<u>Wave setup</u>** is an increase in the stillwater surface near the shoreline, because of the presence of breaking waves.

5. Why is it unwise to assume that flood hazard zones shown on FIRMs accurately reflect current flood hazards?

   Older FIS procedures did not account for the potential loss of protective dunes during the 100-year flood. V zones were delineated without consideration for storm-induced erosion.

UNIT II EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit II. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit III.

1. Briefly explain the concept of coastal sediment budget.

2. __________________________ results when more sediment is transported into a given area than is transported out.

3. The Atlantic coast includes erosion-resistant rocky headlands, barrier islands, mainland beaches, low-relief islands—all of which are subject to high storm surges from hurricanes and/or northeasters.

   True False

4. Open coast storm surges along the Pacific shoreline are generally quite high (over 8 feet) because of shallow waters near the shore.

   True False

For each term on the left, select the best definition from the list on the right. Write the letter of the definition in the space provided.

5. ___ Wave height
6. ___ Wave crest elevation
7. ___ Wave setup
8. ___ Wave runup

a. An increase in the stillwater surface near the shoreline because of the presence of breaking waves.

b. The rush of water up a slope or structure.

c. The vertical distance between the wave crest and wave trough.

d. The elevation of the crest of a wave, referenced to the NGVD or other datum.

9. The maximum wave crest elevation is determined by the maximum wave height, which depends largely on the
   ____.

10. On a FIRM, a V zone is:

    a. Unshaded
    b. Shaded light gray
    c. Shaded dark gray
    d. Indicated by parentheses

11. Base Flood Elevations (BFEs) in coastal areas will be controlled by the highest of:

    a. Stillwater elevation or wave crest.
    b. Wave height or wave setup.
    c. Wave trough or wave runup elevation.
    d. Wave crest elevation or wave runup elevation.

12. Wave setup typically adds ____________________ to the 100-year stillwater flood elevation.

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT II EXERCISE — ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Briefly explain the concept of coastal sediment budget.

   Coastal sediment budget refers to the identification of sediment sources and sinks, and the quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

   If more sediment is transported by coastal processes or human actions into a given area than is transported out, shoreline accretion results. If more sediment is transported out of an area than is transported in, shoreline erosion results.

2. **<u>Shoreline accretion</u>** results when more sediment is transported into a given area than is transported out.

3. The Atlantic coast includes erosion-resistant rocky headlands, barrier islands, mainland beaches, low-relief islands—all of which are subject to high storm surges from hurricanes and/or northeasters.

   True

4. Open coast storm surges along the Pacific shoreline are generally quite high (over 8 feet) because of shallow waters near the shore.

   False. Open coast storm surges along the Pacific shoreline are generally small (less than 2 feet) because of the narrow continental shelf and deep water close to shore.

5. **<u>c</u>** Wave height
6. **<u>d</u>** Wave crest elevation
7. **<u>a</u>** Wave setup
8. **<u>b</u>** Wave runup

a. An increase in the stillwater surface near the shoreline because of the presence of breaking waves.

b. The rush of water up a slope or structure.

c. The vertical distance between the wave crest and wave trough.

d. The elevation of the crest of a wave, referenced to the NGVD or other datum.

9. The maximum wave crest elevation is determined by the maximum wave height, which depends largely on the **100-year stillwater depth.**

10. On a FIRM, a V zone is:

    c. Shaded dark gray

11. Base Flood Elevations (BFEs) in coastal areas will be controlled by the highest of:

    d. Wave crest elevation or wave runup elevation.

12. Wave setup typically adds **1.5 to 2.5 feet** to the 100-year stillwater flood elevation.

UNIT III: FUNDAMENTALS

FUNDAMENTALS

INTRODUCTION

Sound coastal construction depends on accurate **risk assessment** (identifying the natural hazards that affect the area and the risks they pose to the building) and **risk management** (using physical or financial techniques to reduce, modify, offset, or share the risks).

In this unit you will learn about factors to be considered when assessing potential risk in residential coastal construction. You will examine two primary approaches to risk management—insurance and mitigation. And you will consider some of the tradeoffs to be weighed in decisions concerning siting, design, and construction, as well as the cost and insurance implications of those decisions.

UNIT OBJECTIVES

After completing this unit, you should be able to:

3.1 Explain the concept of "building success."
3.2 Describe the role of probability and recurrence interval in risk assessment.
3.3 Explain how safety factors are used in residential coastal design.
3.4 Give examples of risk management through hazard mitigation.
3.5 Describe the role of the NFIP in risk management.
3.6 Identify cost implications of siting and design decisions.

BUILDING SUCCESS

FLOOD, STORM, WIND, OR EROSION EVENTS

In coastal areas, a building can be considered a success only if it is capable of resisting damage from coastal hazards and coastal processes over a period of decades.

This statement does not imply that a coastal residential building must remain undamaged over its intended lifetime. It implies that the impacts of a design-level flood, storm, wind, or erosion event (or a series of lesser events with combined impacts equivalent to a design event) will be limited to the following:

- The building foundation should remain intact and functional.
- The envelope (lowest floor, walls, openings, and roof) should remain structurally sound and capable of minimizing penetration by wind, rain, and debris.
- The lowest floor elevation must be sufficient to prevent floodwaters from entering the elevated building envelope during the design event.
- The utility connections (e.g., electricity, water, sewer, natural gas) should remain intact or be restored easily.
- The building should be accessible and usable following a design-level event.
- Any damage to **enclosures** below the design flood elevation (DFE) should not result in damage to the foundation, the utility connections, or the elevated portion of the building.

def-a-

The *Coastal Construction Manual* defines **enclosure** as that portion of an elevated building below the DFE that is partially or fully surrounded by solid (including breakaway) walls.

SEISMIC EVENTS

Success during a design seismic event is defined differently than in flood, storm, wind, and erosion events. In a seismic event, the building should protect life and provide safety, even though the structure itself may sustain significant damage.

ACHIEVING BUILDING SUCCESS

The foregoing definitions of "building success" can be met through various methods, but they all have one thing in common: careful consideration and use of siting, design, construction, and maintenance practices. Failure to address even one of these four concerns can lead to building damage, destruction, or loss of use. Some examples are given below.

Siting

A design and construction success can be negated by a failure to site the building properly. The house shown in Figure 3-1 appears to be a structural success, but long-term erosion has left it standing permanently in the water. As a result, it is now uninhabitable.

Figure 3-1.
An apparent structural success but a siting failure.

The three houses in Figure 3-2 were built between January 1995 and January 1996, approximately 2 years before the photograph was taken. They were built 100 or more feet landward of the vegetation line, but rapid erosion associated with a nearby tidal inlet has left the houses standing on the beach. The shoreline will probably return to its former location, taking several years to do so. Although the buildings are structurally intact, their siting can be considered a failure.

Figure 3-2.
Houses left standing on the beach because of rapid erosion.

The townhouses shown in Figure 3-3 were built as little as 10 feet landward of a 170-foot-high bluff in 1991–92. By late 1997, storm- and inlet-related erosion at the base of the bluff destabilized the bluff face and threatened some of the buildings. Although experts assured the local government that the site was safe, it was not.

Figure 3-3.
Townhouses built too close to a bluff that has been destabilized by erosion.

NOTE

A conservative approach to siting and design of coastal residential buildings is recommended. Even expert opinion can underestimate the hazards to which a building will be exposed over its lifetime.

Design, Construction, and Maintenance

A siting success can be overshadowed by poor design, construction, or maintenance. The house shown in Figure 3-4 was set back from the shoreline, and safe from long-term erosion. However, it could not resist wind from Hurricane Fran.

Figure 3-4. Properly sited building damaged by Hurricane Fran. High winds from the storm caused heavy damage to the porch walls and roof.

NOTE

It must be recognized that lack of building damage during a high-probability (low-intensity) storm, flood, or other event cannot be construed as a building success. **Success can only be measured against a design event or against a series of lesser events with the cumulative effect of a design event.**

SELF-CHECK REVIEW: BUILDING SUCCESS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. What constitutes “building success” in a flood, storm, wind, or erosion event?

2. What constitutes “building success” in a seismic event?

3. Success can only be measured against a design event or a series of lesser events with the cumulative effect of a design event.

   True False

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. What constitutes "building success" in a flood, storm, wind, or erosion event?

   A building can be considered a success only if it is capable of resisting damage from coastal hazards and coastal processes over a period of decades.

   Hallmarks of a "successful" building include:

   - **Intact and functional foundation.**
   - **Structurally sound building envelope, capable of withstanding wind, rain, and debris.**
   - **Elevation of lowest floor sufficient to prevent floodwaters from entering the building envelope.**
   - **Intact or easily restorable utility connections.**
   - **Accessible and usable after a design-level event.**
   - **Foundation, utility connections, and elevated portion of the building undamaged as a result of damage to below-DFE enclosures.**

2. What constitutes "building success" in a seismic event?

   The building should protect life and provide safety, even though the structure itself may sustain significant damage.

3. Success can only be measured against a design event or a series of lesser events with the cumulative effect of a design event.

   True

RISK TERMINOLOGY

The coastal construction process is intended to reduce damage caused by natural hazards in coastal areas. These hazards include not only those associated with widely recognized, discrete events that recur over time—such as hurricanes, coastal storms, earthquakes, and earthquake-induced landslides and tsunamis—but also continuous and less obvious coastal phenomena such as long-term erosion, shoreline migration, and the corrosion and decay of building materials.

The effects of hazards associated with recurring events are often immediate, severe, and readily apparent, while those associated with long-term processes are more likely to become apparent only after having accumulated over time.

Sound coastal construction, therefore, depends upon:

- An understanding of the **natural hazards** that affect coastal areas.

- An accurate characterization of the variety of **risks** to which coastal construction is exposed.

- An understanding of various **risk management techniques.**

For the purposes of this discussion, several key terms are defined on the next page.

KEY TERMS

TERM	DEFINITION
Hazard Identification	The process of defining and describing a hazard (including its physical characteristics, magnitude, severity, frequency, and causative factors) and the locations or areas it affects.
Risk	The potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences.
Risk Assessment	A process or method for evaluating risk that is associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude, severity, exposure, and consequences.
Risk Management	Measures taken to reduce, modify, offset, or share risks associated with development in areas subject to coastal hazards. In the context of coastal residential construction, risk management is usually accomplished through mitigation or insurance.
Mitigation	Sustained action taken to reduce or eliminate long-term risk to people and property from hazards and their effects. In the context of coastal residential construction, mitigation usually takes the form of siting, design, construction, and maintenance of the building itself, and (sometimes) the form of protective works (e.g., dune or bluff stabilization, erosion control structures, beach nourishment). Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from a specific event.

RISK ASSESSMENT

For the purposes of this course, risk assessment is the process of quantifying the total risk to a coastal building (i.e., the risk associated with all the significant natural hazards that may act on the building).

The risk associated with any one hazard is defined by the combination of two factors:

- The probability that an event of a given recurrence interval will affect the building within a specified period.

- Both the short-term and the long-term consequences of that event for the building.

NOTE

Risk assessment must consider the occurrence and effects of **multiple events**, not just a single event. For example, it is not uncommon for an area to be struck by several minor storms in a short period of time, and for those storms to cause more damage than a major storm.

PROBABILITY AND RECURRENCE INTERVAL

In most coastal areas of the United States, buildings must meet minimum regulatory and code requirements intended to provide protection from natural hazard events of specified magnitudes. These events are usually identified according to their **recurrence intervals.** Examples include:

- The 100-year flood (the flood that has a one percent probability of being equaled or exceeded in any given year).
- The 50-year wind (the wind that has a two percent probability of being equaled or exceeded in any given year).

To determine the **probability** that a building will be affected by a specific natural hazard event, the designer must know not only the recurrence interval of the event, but also the period during which the building will be exposed to the hazard. The length of this period is determined by the designer, but it should not be arbitrary; it should be based on some amount of time relevant to the building, such as the assumed life of the building.

NOTE

While designers may assume a "useful life" for coastal buildings, owners typically view the habitation of the site as permanent (although the building itself may be renovated or replaced several times). Thus, designers may wish to **consider two useful lives**—one for the building itself and a longer lifetime for siting and setback purposes.

When the recurrence interval of a natural hazard is known, the designer can determine the probability of one or more occurrences of that event or a larger event during the specified period. Table 3.1 illustrates this concept for natural hazard events with recurrence intervals of 10, 25, 50, 100, and 500 years.

Table 3.1 Natural Hazard Probabilities During Periods of Various Lengths*

	FREQUENCY — RECURRENCE INTERVAL				
LENGTH OF PERIOD (YEARS)	10-YEAR EVENT	25-YEAR EVENT	50-YEAR EVENT	100-YEAR EVENT	500-YEAR EVENT
1	10%	4%	2%		0.2%
10	65%	34%	18%	10%	2%
20	88%	56%	33%	18%	5%
25	93%	64%	40%	22%	5%
30	96%	71%	45%		6%
50	99+%	87%	64%	39%	10%
70	99.94+%	94%	76%		13%
100	99.99+%	98%	87%	63%	18%

*The percentages shown represent the probabilities of one or more occurrences of an event of a given magnitude or larger within the specified period. The formula for determining these probabilities is $P_n = 1-(1-P_a)^n$, where P_a = the annual probability and n = the length of the period.

Of particular interest in this example is the 100-year event, because the 100-year flood serves as the basis for the floodplain management and insurance requirements of the NFIP regulations. As shown in Table 3.1, the 100-year flood has a 1 percent probability of being equaled or exceeded during a 1-year period.

As the length of the period increases, so does the probability that a flood of this magnitude or greater will occur. For example, during a 30-year period (equivalent to the length of a standard mortgage), the probability increases to 26 percent. And during a 70-year period, which may be assumed to be the useful life of many buildings, the probability increases to 50 percent.

The same principle applies to other natural hazard events with other recurrence intervals.

WARNING

Designers along Great Lakes shorelines should be aware that flood probabilities shown in Table 3.1 may underestimate actual probabilities during periods of high lake levels. For example, during rising lake levels in 1985, Lake Erie had a 10 percent probability of experiencing a 100-year flood event in the next 12 months (vs. one percent as shown in Table 3.1).

CONSEQUENCES OF THE HAZARDS

The nature and severity of an event's consequences for a given building will depend on two things:

- The **hazard forces** associated with the event (over which the designer has no control).
- The **siting, design, construction, and maintenance** of the building (which are largely within the control of the designer).

Because most coastal areas of the United States are subject to multiple hazards, the designer must identify all significant hazards at the construction site and determine the vulnerability of the building to those hazards.

The risk assessment must account for the **short-term and long-term effects** of each hazard, including the potential for **cumulative effects**, and the **combination of effects from different hazards.** Overlooking a hazard or underestimating its long-term effects can have disastrous consequences for the building and its owner.

SAFETY FACTORS

The selection of specific design conditions for an individual building should consider the safety factors inherent in the design, construction, and regulatory process and the consequences of a hazard exceeding the design condition. A good example is the difference in return frequencies used nationally for minimum wind and flood standards.

LENGTH OF PERIOD (YEARS)	50-YEAR EVENT
1	2%
10	18%
20	33%
25	40%
30	45%
50	64%
70	➡ 76%
100	87%

Wind. Minimum wind regulations are generally based on a 50-year return frequency. For a house in use for 70 years, there is a 76 percent probability (from Table 3.1) that a faster wind will occur. However, the **design process for wind applies safety factors** in the estimation of both the force of the wind on the structure and the strength of the materials intended to resist the wind force. If a house is properly designed and constructed, a net safety factor of at least 1.5 in the wind-resisting strength of the building can be expected. The safety factors for a house designed for 120-mph winds should mean that there will be no damage at 121 mph or even considerably faster. The consequences of a wind speed somewhat higher than design wind is very small—a relatively low risk of additional damage.

LENGTH OF PERIOD (YEARS)	100-YEAR EVENT
1	1%
10	10%
20	18%
25	22%
30	26%
50	39%
70	➡ 50%
100	63%

Flood. In comparison, flood regulations include no safety factors but partially compensate by using a longer return frequency of 100 years. From Table 3.1, the 70-year-old house is at lower risk to flood than wind—only a 50 percent chance of experiencing a worse flood, versus 76 percent for wind. However, the consequences of flooding slightly above the standard are severe. A water level a few inches above a minimum floor elevation can result in damaged walls, flooded carpets, warped flooring, and the loss of floor insulation, wiring, and ductwork. **NOTE: Safety factors for flood resistance are not inherent in the design process but must be specified by the designer or owner.**

Wind and flood standards are based on reducing building damage. In contrast, fire safety regulations are based on life safety issues. The protection of human life is held to a much higher standard than the risk of property damage. Similarly, high-occupancy publicly used buildings are held to even higher standards (e.g., the requirement for sprinkler systems) because many more lives are at risk.

Safety factors are not only used for wind, flood, seismic, and other design loads. They are also used by geotechnical engineers to determine the risk of slope failures to blufftop buildings. The ratio of soil strength to soil stresses is commonly used as the safety factor in such cases. The choice of a safety factor depends on:

NOTE

Safety factors are critical when bluff stability and setback distances are calculated.

- Type and importance of blufftop development.
- Bluff height.
- Nature of the bluff failure (e.g., deep rotational failure vs. translational failure).
- Acceptable level of risk associated with a bluff failure.

Studies in the Great Lakes provide guidance for the selection of appropriate safety factors.

Risk assessment for siting and design conditions should consider the return frequency of the hazard and any safety factors inherent in the design process, or safety factors should be explicitly added. In addition, **the design should consider the severity of the consequences that would result if the design conditions are exceeded.**

SELF-CHECK REVIEW: RISK ASSESSMENT

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. The risk associated with any one hazard is defined by the combination of two factors. What are those factors?

   ____

   ____

2. Risk assessment must consider the occurrence and effects of multiple events.

   True False

3. A 100-year event has a _____ probability of being equaled or exceeded in any given year.

   a. 1 percent
   b. 10 percent
   c. 50 percent
   d. 100 percent

4. To determine the probability that a building will be affected by a specific event, the designer must know ______________ and __________________.

   a. Recurrence interval and safety factor
   b. Period of exposure and consequences of the hazard
   c. Recurrence interval and period of exposure
   d. Safety factor and period of exposure

5. Safety factors are included in ___flood / wind___ regulations. (Circle one.)

6. The consequences for slightly exceeding a design event are worse for ___flood / wind___. (Circle one.)

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. The risk associated with any one hazard is defined by the combination of two factors. What are those factors?

   - **The probability that an event of a given recurrence interval will affect the building within a specified period.**
   - **The short-term and long-term consequences of that event for the building.**

2. Risk assessment must consider the occurrence and effects of multiple events.

   True

3. A 100-year event has a _____ probability of being equaled or exceeded in any given year.

   a. 1 percent

4. To determine the probability that a building will be affected by a specific event, the designer must know _______________ and ___________________.

   c. Recurrence interval and period of exposure

5. Safety factors are included in **_wind___** regulations. (Circle one.)

6. The consequences for slightly exceeding a design event are worse for **__flood_**. (Circle one.)

RISK MANAGEMENT

COST CONSIDERATION

There are costs associated with all decisions made regarding coastal construction. Some costs are readily apparent, while others are not.

Risk management refers to the process of reducing or offsetting risks. Therefore, risk management for coastal construction requires an understanding of the following:

- The ways in which siting, design, construction, and maintenance decisions can mitigate or exacerbate the consequences of individual hazard events.
- The role of hazard insurance.
- The acceptable level of residual risk (i.e., risk not offset through siting, design, construction, maintenance, and insurance).

APPROACHES TO RISK MANAGEMENT

There are two primary avenues for managing risk:

- **Physical**—through the protection provided by siting, design, construction, and maintenance.
- **Financial**—through the protection provided by insurance.

Some risks can also be managed through protective works (where permitted by local and state jurisdictions).

ACCEPTABLE LEVEL OF RISK

Eliminating all risk is impossible; therefore, inherent to residual risk management is the concept of an **acceptable level of residual risk**—i.e., the level of risk that is not offset and that must be accepted by the property owner. The principle of residual risk management, including the acceptable level of residual risk, underlies the entire coastal construction process.

RISK MANAGEMENT THROUGH HAZARD MITIGATION

Building codes and Federal, State, and local regulations establish minimum requirements for siting, design, and construction. Among these are requirements that buildings be constructed to withstand the effects of natural hazards with specified recurrence intervals (e.g., 100-year flood, 50-year wind, 500-year earthquake).

Therefore, when building code and regulatory requirements are met, they can help reduce the vulnerability of a building to natural hazards and, in a sense, provide a baseline level of risk management. It should be noted, however, that **meeting minimum regulatory requirements for the siting, design, and construction of a building does not guarantee that the building will be "safe."**

NOTE

Meeting only minimum code and regulatory requirements may result in designs based on different levels of risk for different hazards. The hazard levels addressed by such requirements should therefore be carefully considered during the design process.

Property owners, developers, and builders have the ability to further manage risks by providing an increased level of hazard mitigation. Examples of mitigation strategies are given on the next page.

EXAMPLES OF HAZARD MITIGATION STRATEGIES

- Siting a building further landward than the minimum distance specified by State or local setback requirements.
- Elevating a building above the level required by NFIP, State, and local requirements.
- Embedding supporting piles deeper than required by State or local regulations.
- Using structural members or connections that exceed code requirements for gravity, uplift, and/or lateral forces.
- Using improved roofing systems that provide greater resistance to wind than that required by code.
- Selecting building and roof shapes (e.g., hip roofs) that reduce wind loads.
- Protecting openings (e.g., windows, doors) with permanent or temporary shutters or covers, whether or not such protection is required by code.
- Eliminating or minimizing enclosures below an elevated building. Enclosures will be vulnerable to flood damage (even during minor flood events), are not covered by the Standard Flood Insurance Policy, and will increase flood insurance premiums for the building.

Consider the following example of how just one decision left to the designer, builder, or homeowner can affect risk.

EXAMPLE

Local floodplain management requirements that comply with the NFIP regulations require that any building constructed in the V zone be elevated so that the bottom of the lowest horizontal structural member is at or above the BFE (i.e., 100-year flood elevation, including wave effects). Meeting this requirement should protect the elevated portion of the building from the 100-year and lesser floods.

However, the elevated part of the building is still vulnerable to floods of greater magnitude. As shown in Table 3.1, the probability that the building will be subjected to a flood **greater** than the 100-year flood during an assumed useful life of 70 years is 50 percent. But during the same 70-year period, the probability of a 500-year or greater flood is only 13 percent. Therefore, raising the lowest horizontal structural member to the elevation of the 500-year flood would significantly reduce the risk for that building.

If elevating to the level of the 500-year flood is not possible, because of cost or other considerations, elevating by some lesser amount above the BFE will still reduce the risk.

WARNING

Regulations require a minimum standard but do not imply that any building that meets the standard is "safe." For example, a 30-year erosion setback does not imply that a building will be safe from erosion at that location. In fact, it is an estimation of future erosion based on historical erosion rates. A building located at the 30-year setback may be threatened long before 30 years pass.

Tradeoffs

Like the decision in the example just described, decisions made concerning the placement and orientation of the building, its size and shape, and the materials and methods used in its construction can decrease (or increase) potential damage from natural hazard events. However, these decisions can also affect initial and long-term costs, aesthetic qualities (e.g., the appearance of the finished building, views from within), and convenience for the homeowner (e.g., accessibility).

COST CONSIDERATION

Unless large numbers of buildings perform reasonably well, insurance availability or affordability can be jeopardized. Therefore, enhancing performance through mitigation is important.

The tradeoffs among these factors involve objective and subjective considerations that are often difficult to quantify and are likely to be assessed differently by developers, builders, homeowners, and community officials. Ultimately, however, a balance must be struck between cost, siting, and design decisions on the one hand and the amount of protection provided on the other.

NOTE

In the past, homeowners have relied on insurance for replacement costs when a natural hazard occurred, without regard to the inconvenience and disruption of their daily lives. Little thought was given to mitigation. Taking a mitigation approach can reduce these disruptions and inconveniences.

RISK MANAGEMENT THROUGH INSURANCE

Insurance provides a property owner with a financial tool for managing risk. For houses in coastal areas, earthquakes are of particular concern. These risks can be addressed through a variety of insurance mechanisms, including the NFIP, homeowner's insurance, insurance pools, and self-insurance plans.

Flood Insurance

Federally backed flood insurance is available for both existing and newly constructed buildings in communities that participate in the NFIP. To be insurable under the NFIP, a building must have a roof, have at least two walls, and be at least 50 percent above grade.

COST CONSIDERATION

In some areas, mortgage lenders may require that borrowers obtain specific types of hazard insurance.

Like homeowner's insurance, flood insurance is obtained from private insurance companies. But an important distinction is that insurance companies that issue homeowner's policies occasionally deny wind and earthquake coverage to buildings in areas where the risks from these hazards are high.

Exceptions to Availability. Flood insurance, because it is federally backed, is available for buildings in all coastal areas of participating communities, with the following exceptions:

- Buildings constructed entirely over water or seaward of mean high tide after October 1, 1982.

- Buildings newly constructed, substantially improved, or substantially damaged on designated undeveloped coastal barriers included in the Coastal Barrier Resources System (CBRS) after October 1, 1983. (You will learn more about the CBRS in the next unit.)

- Portions of boat houses located partially over water (e.g., the ceiling and roof over the area where boats are moored).

Rates and Premiums. The flood insurance rates for buildings in participating communities vary according to the:

- Physical characteristics of the building.
- Date the building was constructed.
- Magnitude of the flood hazard at the site of the building.

The flood insurance premium for a building is based on the rate, standard per-policy fees, the amount of the deductible, applicable NFIP surcharges and discounts, and the amount of coverage obtained.

Wind Insurance

Homeowner's insurance policies normally include coverage for wind. However, wind coverage is not always available—especially in coastal areas subject to a significant hurricane or typhoon risk, where wind hazards are usually high.

Insurance Pools. At the time the *Coastal Construction Manual* was prepared, underwriting associations, or "pools," were a last resort for homeowners who need wind coverage but could not obtain it from private companies. Eight States have established windstorm insurance plans: Alabama, Florida, Louisiana, Mississippi, New York, North Carolina, South Carolina, and Texas.

In addition, New Jersey operates the Windstorm Market Assistance Program (Wind-MAP) to help residents in coastal communities find homeowner's insurance in the voluntary market. When Wind-MAP does not identify an insurance carrier for a homeowner, the New Jersey FAIR Plan may provide a policy for perils only.

Earthquake Insurance

A standard homeowner's insurance policy can often be modified through an endorsement to include earthquake coverage. However, like wind coverage, earthquake coverage may not be available in areas where the earthquake risk is high. Moreover, deductibles and rates for earthquake coverage (of typical coastal residential buildings) are usually much higher than those for flood, wind, and other hazard insurance.

Self-Insurance

Where wind and earthquake insurance coverage is not available from private companies or insurance pools—or where property owners choose to forego available insurance—owners with sufficient financial reserves may be able to insure themselves (i.e., assume complete financial responsibility for the risks not offset through siting, design, construction, and maintenance). It is imperative, however, that property owners who contemplate self-insurance understand the true level of risk they are assuming.

SELF-CHECK REVIEW: RISK MANAGEMENT

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Explain what "acceptable level of risk" means.

2. Which of the following is a hazard mitigation strategy?

   a. Rebuilding after a hurricane.
   b. Embedding piles deeper than required.
   c. Determining the probability of a flood impacting a building a specific time period.
   d. Obtaining insurance.

3. An owner or designer may have to make tradeoffs between costs, aesthetic factors, and convenience.

   True False

4. What role does the NFIP play in risk management?

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Explain what "acceptable level of risk" means.

   Acceptable level of risk is the level of risk that is not offset through siting, design, construction, maintenance, and insurance and that must be accepted by the property owner.

2. Which of the following is a hazard mitigation strategy?

   b. Embedding piles deeper than required.

3. An owner or designer may have to make tradeoffs between costs, aesthetic factors, and convenience.

   True

4. What role does the NFIP play in risk management?

   Insurance (along with hazard mitigation) is one of the primary approaches to risk management. The NFIP makes federally backed flood insurance available for both existing and newly constructed buildings in communities that participate in the NFIP.

COST CONSIDERATIONS

Coastal residential buildings, like all buildings, have initial, long-term, and operational costs, as described in the following table.

COSTS	INCLUDE . . .
Initial costs	Property evaluation and acquisition costs, and the costs of permitting, design, and construction.
Long-term costs	Costs for preventive maintenance and for repair and replacement of deteriorated or damaged building components.
Operational costs	Costs associated with the use of the building, such as the costs of utilities and insurance.

In general, the decision to build in any area subject to significant natural hazards—especially coastal areas—increases the initial, long-term, and operational costs of building ownership.

- **Initial costs** increase because the natural hazards must be identified, the associated risks assessed, and the building designed and constructed to resist damage from the natural hazard forces.

- **Long-term costs** are likely to be greater because a building constructed in a natural hazard area will usually require more frequent and more extensive maintenance and repairs than a building sited elsewhere.

- **Operational costs** can increase for buildings in hazard areas because of higher insurance costs and, in some instances, higher utility costs.

WARNING

Enclosures Beneath Elevated Buildings

Improper construction of enclosures below elevated V-zone residential buildings and post-construction conversion of enclosed space to habitable use (in A zones and V zones) are the biggest compliance problems faced by the NFIP.

Designers and owners should realize that:

- Enclosures and items within them are subject to flood damage (even during minor flood events).
- Enclosures—and most items within them—are ***not covered by flood insurance*** and can result in significant costs to the building owner.
- Even the presence of properly constructed enclosures will increase flood insurance premiums for the entire building. (The premium rate will increase as the enclosed area increases.) Including enclosures in a building design can have significant cost implications.

The *Coastal Construction Manual* recommends the use of insect screening or open wood lattice instead of solid enclosures beneath elevated residential buildings. Note that some designers have incorporated open lattice with layers of translucent, reinforced plastic to overcome the most common objection by property owners—passage of salt spray and blowing sand through open lattice.

DECISION FACTORS

After a site has been selected, decisions must be made concerning the placement and orientation (siting or location) of the building and its design. These decisions are driven primarily by the following factors:

- **Awareness of natural hazards** by the owner, designer, and contractor.
- **Risk tolerance** of the owner.
- **Aesthetic considerations** (e.g., the appearance of the building, its proximity to the water, views from within the building, size and number of windows).
- **Building use** (e.g., full-time residence, part-time residence, rental property).
- **Requirements** of Federal, State, and local regulations and codes.
- **Initial costs** and **long-term costs.**

The interrelationships among aesthetics, building use, regulatory and code requirements, and initial cost become apparent during siting and design, and decisions are made according to the individual needs or goals of the property owner, designer, or builder.

What is often lacking in this process is an understanding of the effect of these decisions on long-term and operational costs. The consequences can range from increased maintenance and utility costs to the ultimate loss of the building.

COST IMPLICATIONS OF SITING DECISIONS

The following table provides examples that illustrate some of the effects that siting decisions can have on long-term and operational costs.

SITING DECISION EXAMPLES

SITING DECISION	PROBLEM	COST IMPLICATIONS
Siting Close to Water	The closer buildings are sited to the water, the more likely they are to be affected by flooding, wave action, erosion, scour, debris impact, overwash, and corrosion. In addition, wind speeds are typically higher along coastlines, particularly within the first several hundred feet inland.	Repeated exposure to these hazards, even when buildings are designed to resist their effects, can lead to increased long-term costs for maintenance and damage repair.
Siting in Erosion Hazard Area	Erosion—especially long-term erosion—poses an especially serious threat to buildings near the water, even those situated on high bluffs above the floodplain. Storm-induced erosion can lower ground elevations around coastal buildings, exposing V-zone buildings to higher than anticipated forces, and exposing A-zone buildings to V-zone flood hazards.	Maintenance and repair costs will be high for buildings in erosion hazard areas, both because of damage to the building and because of the need for remedial measures (e.g., building relocation or erosion protection projects, such as seawalls, revetments, or beach nourishment, where permitted). The average annual maintenance cost for shore protection can equal 5 to 10 percent of construction cost or the cost of building relocation.
Siting in a V Zone	Sites nearest the water are more likely to be in a V zone, where building foundations, access stairs, parking slabs, and other components below the building are especially vulnerable to flood, erosion, and scour effects.	The potential for repeated damage and repair costs is greater for V-zone buildings, and the buildings have higher flood insurance rates and increased operational costs. Although elevating a building can protect the superstructure from flood damage, it may make the entire building more vulnerable to earthquake and wind damage.

COST CONSIDERATION

Designers and homeowners should recognize that erosion control measures can be expensive, both initially and over the lifetime of a building. In some instances, erosion control costs can equal or exceed the cost of the property or building being protected.

COST IMPLICATIONS OF DESIGN DECISIONS

The following table provides examples that illustrate some of the effects that design decisions can have on long-term and operational costs.

DESIGN DECISION EXAMPLES

DESIGN DECISION	PROBLEM	COST IMPLICATIONS
Large Number of Openings	For aesthetic reasons, the walls of coastal buildings often include a large number of openings for windows and doors, especially the walls that face the water.	Designs of this type lead to greater initial costs for strengthening the walls and for protecting the windows and doors from wind and windborne debris (missiles). If adequate protection in the form of shutter systems or impact-resistant glazing is not provided, long-term costs will increase because of (1) the need to repair damage to glazing and secondary damage to the building caused by the entry of wind-driven rain and sea spray and/or (2) the need to install retrofit protection devices at a later date.
Building on Perimeter Wall Foundation or Fill	NFIP regulations allow buildings in coastal A zones to be constructed on perimeter wall (e.g., crawlspace) foundations or on earth fill. Open (pile, pier, or column) foundations are required only for V-zone buildings.	Although a coastal A-zone building on a perimeter wall foundation or fill may have a lower initial construction cost than a similar building on an open foundation, it may be subject to damaging waves, velocity flows, and/or erosion scour over its useful life. The long-term costs for a building on these types of foundation may actually be higher because of the increased potential for damage.
Use of High-Maintenance Materials	Designers, in an effort to reduce initial construction costs, may select building materials that require high levels of maintenance.	Two factors tend to counteract any initial savings: (1) Coastal buildings, particularly those near bodies of salt water, are especially prone to the effects of corrosion. (2) Owners of coastal buildings often fail to sustain the required levels of maintenance. The net effect is often increased building deterioration and, sometimes, a reduced capacity to resist the effects of future natural hazard events.

SELF-CHECK REVIEW: COST CONSIDERATIONS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Costs for repair and replacement of deteriorated or damaged building components are an example of:

   a. Initial costs
   b. Long-term costs
   c. Operational costs

2. In general, the decision to build in a coastal area increases initial costs but not long-term or operational costs.

   True False

3. Describe the cost implications of building in a V zone.

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Costs for repair and replacement of deteriorated or damaged building components are an example of:

   b. Long-term costs

2. In general, the decision to build in a coastal area increases initial costs but not long-term or operational costs.

   False.
   It increases all three—initial, long-term, and operational costs.

3. Describe the cost implications of building in a V zone.

   - **Greater potential for repeated damage and repair costs.**
   - **Higher flood insurance rates.**
   - **Increased operational costs.**

UNIT III EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit III. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit IV.

1. To be considered a building success, a coastal residential building must remain undamaged over its intended lifetime.

   True False

2. A building can be considered a success if it does not sustain significant damage during a high-probability (low-intensity) storm or flood event.

   True False

3. Minimum regulations for ______ are based on a 50-year return interval.

   a. Flood
   b. Wind
   c. Earthquake
   d. Tsunami

4. To determine the probability that a building will be affected by a specific natural hazard event, the designer must know the recurrence interval of that event as well as the period during which the building will exposed.

   True False

5. The consequences of slightly exceeding a design flood event are ______________________ than of slightly exceeding a wind event.

   a. Less severe
   b. More severe

6. ___________________________________ refers to the process of reducing or offsetting risk.

7. Safety factors for flood resistance:

    a. Must be specified by the designer or owner.
    b. Are inherent in the design process.
    c. Are not important because floods have a return frequency of 100 years.
    d. Are not important because the consequences of exceeding a design flood are minimal.

8. It is possible to eliminate all risk through prudent siting, design, and construction practices.

    True False

9. Two main approaches to risk management in coastal construction are:

    a. Hazard identification and risk assessment.
    b. Risk assessment and insurance.
    c. Insurance and hazard mitigation.
    d. Hazard mitigation and hazard identification.

10. Which of the following is a hazard mitigation strategy?

    a. Repairing a roof damaged in a storm.
    b. Selecting roof shapes that reduce wind loads.
    c. Determining the probability of a wind event impacting a building during a specific time period.
    d. Obtaining wind insurance.

11. In a coastal A zone, which of the following design decisions is likely to result in **increased** long-term costs?

    a. Using shutter systems or impact-resistant glazing on openings.
    b. Using low-maintenance materials.
    c. Building on an open (e.g., pile) foundation.
    d. Building on a perimeter wall foundation.

12. NFIP insurance:

    a. Is obtained directly from the NFIP.
    b. Covers flood, wind, and earthquake damage.
    c. Is an example of hazard mitigation.
    d. Is obtained from private insurance companies.

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT III EXERCISE—ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. To be considered a building success, a coastal residential building must remain undamaged over its intended lifetime.

   False. It must be able to resist damage over a period of decades, within specified limits related to foundation, envelope, elevation above floodwaters, utility connections, and accessibility.

2. A building can be considered a success if it does not sustain significant damage during a high-probability (low-intensity) storm or flood event.

   False. Success can only be measured against a design event or against a series of lesser events with the cumulative effect of a design event.

3. Minimum regulations for ______ are based on a 50-year return interval.

   b. Wind

4. To determine the probability that a building will be affected by a specific natural hazard event, the designer must know the recurrence interval of that event as well as the period during which the building will exposed.

   True

5. The consequences of slightly exceeding a design flood event are ______________________ than of slightly exceeding a wind event.

   b. More severe

6. **Hazard mitigation** refers to the process of reducing or offsetting risk.

7. Safety factors for flood resistance:

   a. Must be specified by the designer or owner.

8. It is possible to eliminate all risk through prudent siting, design, and construction practices.

   False. There will be some level of residual risk that must be accepted by the property owner.

9. Two main approaches to risk management in coastal construction are:

   c. Insurance and hazard mitigation.

10. Which of the following is a hazard mitigation strategy?

    b. Selecting roof shapes that reduce wind loads.

11. In a coastal A zone, which of the following design decisions is likely to result in **increased** long-term costs?

    d. Building on a perimeter wall foundation.

12. NFIP insurance:

    d. Is obtained from private insurance companies.

UNIT IV: IDENTIFYING AND EVALUATING SITE ALTERNATIVES

IDENTIFYING AND EVALUATING SITE ALTERNATIVES

INTRODUCTION

NOTE

One of the principal objectives of the *Coastal Construction Manual* is to improve site selection for coastal residential buildings.

Experience has shown that not all coastal lands are suitable for development—or at least not the type and intensity of development that has occurred on coastal lands in the past. Figures 3-1, 3-2, and 3-3 in the previous unit showed some of the results of inappropriate site selection and development.

Unfortunately, many similar siting and development decisions are made every day based on site conditions at the time of purchase or on an incomplete or inaccurate assessment of future conditions. Too often these decisions leave property owners and local governments to struggle at a later point with a number of **avoidable problems**, such as:

- Damage to or loss of buildings.
- Damage to attendant infrastructure.
- Encroachment of buildings onto public beaches.
- Having to provide emergency or permanent measures to protect vulnerable buildings and infrastructure.
- Having to relocate buildings.
- Emergency evacuation.
- Injuries and loss of life.

Informed decisions regarding siting, design, and construction begin with a complete and detailed understanding of the advantages and disadvantages of potential sites for coastal residential construction—knowledge that should be gained **before** purchasing coastal property and initiating development.

This unit provides information about identifying suitable property for coastal residential structures, compiling information about coastal property, and the process of evaluating hazards and potential vulnerability.

UNIT OBJECTIVES

After completing this unit, you should be able to:

4.1 Identify the factors to be considered when identifying sites for residential coastal development.
4.2 Identify the types of information that should be obtained to evaluate coastal property.
4.3 Identify sources of information about coastal property.
4.4 Describe the major steps in evaluating hazards and potential vulnerability of coastal property.

THE EVALUATION PROCESS

A thorough evaluation of coastal property for development purposes involves four steps:

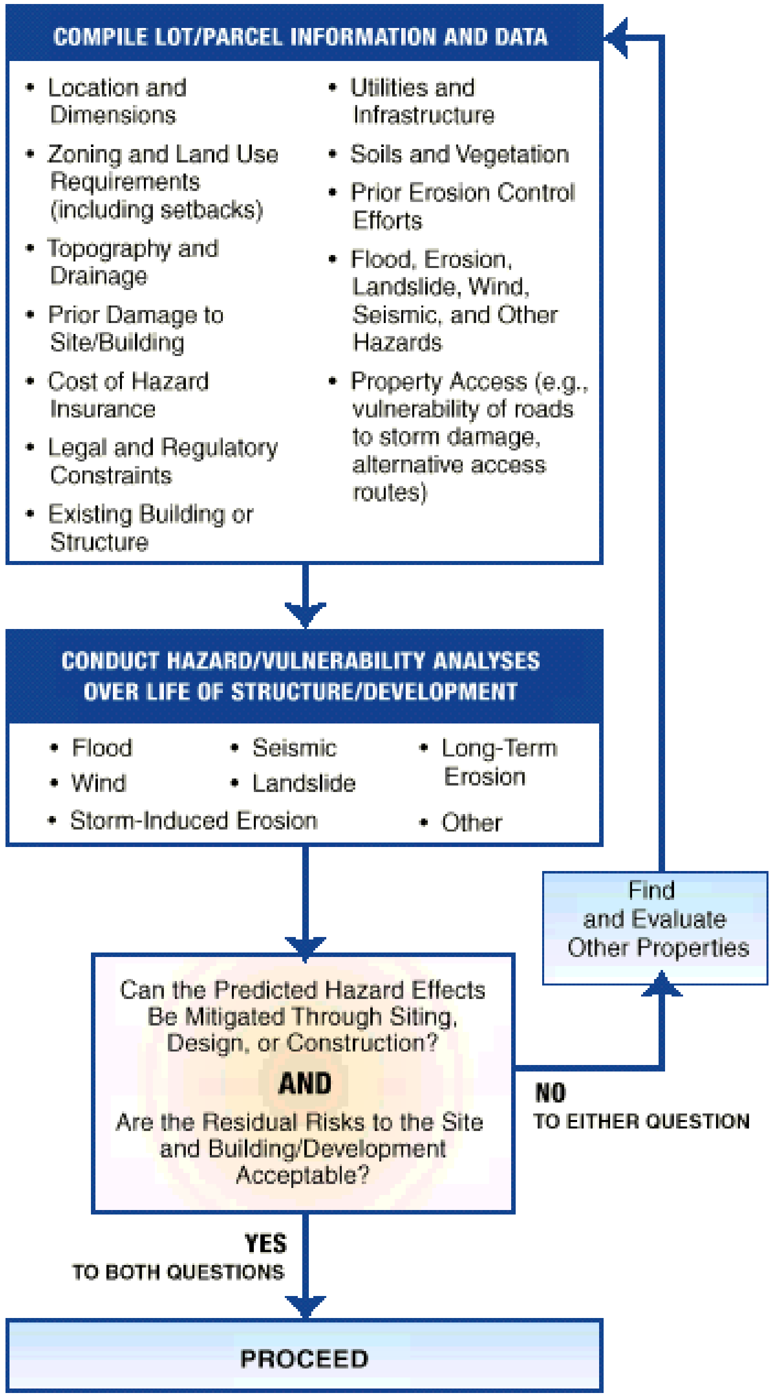
WARNING

Many coastal property buyers fail to investigate potential hazards to their land and buildings. Designers should work with owners to identify and mitigate those hazards.

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

This evaluation process is depicted in the graphic on the next page and described in the remainder of this unit.

Figure 4-1. Evaluation of coastal property.



TYPES OF DEVELOPMENT

A building or development site need not be vacant or undeveloped land. Indeed, much of the coastal construction occurring today involves redevelopment or replacement of existing buildings. Therefore, property evaluation as discussed in this unit applies to the following types of development:

- **Infill development**—Development on previously subdivided or platted vacant lots or small parcels, with roads and utilities in place. These lots are surrounded by or adjacent to residential structures.
- **Redevelopment**—Development on previously developed lots or small parcels on which a building currently exists (see Fig. 4-2).
- **Development of raw land**—Development on large, vacant parcels, usually without on-site access roads and utilities.

Figure 4-2. Redevelopment of previously developed property—post-Hurricane Fran elevation and reconstruction project on Figure Eight Island, North Carolina.

IDENTIFYING CANDIDATE PROPERTIES

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

The first step in the coastal development or construction process involves identifying and purchasing a vacant or previously developed lot or parcel. It is this step that, in many ways, constrains subsequent siting, design, and construction decisions and determines the long-term vulnerability of coastal residential buildings.

Prospective property buyers who fail to fully investigate properties before acquiring them may subsequently be faced with a variety of problems that are difficult, costly, or essentially impossible to solve.

FACTORS TO CONSIDER

Although this course will not address the initial identification of candidate properties in detail, property buyers and design professionals who are assisting them in property evaluations should keep the following factors in mind as they narrow their search for a building/development site.

- **Risk.** Before any purchase, each property buyer should, in consultation with experts, determine the acceptable level of residual risk and decide how to manage the actual risks expected over the life of the building or development. Note that risk assessment, risk tolerance, and risk management issues are not simple; ***property acquisition and development decisions must often be made with inadequate or imprecise information.***

- **Types of hazards.** The geographic region or area a purchaser is interested in will determine the types of hazards to which the property will be exposed.

- **Historical records.** In the absence of better information, historical records can be used to predict future hazard conditions, impacts, and frequencies. However, natural and manmade changes at a site may render simple extrapolation of historical patterns inaccurate.

- **Intended use.** Any given lot or parcel may or may not be suitable for the purchaser's intended use of the property.

- **Regulatory requirements.** Requirements related to land use, zoning, setbacks, health, floodplain management, building code, and related issues will, in large part, determine development densities, building size and location limitations, minimum design and construction practices, and allowable responses to erosion hazards. However, ***compliance with these requirements does not ensure the future safety of the building or development.***

- **Unreliability of historical development practices.** Development practices that perpetuate or duplicate historical siting, design, or construction practices will not ensure the future safety of a new building or development. Many historical practices are inadequate by today's standards. Further, historical practices that were at one time adequate may be rendered inadequate by changing shoreline conditions.

- **Erosion control.** An existing erosion control structure on a lot or parcel is an indication of prior erosion, but the structure may or may not be adequate to protect a building or development in the future. Moreover, many States and communities limit or prohibit construction or reconstruction of erosion-control devices (see Fig. 4-3).

Figure 4-3.
Groins and revetments at a Massachusetts community. Narrowing the search for coastal property suitable development or redevelopment requires careful consideration of many factors, including the nature and success of such previous erosion-control efforts. (Note that come communities and States restrict or prohibit such structures.)

- **Increasing vulnerability.** The vulnerability of a coastal building will probably increase with time, as a result of one or more of the following:

  - Gradual weakening or deterioration of the building itself.
  - Sea-level or lake-level rise.
  - Erosion-induced shoreline recession (which affects the majority of coastal areas).

- **Adjacent and nearby development activities.** Future development activities and patterns on adjacent and nearby properties may affect the vulnerability of buildings or development on any given property.

- **Actual vulnerability and risk.** Property selection, along with subsequent siting, design, construction, and maintenance decisions, will determine the actual vulnerability of and risk to any building or improvements.

SELF-CHECK REVIEW: IDENTIFYING CANDIDATE PROPERTIES

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. List the four steps of the process for evaluating coastal property.

   1) ____

   2) ____

   3) ____

   4) ____

2. Thorough property evaluation needs to be conducted for development of raw land and infill development, but it is not important for redevelopment projects.

   True False

3. In the absence of better information, historical records can be used to predict future hazard conditions, impacts, and frequencies.

   True False

4. To what extent can past development practices at a location be used as a guide for current development?

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. List the four steps of the process for evaluating coastal property.

   1) COMPILE INFORMATION: Identify candidate properties and compile lot/parcel information for each.

   2) EVALUATE: Conduct a hazards analysis and risk assessment.

   3) DECIDE: Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.

   4) TAKE ACTION: Either proceed with the purchase or redevelopment of a property, or reject the candidate properties and find and evaluate other properties.

2. Thorough property evaluation needs to be conducted for development of raw land and infill development, but it is not important for redevelopment projects.

   False. Thorough property evaluation should be conducted for any coastal development—whether infill development, redevelopment, or development of raw land.

3. In the absence of better information, historical records can be used to predict future hazard conditions, impacts, and frequencies.

   True

4. To what extent can past development practices at a location be used as a guide for current development?

   Past development practices are not a reliable guide for current development and will not ensure the future safety of a new building or development. Many historical practices are inadequate by today's standards. Even historical practices that were at one time adequate may be rendered inadequate by changing shoreline conditions.

COMPILING INFORMATION ON COASTAL PROPERTY

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

After candidate properties are identified, a wide range of information should be compiled for each property. This task is no trivial matter and may require considerable time and effort.

Table 4.1 outlines the types of information that should be obtained to evaluate coastal property. Information listed in this table is usually available from local, regional, State, or Federal governments, from universities, or from knowledgeable professionals. However, the availability and quality of the information will vary by State and community.

Table 4.1. General Information Checklist

PROPERTY LOCATION	
• Municipal, township, county, or other local jurisdiction • Street address • Parcel designation (e.g., tax map ID)	• Subdivision information • Special zoning or land use districts • Other hazard area designation • Natural resource protection area designation
PROPERTY DIMENSIONS	
• Total acreage • Seaward or waterward property boundary—platted or fixed line, moving line (e.g., Mean High Water line, Mean Low Water line, or other datum, elevation, or feature) • Property shape • Property elevations and topography	• Location relative to adjacent properties; configuration of adjacent properties • Shoreline frontage (i.e., dimension parallel to shoreline) • Property depth (i.e., dimension perpendicular to shoreline) • Acreage landward/outside of natural, physical, or regulatory construction or development limits (i.e., usable acreage)

Table 4.1. General Information Checklist (Continued)

LEGAL AND REGULATORY INFORMATION

- Land use designation at property and adjacent properties
- Zoning classification and resulting restrictions on use
- Building code and local amendments
- Flood hazard area: elevation and construction requirements
- Natural resource protection area: siting, construction, or use restrictions
- Easements and rights-of-way on property (including beach access locations for nearby properties or the general public)
- Local/State siting and construction regulations
- Regulatory front, back, and side setbacks
- Local/State permitting procedures and requirements
- Local/State regulations regarding use, construction, and repair of erosion-control measures
- Riparian rights
- Local/State restrictions on cumulative repairs or improvements
- Conditions or other requirements attached to building or zoning permits
- Subdivision covenants and other restrictions imposed by developers and homeowners associations
- Hazard disclosure requirements for property transfer, including geologic hazard reports

PHYSICAL AND NATURAL CHARACTERISTICS

- Soils, geology, and vegetation—site and region
- Topography of nearshore (including nearshore slope), beach, dune, bluff, uplands
- Site drainage—surface water and goundwater
- Littoral sediment supply and sediment budget
- Storm, erosion, and hazard history of property
- Erodibility of the nearshore bottom
- Erosion-control structure on site: type, age, condition, and history
- Proximity to inlets and navigation structures
- Previous or planned community/regional beach/dune restoration projects
- Relative sea-level/water-level changes—land subsidence or uplift

INFRASTRUCTURE AND SUPPORTING DEVELOPMENT

- Access road(s)
- Emergency evacuation route(s)
- Electric, gas, water, telephone, and other utilities—onsite or offsite lines and hookups
- Sewer or septic
- Limitations imposed by utility/infrastructure locations on property use

Table 4.1. General Information Checklist (Continued)

FINANCIAL CONSIDERATIONS	
• Intended use: owner-occupied or rental property • Real estate taxes • Development impact fees • Permit fees • Hazard insurance: availability, premiums, deductibles, and exclusions • Property management fees	• Special assessments for community/association projects (e.g., private roads and facilities, dune preservation) • Maintenance and repair of private erosion-control structures • Increased building maintenance and repairs in areas subject to high winds, wind-driven rain, and/or salt spray • Building damage costs (insured and uninsured) from previous storms

SOURCES OF INFORMATION

Both publications and agencies and/or organizations can be sources of information for evaluating coastal properties.

Publications

Many States and communities have produced brochures or publications that will help property owners and prospective buyers evaluate coastal property. The publications listed below are examples of the types of information available.

EXAMPLES OF AVAILABLE PUBLICATIONS

- *Purchasing Paradise: Things to know and questions to ask when buying coastal property in Florida* (Florida Coastal Management Program, 1997).

  This brochure briefly summarizes coastal ecosytems, coastal processes, the impacts humans have on coastal environments, and important considerations regarding the purchase of coastal property.

- *Coastal Processes Manual: How to Estimate the Conditions of Risk to Coastal Property from Extreme Lake Levels, Storms, and Erosion in the Great Lakes Basin,* 2nd edition (Keillor, 1998).

  Although this manual contains information specific to the Great Lakes shorelines of Wisconsin, it also provides a technical framework for evaluating coastal processes and erosion-control measures in other areas. A videotape was produced in conjunction with the first edition (1987) of the manual. The following web site complements, supplements, and updates the current manual:
  http://www.seagrant.wisc.edu/advisory/coastal_engr/index.html

- *A Manual for Researching Historical Coastal Erosion* (Fulton, 1981).

  This manual describes in detail how one might use historical weather data, local government records, and historical maps and photos to understand and quantify shoreline, sea bluff, and cliff retreat. Two communities in San Diego County, California, are used as case studies to illustrate the research methods presented.

- *Questions and Answers on Purchasing Coastal Real Estate in North Carolina* (North Carolina Real Estate Commission, 1996).

  This brochure provides prospective property owners with basic information on a variety of topics: shoreline erosion, erosion control, siting, storm-resistant construction techniques, flood and wind insurance, and building repair regulations.

EXAMPLES OF AVAILABLE PUBLICATIONS (CONTINUED)

- *The Citizen's Guide to North Carolina's Shifting Inlets* (Baker, 1977).

  This publication illustrates the dynamic nature of tidal inlets by superimposing historical shorelines onto more recent aerial photographs (see Fig. 4-4). This excellent method of presentation could serve as a model for other States to follow.

- *A Pictorial Atlas of North Carolina Inlets* (Cleary and Marden, 1999).

  This is North Carolina Sea Grant's replacement for *The Citizen's Guide to North Carolina's Shifting Inlets* (see above).

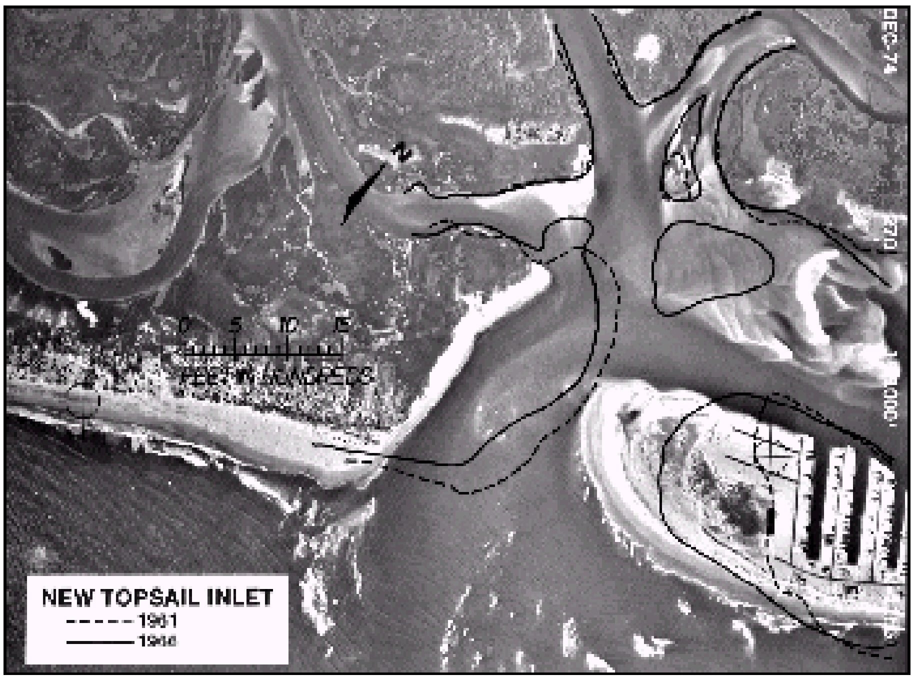


Figure 4-4.
1974 photograph with earlier shorelines superimposed—evidence that development near tidal inlets requires special attention.

Agencies and Organizations

Prospective property buyers and designers can contact agencies and organizations listed in Table 4.2. These sources may be able to provide information that will support an evaluation of the suitability of coastal property for residential construction or development. The *Coastal Construction Manual* lists additional sources of information.

Table 4.2. Potential Sources of Supporting Information for Evaluating Coastal Property

LOCAL, REGIONAL, AND STATE AGENCIES RESPONSIBLE FOR:		
LOCAL	• Environmental • Planning • Zoning • Floodplain Management • Land Use • Health • Building Permits	• Soils and Geology • Municipal Engineering • Utilities • Deeds and Property Records • Assessments and Taxes • Emergency Management
REGIONAL	• Health • Planning • Utilities • Water/Waste Management • Soils and Geology • Beach or Shore Management/ Erosion Control	• Navigation and Ports • Natural Resource Conservation and Management • Geographic Information Systems • Photogrammetry and Remote Sensing
STATE	• Coastal Zone Management • Planning • Building Codes and Standards • Soils and Geology • Floodplain Management • Natural Resource Management • Beach or Shore Management/ Erosion Control	• Department of Insurance • Navigation and Ports • Emergency Management • Transportation • Natural Resource Conservation and Management • Geographic Information Systems • Photogrammetry and Remote Sensing

Table 4.2. Potential Sources of Supporting Information (Continued)

FEDERAL AGENCIES, INCLUDING:

- Federal Emergency Management Agency (FEMA)
- U.S. Army Corps of Engineers (USACE)
- U.S. Geological Survey (USGS)
- National Ocean Service, Office of Ocean and Coastal Resource Management (OCRM)
- U.S. Natural Resources Conservation Service (NRCS)
- National Weather Service (NWS)
- International Joint Commission (Great Lakes)

UNIVERSITY DEPARTMENTS, INCLUDING:

- Coastal or Ocean Engineering
- Geology, Civil Engineering, or Soils
- Architecture and Building Construction
- Planning
- Atmospheric Sciences
- Botany, Biology, or Marine Biology
- Coastal or Ocean Law
- Sea Grant Programs (Research and Advisory Components)

PROFESSIONAL ORGANIZATIONS, INCLUDING:

- American Society of Civil Engineers (ASCE)
- National Society of Professional Engineers (NSPE)
- American Institute of Architects (AIA)
- American Planning Association (APA)
- Model Building Code Organizations
  - Building Officials & Code Administrators International, Inc. (BOCA)
  - International Conference of Building Officials (ICBO)
  - Southern Building Code Congress International, Inc. (SBCCI)
- American Society of Landscape Architects (ASLA)
- Geological Society of America (GSA)
- Association of State Flood Plain Managers (ASFPM)
- National Association of Home Builders (NAHB)

PROPERTY DISCLOSURE REQUIREMENTS

A number of States require that residential real estate transactions be accompanied by a disclosure of information pertaining to flood hazards and/or other hazards (if the seller or agent knows of such hazards).

However, the requirements concerning the form and timing of disclosures differ from State to State, so the type and amount of information that must be disclosed varies widely.

WARNING

Even in States that require hazard disclosures in residential real estate transactions, property buyers should conduct their own investigations of prospective sites rather than rely solely on information provided by sellers and real estate agents.

Table 4.3 summarizes disclosure requirements for selected States. This list is based on information presented in *Coastal Hazard Mitigation 309 State Enhancement Grants, Assessment & Strategy Summary*, by the National Ocean Survey, Office of Ocean and Coastal Resource Management (OCRM 1998), as well as a review of selected State statutes and regulations.

Taken collectively, the disclosure requirements (in force and as proposed) provide a good indication of the types of information that prospective property buyers and designers should seek—whether or not their State requires such a disclosure.

Table 4.3.
Selected State Disclosure Requirements and Ongoing Efforts to Require Hazard Disclosure

STATE	COMMENTS
CALI-FORNIA	Section 8589.3 of the California Codes requires disclosure if a property is within a Special Flood Hazard Area (A zone or V zone). Section 1102.6c requires sellers or agents to complete a natural hazard Disclosure Statement, disclosing whether property lies within any of the following: an SFHA; an area of potential flooding in the event of a dam failure; a very high fire hazard severity zone; a wildland area that may contain substantial forest fire risks and hazards; an earthquake fault zone; a seismic hazard zone.
FLORIDA	Chapter 161, "Beach and Shore Preservation," and Chapter 498, "Land Sales Practices," of the Florida Statute address property disclosure statements. Section 161.57, "Coastal Properties Disclosure Statements," sets forth specific requirements. Section 498.037 requires that any public offering statement for subdivided lands disclose fully and accurately the physical characteristics of the lands and make known to prospective buyers all unusual and material circumstances of features that affect those lands.
HAWAII	Hawaii has adopted procedures, as part of its NFIP ordinances, requiring disclosure of flood zone information.
ILLINOIS	Illinois requires that sellers sign a form that states whether they know if the property has ever been flooded.

Table 4.3. Selected State Disclosure Requirements (Continued)

STATE	COMMENTS
MAINE	The Maine Coastal Management Program is working with real estate agents to develop a mechanism for disclosing the risks of coastal hazards.
MASSA-CHUSETTS	Massachusetts Coastal Zone Management has generated shoreline change maps depicting long-term average annual shoreline change rates at 50-meter intervals along the shore. A Coastal Hazards Notification bill (disclosing erosion rate and flood zone information) has been submitted to the legislature.
NEW JERSEY	Amendments to the Coastal Area Facility Review Act (CAFRA) include a provision that permits issued for properties in the coastal zone, and conditions that must be met to receive the permit, must be recorded with the deed to the property.
NEW YORK	A Coastal Erosion Task Force report recommended notification if a property lies within a designated State Coastal Erosion Hazard Area. Draft disclosure legislation was developed by the Department of State but has not been enacted by the legislature.
NORTH CAROLINA	The Division of Coastal Management is working to develop disclosure mechanisms, in response to recommendations from the Governor's Task Force on Hurricane Mitigation.
OHIO	Section 1506.06(F) of the Ohio Administrative Code requires disclosure if a property is included in a Lake Erie Coastal Erosion Area. Section 5302.30(D) of the Ohio Revised Code requires completion of a disclosure form developed by the Director of Commerce.
OREGON	A Coastal Natural Hazards Policy working group (Oregon Sea Grant 1994) concluded that Oregon law requires only minimal disclosure of natural hazards information. The Working Group recommended creation of a new category of information (Geotechnical) to be included in the disclosure form required under Oregon Revised Statute 696. The legislature has not yet acted on the recommendation.
SOUTH CAROLINA	Section 48-39-330 of the Code of Laws of South Carolina requires a disclosure statement for the transfer of property extending seaward of the 40-year setback line. The statement must include language that states the property is or may be affected by setback requirements, must include the local erosion rate, and must include the State plan coordinates of the seaward corners of habitable structures.

Table 4.3. Selected State Disclosure Requirements (Continued)

STATE	COMMENTS
TEXAS	Section 61.025 of the Texas Statutes, Natural Resources Code, requires disclosure of the following to purchasers of property in close proximity to Gulf of Mexico beaches: that the public has acquired a right-of-use or easement over the area seaward of the vegetation line; that State law prohibits any obstruction of, barrier to, restraint of, or interference with use of the public easement; and that structures erected seaward of the vegetation line, or that become seaward of the vegetation line as a result of natural processes, are subject to a lawsuit by the State seeking removal.
WASHING-TON	Section 64.06.020 of the Revised Code of Washington requires, among other things, that sellers complete a disclosure form that lists the following information (if known by the seller): if the property is in a designated floodplain; if the property or structure is damaged as a result of fire, wind, flood, beach movements, earthquake, expansive soils, or landslides; if rights-of-way, easements, and access limitations affect the property; or if settling, slippage, or sliding of the house or improvements has occurred.

SELF-CHECK REVIEW: COMPILING INFORMATION

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Where can a prospective home buyer obtain information about a coastal property's location in relation to the floodplain?

2. Where could the developer obtain relevant information about floodplain management and about soils and geology?

ANSWER KEY

NOTE: Your answers may be slightly different, but they should include the same main points.

1. Where can a prospective home buyer obtain information about a coastal property's location in relation to the floodplain?

   In some States, the seller is required to disclose information pertaining to flood hazards. The buyer can also contact local and State agencies responsible for floodplain management, as well as FEMA. In addition, the State or community may have publications available that provide useful information.

2. Where could the developer obtain relevant information about floodplain management and about soils and geology?

   - **Local, regional, and State agencies responsible for floodplain management and for soils and geology.**
   - **Federal agencies (e.g., FEMA, U.S. Geological Survey).**
   - **University departments (e.g., coastal or ocean engineering, geology, civil engineering, soils).**
   - **Professional organizations (e.g., Geological Society of America, Association of State Flood Plain Managers).**

EVALUATING HAZARDS AND POTENTIAL VULNERABILITY

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

This step is perhaps the most crucial in evaluating the suitability of coastal lands for development or redevelopment.

Basing hazard and vulnerability analyses solely on building code requirements, the demarcation of hazard zones or construction setback lines, and the location and design of nearby buildings is clearly an inadequate approach.

A recommended procedure for evaluating hazards and potential vulnerability is outlined below.

DEFINE COASTAL HAZARDS AFFECTING THE PROPERTY

1. **Characterize hazards.** Use all available information to characterize the type, severity, and frequency of hazards (e.g., flood, storm-induced and long-term erosion, accretion or burial, wind, seismic, tsunami, landslide, wildfire, and other natural hazards) that have affected or could affect the property.

2. **Identify trends.** Examine the record for long-term trends (> 50–100 years), short-term trends (< 10–20 years), and periodic or cyclic variations (both spatial and temporal) in hazard events. Determine whether particularly severe storms are included in the short-term or long-term records and what effects those storms had on the overall trends. If cyclic variations are observed, determine the periods and magnitudes of the variations.

3. **Consider extrapolation.** Determine whether or not extrapolation of historical trends is reasonable. Examine the record for significant changes to the coastal system or upland areas that will reduce, intensify, or modify the type, severity, and frequency of hazard occurrence at the property.

   Examples of events or processes that will preclude simple extrapolation of historical trends are given on the next page.

NOTE

This process is intended primarily for design professionals, coastal specialists, and others with the expertise to evaluate coastal hazards and the vulnerability of sites and buildings to those hazards. If you are not familiar with hazard and vulnerability evaluations, you should seek the services of qualified professionals.

EXAMPLES: EVENTS OR PROCESSES THAT PRECLUDE SIMPLE EXTRAPOLATION OF HISTORICAL TRENDS

- **Dune or bluff loss.** Loss of a historically present protective dune or bluff feature may lead to increased incidence and severity of flood or erosion damage.
- **Sea-, bay-, or lake-level rise.** Significant increases in sea, bay, or lake levels will probably increase vulnerability to flooding and coastal storm events.
- **Effects of erosion.** Erosion or storms may create weak points along the shoreline that will be predisposed to future breaching, inlet formation, and accelerated erosion, or may expose geologic formations that are more resistant to future erosion.
- **Inlet modifications.** Recent or historical modifications to an inlet (e.g., construction or modification of jetties, creation or deepening of a dredged channel) may alter the supply of littoral sediments and modify historic shoreline change trends.
- **Inlet formation/closure.** Formation or closure of an inlet during a storm will alter local tide, wave, current, and sediment transport patterns and may expose previously sheltered areas to damaging waves (see Figures 4-5 and 4-6).
- **Construction of erosion-control devices.** Widespread construction of erosion-control devices may reduce the input of sediments to the littoral system and cause or increase local erosion.
- **Seismic events.** Recent seismic events may have caused uplift, settlement, submergence, or fracturing of a region, altering its hazard vulnerability to flood and other hazards.
- **Groundwater changes and loss of vegetative cover.** Changes in surface water flows, drainage patterns, or groundwater movements, and reduction in vegetative cover may increase an area’s susceptibility to landslides.
- **Sea cliff or bluff changes.** Topographic changes resulting from the retreat of a sea cliff or coastal bluff may increase wind speeds at a site.

Figure 4-5.
A breach cut across Nauset Spit on Cape Cod, MA, by a January 1987 northeaster. The breach grew from an initial width of approximately 20 feet to over a mile within 2 years, exposing the previously sheltered shoreline of Chatham to ocean waves and erosion.

Figure 4-6.
Ocean City Inlet, MD, opened by a hurricane in 1933 and stabilized by jetties in 1934–35. Note extreme shoreline offset and downdrift erosion resulting from inlet stabilization (1992 photo).

4. **Forecast.** Forecast the type, severity, and frequency of future hazard events likely to affect the property over a suitably long period of time—over at least 50–70 years.

   This forecast should be based on either: (1) extrapolation of observed historical trends, modified to take into account those factors that will cause deviations from historical trends, or (2) detailed statistical and modeling studies calibrated to reflect basic physical and meteorological processes, and local conditions.

   The first procedure should be attainable for almost any coastal site and project. The second procedure will be beyond the scope and capabilities of all but a few coastal development projects.

EVALUATE HAZARD EFFECTS ON THE PROPERTY

After the type, severity, and frequency of future hazard events have been forecast, designers should use past events as an indication of the nature and severity of effects likely to occur during those forecast events.

Information about past events at the site of interest and at similar sites should be considered. This historical information should be combined with knowledge about the site and local conditions to estimate future hazard effects on the site and any improvements.

Designers should consider the effects of low-frequency, **rare events** (e.g., major storms, extreme water levels, tsunamis, earthquakes) and **multiple, closely spaced lesser events** (see Figure 4-7). For example, many of the post-storm damage assessments you read about in Unit I show that the cumulative erosion and damage caused by a series of minor coastal storms can be as severe as the effects of a single, major storm.

Figure 4-7.
Siting and design should include consideration of multiple storms or hazards within a short period, whose cumulative effects can exceed those of a design-level event.

SELF-CHECK REVIEW: EVALUATING HAZARDS AND VULNERABILITY

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Give an example of **trend information** that would be useful in evaluating hazards and potential vulnerability of a coastal property.

2. Give two examples of coastal events or processes that might make simple extrapolation of historical trends unreasonable.

   ____

   ____

3. Designers should consider the effects of low-frequency, rare events when determining potential vulnerability to hazards.

   True False

4. Designers should consider the effects of multiple, closely spaced lesser events when determining potential vulnerability to hazards.

   True False

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Give an example of **trend information** that would be useful in evaluating hazards and potential vulnerability of a coastal property.

   Any of the following:
   - **Long-term trends (> 50–100 years) in hazard events.**
   - **Short-term trends (< 10–20 years) in hazard events.**
   - **Whether particularly severe storms are included in the short- or long-term records and what effects those storms had on the overall trends.**
   - **Periods and magnitudes of any cyclic variations.**

2. Give two examples of coastal events or processes that might make simple extrapolation of historical trends unreasonable.

   Any two of the following:
   - **Dune or bluff loss.**
   - **Sea-, bay-, or lake-level rise.**
   - **Effects of erosion.**
   - **Inlet modifications.**
   - **Inlet formation/closure.**
   - **Construction of erosion-control devices.**
   - **Seismic events.**
   - **Changes in surface water, drainage patterns, or groundwater movements.**
   - **Loss of vegetative cover.**
   - **Sea cliff or bluff changes.**

3. Designers should consider the effects of low-frequency, rare events when determining potential vulnerability to hazards.

   True

4. Designers should consider the effects of multiple, closely spaced lesser events when determining potential vulnerability to hazards.

   True

DECISION TIME

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

Having performed the hazard analysis and risk assessment, it is time to decide.

To complete this step in evaluating a lot or parcel for potential development or redevelopment, two questions must be answered:

- **Can the predicted hazard effects be mitigated through siting, design, or construction?**

- **Are the residual risks to the site and building/development acceptable?**

WARNING

Remember, buildings near the shoreline are at a far greater risk of being damaged by natural causes than buildings farther inland.

TAKING ACTION

1. Compile information.	Identify candidate properties and compile lot/parcel information for each. Then, for each property, follow steps 2 through 4.
2. Evaluate.	Conduct a hazards analysis and risk assessment.
3. Decide.	Determine whether the hazards can be mitigated through siting, design, or construction and whether the residual risks to the site and the building are acceptable.
4. Take action.	Either (a) proceed with the purchase or development of a property, or (b) reject the candidate properties and find and evaluate other properties.

The last step is to take action based on the decision you have made. Unless both questions can be answered affirmatively, the property should be rejected (at least for its intended use) and other properties should be identified and evaluated.

Alternatively, the intended use of the property might be modified so that it is consistent with predicted hazard effects and other constraints.

Ultimately, however, reducing the long-term risks to coastal residential buildings requires an approach to site evaluation such as the process described in this unit.

UNIT IV EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit IV. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit V.

1. A thorough property evaluation is needed before developing **or** redeveloping coastal property.

   True   False

2. After identifying candidate properties, the next task is to:

   a. Conduct a risk assessment.
   b. Compile information about the properties.
   c. Determine whether hazards can be mitigated through siting, design, or construction.
   d. Either proceed with development or reject the candidate properties.

3. The ___________________ will determine the types of hazards to which a particular property will be exposed.

   a. Building design.
   b. Building code.
   c. Intended use.
   d. Geographic region or area.

4. ______________ may render simple extrapolation of historical patterns inaccurate.

   a. Natural and manmade changes to the coastal system.
   b. Intended use of the property.
   c. Future development activities.
   d. Trends.

5. Compliance with regulatory requirements ensures the future safety of a building or development.

   True   False

6. Information compiled about a candidate property should include property location and dimensions, physical and natural characteristics, infrastructure and supporting development, financial considerations, and ____.

7. Potential sources of information about coastal property include local, regional, State, and Federal agencies; university departments; and
   ____.

8. Requirements concerning disclosure of hazards affecting residential real estate are standard and uniform in the coastal States of the United States.

   True False

9. In evaluating hazards affecting coastal property, simple extrapolation of historical trends:

   a. May be reasonable if significant changes to the coastal system have not occurred.
   b. Is the best approach if significant changes to the coastal system have occurred.
   c. Is reasonable for short-term trends but not long-term trends.
   d. Is reasonable for long-term trends but not short-term trends.

10. Designers should forecast the type, severity, and frequency of future hazard events likely to affect the property over a period of:

    a. Up to 20 years.
    b. At least 30 years.
    c. At least 50–70 years.
    d. 200 years.

11. In determining potential vulnerability to hazards, designers should consider: (mark all that apply)

    ___ a. Past events at the site.
    ___ b. Past events at similar sites.
    ___ c. Knowledge about the site and local conditions.
    ___ d. Low-frequency, rare events.
    ___ e. Multiple, closely spaced lesser events.

12. In deciding whether to proceed with development, designers must determine (1) whether the predicted hazard effects can be mitigated through siting, design, or construction and (2)

    ____.

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT IV EXERCISE—ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. A thorough property evaluation is needed before developing **or** redeveloping coastal property.

   True

2. After identifying candidate properties, the next task is to:

   b. Compile information about the properties.

3. The ___________________ will determine the types of hazards to which a particular property will be exposed.

   d. Geographic region or area.

4. ______________ may render simple extrapolation of historical patterns inaccurate.

   a. Natural and manmade changes to the coastal system.

5. Compliance with regulatory requirements ensures the future safety of a building or development.

   False

6. Information compiled about a candidate property should include property location and dimensions, physical and natural characteristics, infrastructure and supporting development, financial considerations, and **legal and regulatory information**.

7. Potential sources of information about coastal property include local, regional, State, and Federal agencies; university departments; and **professional organizations**.

8. Requirements concerning disclosure of hazards affecting residential real estate are standard and uniform in the coastal States of the United States.

   False. Not all States have such requirements, and in those that do, the requirements vary.

9. In evaluating hazards affecting coastal property, simple extrapolation of historical trends:

   a. May be reasonable if significant changes to the coastal system have not occurred.

10. Designers should forecast the type, severity, and frequency of future hazard events likely to affect the property over a period of:

    c. At least 50–70 years

11. In determining potential vulnerability to hazards, designers should consider: (mark all that apply)

    __x__ a. Past events at the site.
    __x__ b. Past events at similar sites.
    __x__ c. Knowledge about the site and local conditions.
    __x__ d. Low-frequency, rare events.
    __x__ e. Multiple, closely spaced lesser events.

12. In deciding whether to proceed with development, designers must determine (1) whether the predicted hazard effects can be mitigated through siting, design, or construction and (2)

    Whether the residual risks to the site and building/development are acceptable.

UNIT V: INVESTIGATING REGULATORY REQUIREMENTS

INVESTIGATING REGULATORY REQUIREMENTS

INTRODUCTION

States and communities throughout the United States enforce regulatory requirements that determine where and how buildings may be sited, designed, and constructed. These requirements include those associated with regulatory programs established by Federal and State statutes, building codes and standards, and locally adopted floodplain management and land use ordinances and laws.

Applicable regulatory programs include:

- The National Flood Insurance Program (NFIP), which is intended to reduce the loss of life and damage caused by natural hazards.
- Programs established to protect wetlands and other wildlife habitat, which seek to minimize degradation of the environment.
- State- and community-enforced requirements aimed specifically at the regulation of construction along the shorelines of oceans, bays, and lakes.

Federal, State, and local regulatory requirements can have a significant effect on the siting, design, construction, and cost of buildings. Therefore, designers, property owners, and builders engaged in residential construction projects in the coastal environment should conduct a thorough investigation to identify all regulations that may affect their properties and projects.

This unit will provide information about land use regulations, building codes and standards, NFIP minimum requirements and recommendations for exceeding those requirements, and other Federal legislation.

UNIT OBJECTIVES

After completing this unit, you should be able to:

5.1 Identify ways in which the following regulatory measures help reduce damage to coastal residential structures:
- Land use regulations.
- Building codes and standards.
- NFIP minimum requirements.
- Coastal Barrier Resources Act regulations.
- Coastal Zone Management regulations.

5.2 Identify minimum NFIP requirements for buildings in V and A zones and recommendations for exceeding those requirements.

LAND USE REGULATIONS

State and local governments establish regulations governing the development and use of land within their jurisdictions. The goal of these land use regulations is generally to promote sound physical, social, and economic development. The regulations take many forms, including:

- Zoning and floodplain management ordinances.
- Subdivision regulations.
- Utility codes.
- Impact fees.
- Historic preservations requirements.
- Environment regulations.

Land use regulations are often incorporated into and implemented under comprehensive or master plans developed by local jurisdictions in coordination with their State governments.

IMPACT OF LAND USE REGULATIONS

With land use regulations, communities can control development in a variety of ways. For example, they can:

- Prohibit or restrict development in specified areas.
- Establish requirements for:
  - Lot size.
  - Clearing and grading.
  - Drainage.
  - Siting of buildings.
  - Floodplain management.
  - Construction of access roads.
  - Installation of utility lines.
  - Planting of vegetative cover.
  - Other aspects of the land development and building construction processes.

The land use regulations enacted and enforced by State and local governments across the country vary in content and complexity according to the needs and concerns of individual jurisdictions. Therefore, it is beyond the scope of this course to list or describe specific regulations.

However, such regulations can have a significant impact on the construction and improvement of residential and other types of buildings in both coastal and non-coastal areas. Therefore, it is important that designers, builders, and property owners be aware of the regulations that apply to their projects.

SOURCES OF INFORMATION

The best sources of information about land use regulations include the following:

- **State and local officials** in charge of planning, land management, economic development, building code, floodplain management, and community affairs.

- **Professional organizations** such as the American Planning Association (APA) and its State chapters.

Community officials may be interested in several recent APA projects and publications described below. More detailed information is available on the APA website: http://www.planning.org.

EXAMPLES OF APA PROJECTS AND PUBLICATIONS

- *Subdivision Design in Flood Hazard Areas* (Morris, 1997), APA Planning Advisory Service Report Number 473.

  This report provides information and guidance on subdivision design appropriate for floodplain areas. It includes several examples of State and local subdivision requirements in coastal floodplains. The report was prepared under a cooperative agreement with FEMA.

- *Modernizing State Planning Statutes: The Growing Smart^{SM} Working Papers* (APA 1996), American Planning Advisory Service Report Number 462/463, and *Growing Smart^{SM} Legislative Guidebook* (APA, 1998).

  Growing Smart^{SM} is a major initiative launched by the APA in 1994. The project will result in a National planning statute clearinghouse and database of State legislative materials, and in model planning legislation and commentary. Chapter 7 of the document includes a model Natural Hazards Element for incorporation into local government comprehensive plans.

- *Planning for Post-Disaster Recovery and Redevelopment* (Schwab et al., 1998), APA Planning Advisory Service Report Number 483/484.

  This report provides all-hazards guidance for local planners. It includes a model ordinance for regulating hazard areas and includes case studies for five hazard scenarios (flood, hurricane, wildfire, earthquake, and tornado). The report includes a model Natural Hazards Element (taken from the *Growing Smart^{SM} Legislative Guidebook*) for incorporation into local comprehensive plans. The report was prepared under a cooperative agreement with FEMA.

WARNING

Hazard area identifications (including those on FIRMs) and associated development regulations can be rendered obsolete by a natural event. Take extreme care in siting and designing residential buildings in post-disaster situations.

BUILDING CODES AND STANDARDS

Many States and communities regulate the construction of buildings by adopting and enforcing building codes and standards that affect how buildings are designed and constructed.

BUILDING CODES

The purpose of a building code is to establish the minimum acceptable requirements necessary for protecting the public, health, safety, and welfare in the built environment. Building codes set forth requirements for:

- Structural design.
- Materials.
- Fire safety.
- Exits.
- Natural hazard mitigation.
- Sanitary facilities.
- Light and ventilation.
- Environmental control.
- Fire protection.
- Energy conservation.

Building codes apply primarily to new construction, but they may also apply to existing buildings that are being rebuilt, rehabilitated, or modified. Codes may also apply when a building is undergoing a change of occupancy as defined by the code.

STANDARDS

A standard, according to the Council of American Building Officials, is:

> "a prescribed set of rules, conditions, or requirements concerned with the definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, design, or operations; descriptions of fit and measurement of size; or measurement of quality and quantity in describing materials, products, systems, services, or practices."

There are hundreds of standards related to design and construction practices, and thousands of standards related to construction materials.

When a standard is developed according to definitive rules of procedure and consensus, it may be incorporated into a building code **by reference** rather than by including all of the text of the standard in the code.

WARNING

The adoption and enforcement of building codes and standards is not consistent across the United States. Codes and standards in some States and communities may be more restrictive than in others. Some States and communities have not adopted any building codes or standards.

MODEL BUILDING CODES

Most building codes in the United States are based on model building codes. Model building codes are the result of an effort begun early in the 20th century to produce a model law or guide document that could be adopted by a legislative body to reduce losses caused by fire and other hazards. Six model building codes are now used in the United States:

- *International Building Code* (IBC), published by the International Code Council (ICC), 2000.
- *International Residential Code for One- and Two-Family Dwellings* (IRC), published by the ICC, 2000.
- *Uniform Building Code* (UBC), published by the International Conference of Building Officials (ICBO), 1997.
- *The BOCA National Building Code*, published by the Building Officials & Code Administrators International (BOCA), 1996.
- *Standard Building Code* (SBC), published by the Southern Building Code Congress International (SBCCI), 1997.
- *International One- and Two-Family Dwelling Code*, published by the Council of American Building Officials (CABO), 1998.

NOTE

For more information about building codes and standards, refer to *An Introduction to Model Codes* (CABO 1997), published by the Council of American Building Officials—now the International Code Council (ICC).

States and local jurisdictions may adopt a model code—unaltered or with amendments and revisions. They may also adopt and enforce other codes and standards to meet specific needs, such as providing additional resistance to damage in areas subject to flood, wind, and earthquake hazards. Examples of these State and local codes and standards include the South Florida Building Code, the Massachusetts State Building Code, and the Texas Department of Insurance Windstorm Resistant Construction Guide (1998).

Other codes and standards in use include:

- American Society of Civil Engineers (ASCE) *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-98.
- SBCCI *Standard for Hurricane Resistant Residential Construction*, SSTD 10-99.

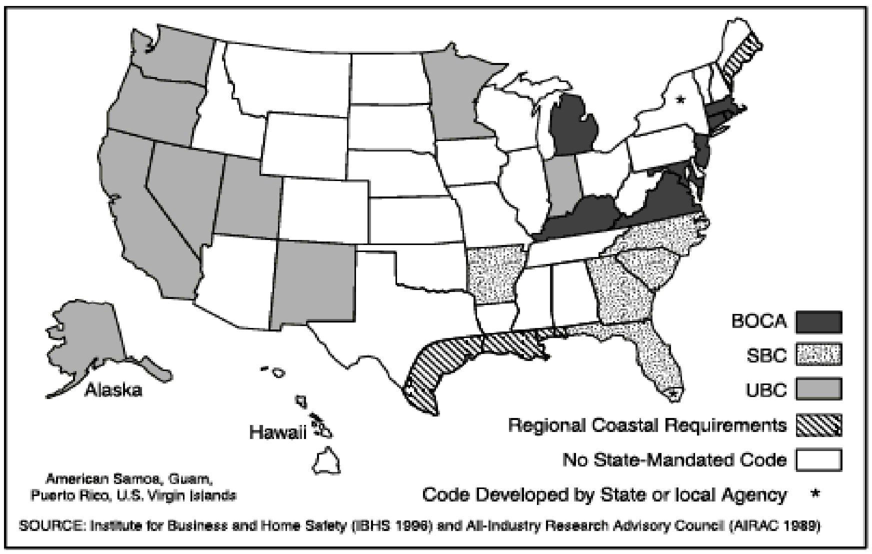
In addition, trade organizations publish design documents—for example, the High Wind Edition of the *Wood Frame Construction Manual for One- and Two-Family Dwellings* by the American Forest & Paper Association.

ADOPTION OF MODEL CODES

It is important to note that not every State has adopted a model building code, and some of those that have do not require that the code be applied to the construction of one- and two-family residential buildings.

The map in Figure 5-1 shows the States that have adopted a mandatory State building code, based on one of the model codes, that applies to some or all types of construction within the State. The figure also shows areas of the United States that have adopted regional requirements governing coastal construction.

Figure 5-1. States That Have a Mandatory Building Code Based on One of the Model Building Codes.



In general, most coastal States have adopted a model building code and/or specific requirements concerning the construction of buildings in coastal flood and wind hazard areas.

In States where no mandated codes exist, it is common for relatively populous political jurisdictions, towns, and cities to have some form of regulatory control on the construction of housing. In the entire United States, about 4,400 political jurisdictions have adopted some type of building code.

NOTE

In areas where a model building code has not been adopted or where the existing code is not applied to one- and two-family residential buildings, those engaged in the design and construction of coastal residential buildings are encouraged to follow the requirements of a model building code and the recommendations presented in the *Coastal Construction Manual*.

INTERNATIONAL CODES

The International Code Council was formed to bring together the three model code groups—ICBO, BOCA, and SBCCI—under a unifying code body in support of common code development.

Among the new codes developed by the ICC are:

- *International Building Code 2000* (IBC 2000).
- *International Residential Code for One- and Two-Family Dwellings 2000* (IRC 2000).
- Mechanical, plumbing, and private sewage disposal codes.

Compliance with NFIP and NEHRP

Both the IBC 2000 and the IRC 2000 meet the minimum building science requirements of the NFIP regulations. Together, the IBC 2000 (with its Appendix G) and the IRC 2000 meet the minimum requirements of the NFIP regulations. (Communities must adopt **both codes** to be compliant with the regulatory requirements of the NFIP.)

The mechanical, plumbing, and private sewage disposal codes are compliant with the applicable provisions of the NFIP regulations.

The IRC 2000 and the IBC 2000 are both substantially equivalent to the National Earthquake Hazards Reduction Program 1997 *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* (FEMA 1997).

Adoption of the International Codes

At the time the *Coastal Construction Manual* went to print, many States and communities were considering adoption of the IBC 2000 and the IRC 2000. Thus many State and local building code requirements may change as a result.

Variations from one State or jurisdiction to the next, coupled with potential code revisions, make it imperative that the designer work with local officials to identify the current codes, standards, and other construction requirements that apply. Even in States and communities that have not adopted the IBC 2000 and IRC 2000, designers may elect to use the new codes.

SELF-CHECK REVIEW: LAND USE REGULATIONS, BUILDING CODES, AND STANDARDS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. _____________________ may prohibit development in specified areas.

   a. Land use regulations
   b. Building codes
   c. Standards
   d. Model building codes

2. _____________________ set forth requirements for the overall design of a building.

   a. Land use regulations
   b. Building codes
   c. Standards

3. A single residential building design may be subject to hundreds of _____________________.

   a. Building codes
   b. Standards

4. The International Building Code is an example of a _______________________.

   a. Trade organization code
   b. Land use regulation
   c. Standard
   d. Model building code

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

1. **Land use regulations** may prohibit development in specified areas.

2. **Building codes** set forth requirements for the overall design of a building.

3. A single residential building design may be subject to hundreds of **standards**.

4. The International Building Code is an example of a **model building code**.

NATIONAL FLOOD INSURANCE PROGRAM—AN OVERVIEW

PURPOSE

Congress created the NFIP in 1968 when it passed the National Flood Insurance Act. The NFIP, which is administered by FEMA, is a voluntary program whose goals are:

- To reduce the loss of life and the damage caused by flooding.
- To help victims recover from floods.
- To promote an equitable distribution of costs among those who are protected by flood insurance and the general public.

NFIP ACTIVITIES

The NFIP achieves these goals through the following activities:

- Conducting **flood hazard studies** and providing each community with a Flood Insurance Rate Map (FIRM) and Flood Insurance Study (FIS) report, which present flood hazard information. The provided information includes:
  - Boundaries of the Special Flood Hazard Area (SFHA)—the area subject to inundation by the flood that has a one percent probability of being equaled or exceeded in any given year.
  - Base flood elevations (BFEs).
  - Flood insurance zones.

- Providing State and local agencies with **technical assistance and funding** in support of flood hazard mitigation.

NOTE

An explanation of ***substantial improvement*** and ***substantial damage*** is provided on the next page.

- Requiring participating communities to **control construction** so that new buildings, ***substantially improved*** buildings, and repaired ***substantially damaged*** buildings in the SFHA are in compliance with floodplain management ordinances and laws intended to eliminate or reduce flood damage.

- Providing residents in participating communities with **flood insurance** so that the need for disaster relief is reduced.

- Requiring the purchase of **flood insurance as a condition of receiving Federal or federally regulated financial assistance** for the acquisition and/or construction of buildings in SFHAs.

  The NFIP provides the means by which disaster assistance agencies and Federal lending regulatory agencies can fulfill their obligation to require that flood insurance be purchased for property in the SFHA that is securing a Federal or federally regulated loan or that has received Federal disaster assistance.

Substantial Damage and Substantial Improvement

Under the NFIP, substantially damaged and substantially improved buildings must meet the floodplain management requirements for new buildings.

- **Substantial damage:** Damage to a building (regardless of the cause) is considered substantial damage if the cost of restoring the building to its before-damage condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.
- **Substantial improvement:** An improvement of a building (such as reconstruction, rehabilitation, or addition) is considered a substantial improvement if its cost equals or exceeds 50 percent of the market value of the building before the start of construction of the improvement.

For more information, consult your local floodplain management officials or refer to *Answers to Questions About Substantially Damaged Buildings*, FEMA 213 (FEMA 1991).

HOW THE NFIP PROGRAM WORKS

The NFIP operates through a partnership between the Federal Government, the States, and individual communities (e.g., counties; parishes; and incorporated cities, towns, townships, boroughs, and villages). Participation in the NFIP is voluntary.

In participating communities, affordable federally backed flood insurance is made available to property owners and renters. In return, each community adopts and enforces a floodplain management ordinance or law, which it uses to define regulatory floodplains and to control floodplain development—including new construction, substantial improvement of existing buildings, and repairs of substantially damaged buildings.

A participating community's floodplain management ordinance or law must, at a minimum, meet the requirements of the NFIP regulations. However, FEMA encourages communities to establish additional or more stringent requirements as they see fit.

Community Rating System

In 1990, to provide incentives for communities to adopt more stringent requirements, FEMA established the NFIP Community Rating System (CRS). Through the CRS, FEMA encourages and recognizes community floodplain management activities that exceed the minimum NFIP requirements.

Goals of the CRS. Under the CRS, flood insurance premium rates within participating communities are adjusted to reflect the reduced flood risk resulting from community activities that meet the three goals of the CRS: reducing flood losses, facilitating accurate insurance rating, and promoting the awareness of flood insurance.

Class Determination. Through the CRS, communities are awarded credit points for carrying out floodplain management activities in the following areas:

- Public information.
- Mapping and regulations.
- Flood damage reduction.
- Flood preparedness.

The number of points awarded determines a community's CRS class, from 1 to 10. The class then determines the amount of reduction in the flood insurance premium rates for structures within and outside the SFHA.

Participation in the CRS is voluntary; any community compliant with the rules and regulations of the NFIP may apply for a CRS classification. In addition to helping communities obtain insurance premium discounts, the CRS promotes floodplain management activities that help save lives, reduce property damage, and promote sustainable, more livable communities.

NOTE

In 1999, nearly 900 communities throughout the United States were receiving flood insurance premium discounts through the CRS as a result of implementing local mitigation, outreach, and educational activities that go beyond minimum NFIP requirements.

For more information about the CRS, contact the NFIP Coordinating Agency for your State or the appropriate FEMA Regional Office.

FIRMs and FIS Reports

The regulatory requirements of the NFIP are based on the base flood—the flood that has a one percent probability of being equaled or exceeded in any given year.

To provide communities with the information they need to enact and enforce floodplain management ordinances or laws compliant with the NFIP requirements, FEMA conducts flood hazard studies for communities throughout the United States and publishes the results in the form of FIRMs and FIS reports.

Information Provided. FIS reports and FIRMs provide the following information:

- Names and locations of flooding sources.
- Sizes and frequencies of past floods.
- Limits of the SFHA in areas subject to riverine, lacustrine, and coastal flooding.
- Flood insurance zone designations.
- BFEs throughout the SFHA.

With this information, communities can manage floodplain development and FEMA can establish insurance rates for houses and other buildings.

Of particular importance for a coastal construction project are the BFE and the flood insurance designation at the building site. The following sections explain how BFEs and zone designations are determined for coastal flood hazard areas and how they affect coastal construction.

NOTE

A FIRM consists of one or more numbered panels that cover the geographic area of a community such as a city, town, or county.

FIRMs that consist of two or more panels are accompanied by an index map that shows the layout of the panels.

For more information about FIRMs, refer to FEMA's *Guide to Flood Maps*, FEMA 258 (1995).

DETERMINATION OF BFEs

To determine BFEs for areas affected by coastal flooding, FEMA computes 100-year stillwater elevations and then determines the maximum 100-year wave heights (and, in some areas, the maximum 100-year wave runup) associated with those stillwater elevations.

- **Stillwater elevations** are the elevations of the water surface resulting solely from storm surge (i.e., the rise in the surface of the ocean as a result of the action of wind and the drop in atmospheric pressure associated with hurricanes and other storms).
- **Wave heights** are the heights, above the wave trough, of the crests of wind-driven waves.
- **Wave runup** is the rush of wave water up a slope or structure.

The BFEs for coastal flood hazard areas on FIRMs are established at the maximum elevation of either the wave crest or the wave runup—whichever is greater.

Whether the wave crest elevation or the wave runup elevation is greater depends primarily on upland topography. In general, wave crest elevations are greater where the upland topography is gentle, such as along most of the Gulf, southern Atlantic, and middle-Atlantic coasts. Wave runup elevations are greater where the topography is steeper, such as along portions of the Great Lakes, northern Atlantic, and Pacific coasts.

FLOOD INSURANCE ZONES

The insurance zone designations shown on FIRMs indicate the magnitude and severity of flood hazards. The zone designations that apply to coastal flood hazard areas are listed below, in decreasing order of magnitude and severity.

Zones VE, V1–V30, and V

These zones, collectively referred to as V zones, identify the Coastal High Hazard Area—the portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast.

NOTE

Zones AE, VE, and X appear on FIRMs produced since the mid-1980s. On older FIRMs, the corresponding zones are A1–A30, V1–V30, and B or C, respectively.

V zones also include any other portion of the SFHA that is subject to high-velocity wave action from storms or seismic sources. V zones are generally based on wave heights (3 feet or greater) or wave runup depths (3 feet or greater).

Zones AE, A1–A30, AO, and A

These zones, collectively referred to as A zones, identify portions of the SFHA that are not within the Coastal High Hazard Area. Although both A zones and V zones designate areas at risk from a flood of the same magnitude, the hazard in V zones is greater because of the presence of breaking waves with heights equal to or greater than 3 feet.

NOTE

It is important to note that FIRMs use Zones AE, A1–A30 AO, and A to designate both coastal and non-coastal SFHAs, and that the regulatory requirements of the NFIP are the same for buildings in coastal and non-coastal A zones. However, buildings in coastal A zones may be subject to breaking waves with heights less than 3 feet and wave runup with depths less than 3 feet.

The Coastal A zone defined in the *Coastal Construction Manual* is not established by the NFIP regulations. However, this zone designation is useful because the hazards in coastal A zones are greater than those in non-coastal A zones but less severe than those in V zones.

Zones X, B, and C

These zones identify areas outside the SFHA. Zone B and shaded Zone X identify areas subject to inundation by the flood that has a 0.2 percent probability of being equaled or exceeded during any given year (the 500-year flood). Zone C and unshaded Zone X identify areas above the level of the 500-year flood.

SELF-CHECK REVIEW: NFIP OVERVIEW

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. The NFIP conducts ____ to provide communities with information about flood hazards.

2. List three activities carried out by the NFIP.

   (1) ____

   (2) ____

   (3) ____

3. The ____ provides incentives for communities to adopt more stringent requirements than the NFIP regulations.

4. __________________________________ is the elevation of the water surface resulting solely from storm surge.

5. The BFEs on FIRMs are established at the maximum elevation of ____________________________

   or ____________________________, whichever is greater.

6. Which of the following zones has the least risk of damage from high-velocity wave action?

   a. V1–V30
   b. AE
   c. Coastal A
   d. X

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. The NFIP conducts **flood hazard studies** to provide communities with information about flood hazards.

2. List three activities carried out by the NFIP.

   Any of the following:
   - **Conducting flood hazard studies**
   - **Providing technical assistance and funding**
   - **Requiring participating communities to control construction in the SFHA**
   - **Providing flood insurance**
   - **Requiring the purchase of flood insurance as a conditions of receiving Federal or federally regulated loans**

3. The **Community Rating System** provides incentives for communities to adopt more stringent requirements than the NFIP regulations.

4. **Stillwater elevation** is the elevation of the water surface resulting solely from storm surge.

5. The BFEs on FIRMs are established at the maximum elevation of **wave crest** or **wave runup**, whichever is greater.

6. Which of the following zones has the least risk of damage from high-velocity wave action?

   d. X

NFIP MINIMUM REGULATORY REQUIREMENTS

INTRODUCTION

The floodplain management ordinances or laws adopted by communities that participate in the NFIP are based, in part, on the minimum NFIP regulatory requirements set forth at Title 44, Chapter 1, Section 60.3 of the U.S. Code of Federal Regulations (44 CFR 60.3).

Types of Buildings Affected

Community floodplain management ordinances and laws include requirements concerning the following types of buildings in the SFHA, including those in both A zones and V zones:

- Newly constructed buildings.
- Substantially damaged buildings.
- Substantially improved buildings.

Additional requirements apply to new subdivisions and other development in the SFHA.

Aspects of the Building Affected

Under the NFIP, the **lowest floor** of a building includes the floor of a basement. The NFIP regulations define a basement as "…any area of a building having its floor subgrade (below ground level) on all sides."

For insurance rating purposes, this definition applies even when the subgrade floor is not enclosed by full-height walls, such as in a subgrade parking area under a building elevated on an open foundation.

The minimum NFIP regulatory requirements regarding newly constructed, substantially damaged, and substantially improved buildings affect primarily:

- Type of foundation allowed.
- Required height of the ***lowest floor***.
- Installation of building utility systems.
- Use of flood-resistant materials.
- Use of the area below the lowest floor.

In recognition of the greater hazard posed by breaking waves 3 feet high or higher, FEMA has established minimum NFIP regulatory requirements for V-zone buildings that are more stringent than the minimum requirements for A-zone buildings. Therefore, the location of a building in relation to the A-zone/V-zone boundary on a FIRM can affect the design of the building. In that regard, it is important to note that **a building or other structure that has any portion of its foundation in a V zone must be built to comply with V-zone requirements.**

The following sections summarize the minimum NFIP regulatory requirements that apply throughout the SFHA and to A zones and V zones specifically.

MINIMUM REQUIREMENTS— ALL BUILDINGS IN ALL SFHAs

The **minimum** floodplain management requirements applied in **all** SFHAs by communities participating in the NFIP affect:

- Buildings.
- Subdivisions and other new development.
- New and replacement water supply systems.
- New and replacement sanitary sewage systems.

These requirements, set forth at 44 CFR 60.3(a) and (b), are summarized below.

Newly Constructed, Substantially Damaged, and Substantially Improved Buildings in the SFHA

These buildings are subject to the following NFIP regulations:

- Building sites must be reasonably safe from flooding.

- Buildings must be:
  - Designed (or modified) and anchored to prevent flotation, collapse, and lateral movement of the building resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.
  - Constructed with materials resistant to damage from immersion in flood waters.
  - Constructed with methods and practices that minimize flood damage.
  - Constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within their components during conditions of flooding.

- If FEMA has not provided BFE data on the FIRM, the community must obtain and reasonably use any BFE data available from other sources for the purpose of regulating construction in Zone A.

WARNING

Communities participating in the NFIP are encouraged to adopt and enforce flood-plain management ordinances or laws that include requirements more stringent than the minimum NFIP requirements of the NFIP regulations.

For example, some States and communities require that buildings be elevated **above** rather than simply to the BFE (i.e., freeboard is required).

Check with local floodplain managers and building officials concerning such requirements.

Subdivisions and Other New Development

This type of development must conform to the following NFIP regulations:

- All proposals for subdivisions and other new development in the SFHA must be consistent with the need to minimize flood damage within the floodprone area.
- All public utilities and facilities (such as sewer, gas, electrical, and water systems) for such subdivisions and other new developments must be located and constructed to minimize or eliminate flood damage.
- Adequate drainage must be provided for all such subdivisions and new developments to reduce exposure to flood hazards.
- All proposals for subdivisions and other new developments greater than 50 lots or 5 acres (whichever is less) in an SFHA for which no BFEs are shown on the effective FIRM must be accompanied by 100-year flood elevation data.

New and Replacement Water Supply Systems

Within the SFHA, these systems must be designed to minimize or eliminate infiltration of flood waters.

New and Replacement Sanitary Sewage Systems

Within the SFHA, these systems must be designed to minimize or eliminate infiltration of flood waters into the systems, and discharges from the systems into flood waters.

On-site waste disposal systems must be located to avoid impairment to them or contamination from them during flooding.

NOTE

The NFIP regulations also include requirements specific to **floodplains along rivers and streams.** For more information about these requirements, consult local floodplain management officials. Also refer to *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings*, FEMA 259 (1995).

For NFIP requirements concerning **manufactured housing**, refer to Section 60.3 of the NFIP regulations.

ADDITIONAL REQUIREMENTS—BUILDINGS IN A ZONES

The additional **minimum** requirements specific to buildings in Zones AE, A1–A30, AO, and A pertain to:

- Elevation of the lowest floor (including basement), in relation to BFE.
- Enclosed areas below the lowest floor.

These requirements, which are the same for coastal and non-coastal A zones, are summarized below

Building Elevation in Zones AE and A1–A30

The top of the lowest floor, including the basement floor, of all newly constructed, substantially damaged, and substantially improved buildings must be **at or above the BFE** (see Fig. 5-2).

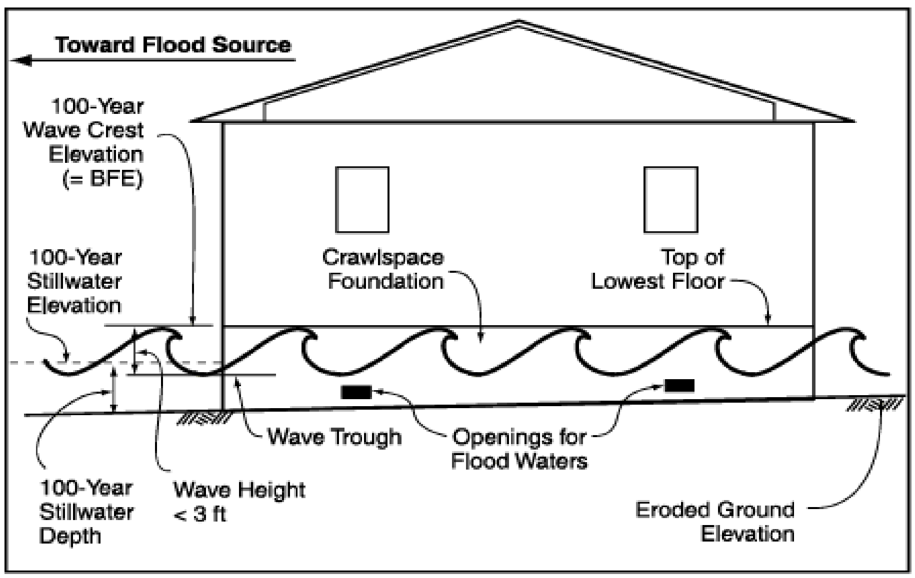


Figure 5-2. Minimum NFIP A zone requirements. The lowest floors of buildings in Zones AE, A1–A10, and A must be at or above the BFE. Foundation walls below the BFE must be equipped with *openings* that allow the entry of flood waters so that interior and exterior hydrostatic pressures can equalize.

Building Elevation in Zone A

FIRMs do not present BFEs in SFHAs designated Zone A (i.e., unnumbered A zones). The lowest floors of buildings in Zone A must be elevated to or above the BFE whenever BFE data are available from other sources. If no BFE data are available, communities must ensure that the building is constructed with methods and practices that minimize flood damage.

WARNING

Even waves less than 3 feet high can impose large loads on foundation walls. The *Coastal Construction Manual* recommends that buildings in coastal A zones be designed and constructed to meet V zone requirements.

Building Elevation in Zone AO

Zone AO designates areas where flooding is characterized by shallow depths (averaging 1–3 feet) and/or unpredictable flow paths.

In Zone AO, the top of the lowest floor, including the basement floor, of all newly constructed, substantially damaged, and substantially improved buildings must be **above the highest grade adjacent to the building by at least the depth of flooding** in feet shown on the FIRM.

For example, if the flood depth shown on the FIRM is 3 feet, the top of the lowest floor must be at least 3 feet above the highest grade adjacent to the building.

If no depth is shown on the FIRM, the minimum required height above the highest adjacent grade is 2 feet.

NOTE

Areas adjacent to V zones—behind bulkheads or on the back sides of dunes—are sometimes designated Zone AO. For these areas, the *Coastal Construction Manual* encourages the use of open foundations, as required in V zones.

Enclosures Below the Lowest Floor in Zones AE, A1–A30, AO, A

Enclosed space below the lowest floors of newly constructed, substantially damaged, and substantially improved buildings may be used only for parking of vehicles, access to the building, or storage.

The walls of such areas must be equipped with openings designed to allow the automatic entry and exit of flood waters so that interior and exterior hydrostatic pressures will equalize during flooding. Designs for openings must either meet or exceed the following minimum criteria:

NOTE

For more information about **openings** requirements, refer to *Openings in Foundation Walls for Buildings Located in Special Flood Hazard Areas*, FEMA NFIP Technical Bulletin 1 (1993).

- **Net Area of Openings.** A minimum of two openings with a total net area of not less than 1 in^2 for every 1 ft^2 of enclosed area subject to flooding must be provided.

  Alternatively, a certification may be provided by a registered engineer or architect stating that the openings are designed to automatically equalize hydrostatic forces on exterior walls by allowing the entry and exit of flood waters. Even if such a certification is provided, however, the openings must still meet the next two criteria.

- **Placement.** The bottoms of all openings must be no higher than 1 foot above grade.

- **Coverings.** The openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of flood waters.

ADDITIONAL REQUIREMENTS—BUILDINGS IN V ZONES

The additional **minimum** requirements specific to buildings in Zones VE, V1–V30, and V pertain to:

- Siting of the building.
- Alterations of sand dunes and mangrove stands.
- Elevation of the lowest floor in relation to the BFE.
- Foundation design.
- Enclosures below the BFE.

These requirements, set forth at 44 CFR 60.3(d), are summarized below.

Siting

All newly constructed buildings must be **located landward of the reach of mean high tide** (i.e., the mean high water line).

Manmade **alterations of sand dunes or mangrove stands** are prohibited if those alterations would increase potential flood damage. Removing sand or vegetation from, or otherwise altering, a sand dune or removing mangroves may increase potential flood damage. Therefore, such actions must not be carried out without the prior approval of a local official.

Building Elevation

All newly constructed, substantially damaged, and substantially improved buildings must be elevated on pilings, posts, piers, or columns so that the bottom of the lowest horizontal structural member of the lowest floor (excluding the vertical foundation members) is **at or above the BFE** (see Fig. 5-3).

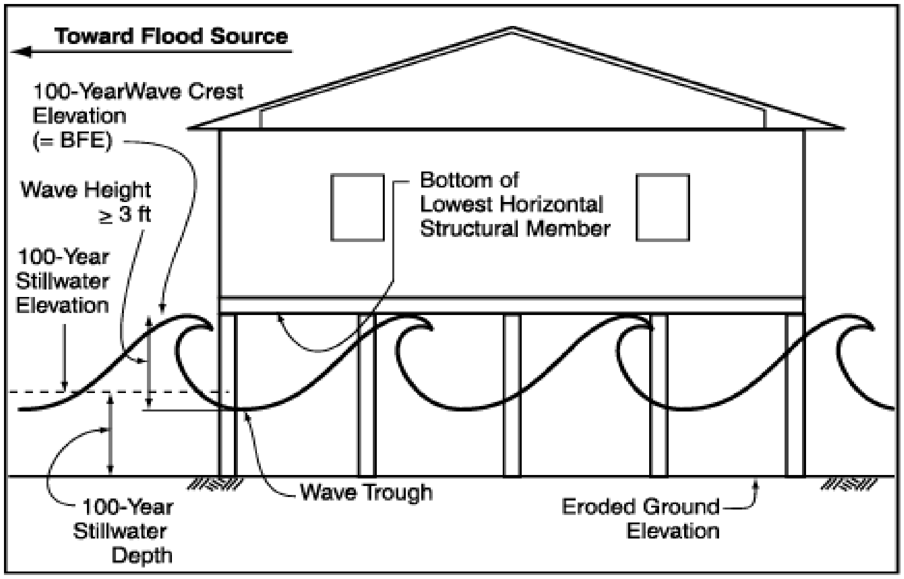


Figure 5-3.
Minimum NFIP V zone requirements.
Buildings must be elevated on an open foundation so that the bottom of the lowest horizontal structural member is at or above the BFE.

Foundation Design

The piling or column foundations for all newly constructed, substantially damaged, and substantially improved buildings, as well as the buildings attached to the foundations, must be **anchored** to resist flotation, collapse, and lateral movement from the effects of wind and water loads acting simultaneously on all components of the building.

A **registered engineer or architect must develop or review** the structural design, construction specifications, and plans for construction and must **certify** that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the building elevation and foundation design standards described above.

Erosion control structures and other structures such as bulkheads, seawalls, and retaining walls may not be attached to the building or its foundation.

Use of Fill

Fill may not be used for the structural support of any building within Zones VE, V1–V30, and V. Fill may be used in V zones for minor landscaping and site drainage purposes.

NOTE

For more information about the use of fill in V zones, refer to *Free of Obstructions Requirements for Buildings Located in Coastal High Hazard Areas*, FEMA NFIP Technical Bulletin 5 (1993). Consult local officials for specific guidance or requirements.

Space Below the BFE

The space below all newly constructed, substantially damaged, and substantially improved buildings must meet the following requirements:

WARNING

These requirements have been developed over the years, based on damage to thousands of structures during many flood events. They should not be ignored by the designer, contractor, or owner. Failure to comply with these requirements not only violates the local floodplain management ordinance and NFIP regulations but can also lead to large, uninsured losses.

- **Freedom from Obstructions.** The space below the BFE must either be (1) free of obstructions or (2) enclosed only by non-supporting breakaway walls, open wood latticework, or insect screening intended to collapse under water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or the supporting foundation system.

  The current NFIP regulatory requirements regarding **breakaway walls** are set forth in 44 CFR 60.3(e)(5). The regulations specify a design safe loading resistance for breakaway walls of not less than 10 lb/ft^2 and not more than 20 lb/ft^2.

  However, the regulations also provide for the use of **alternative designs** that do not meet the specified loading requirements. In general, breakaway walls built according to such designs are permitted if a registered professional engineer or architect certifies that (1) the walls will collapse under a water load less than that which would occur during the base flood and (2) the elevated portion of the building and supporting foundation system will not be subject to collapse, displacement, or other structural damage from the effects of wind and water loads acting simultaneously on all components of the building.

- **Permitted Uses.** Additional requirements apply to the use of an enclosed area below the BFE. It may be used only for parking, building access, or storage.

- **Materials.** An enclosed area below the BFE must be constructed of flood-resistant materials.

- **Mechanical/Utility Equipment.** There are specific requirements regarding the placement of mechanical/utility equipment below the BFE.

WARNING

Although the NFIP regulations permit below-BFE enclosures that meet the criteria presented here, many communities may have adopted ordinances that prohibit all such enclosures or that establish more stringent criteria, such as an enclosure size limitation. Check with local officials about such requirements.

NOTE

Additional Information

Alternative Breakaway Wall Designs. The current NFIP regulations do not provide specifications or other detailed guidance for the design and construction of alternative types of breakaway walls. However, the results of recent research conducted for FEMA and the National Science Foundation by North Carolina State University (NCSU) and Oregon State University (OSU), including full-scale tests of breakaway wall panels, provide the basis for prescriptive criteria for the design and construction of breakaway wall panels that do not meet the requirement for a loading resistance of 10-20 lb/ft^2.

These criteria are presented in *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings*, FEMA NFIP Technical Bulletin 9 (1999). The criteria address:

- Breakaway wall construction materials, including wood framing, light-gauge steel framing, and masonry.
- Attachment of the walls to floors and foundation members.
- Utility lines.
- Wall coverings such as interior and exterior sheathing, siding, and stucco.
- Other design and construction issues.

The bulletin also describes the results of the NCSU-OSU tests.

Other Sources of Information. For more information about enclosures, the use of space below elevated buildings, and breakaway walls, refer to:

- *Flood-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas*, FEMA NFIP Technical Bulletin 2 (1993).

- *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas*, FEMA NFIP Technical Bulletin 5 (1993).

SELF-CHECK REVIEW: NFIP MINIMUM REQUIREMENTS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. If the foundation of a coastal building is 1/3 within the V zone and 2/3 within the A zone, the building must comply with _____________ requirements.

   a. A zone
   b. V zone

2. According to NFIP minimum requirements, newly constructed buildings in a V zone must have the bottom of the lowest structural member at what elevation?

   ____

3. One NFIP requirement is that the building site must be reasonably safe from flooding. This requirement applies to buildings _____________________.

   a. Only in A zones
   b. Only in V zones
   c. In all SFHAs
   d. Only in subdivisions and other new developments

4. Enclosed space below the lowest floors in A and V zones may be used for:

   _________________________, _________________________, and _________________________.

5. Newly constructed buildings in _____ zones must be elevated on pilings, posts, piers, or columns.

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. If the foundation of a coastal building is 1/3 within the V zone and 2/3 within the A zone, the building must comply with **V zone** requirements.

2. According to NFIP minimum requirements, newly constructed buildings in a V zone must have the bottom of the lowest structural member at what elevation?

   At or above the BFE

3. One NFIP requirement is that the building site must be reasonably safe from flooding. This requirement applies to buildings ______________________.

   c. In all SFHAs

4. Enclosed space below the lowest floors in A and V zones may be used for:

   Parking, building access, and storage.

5. Newly constructed buildings in **V** zones must be elevated on pilings, posts, piers, or columns.

RECOMMENDATIONS FOR EXCEEDING MINIMUM NFIP REQUIREMENTS

The *Coastal Construction Manual* presents recommendations for exceeding NFIP minimum requirements. These recommendations address the significant hazards present in coastal A zones and V zones and are aimed at increasing the ability of coastal residential buildings to withstand natural hazard events.

Table 5.1, presented at the end of this section, summarizes the NFIP requirements and the recommendations for exceeding those requirements.

NON-COASTAL A ZONES

Recommendations for the design and construction of buildings in non-coastal A zones are not within the scope of this course. Designers seeking guidance regarding good practice for the design and construction of such buildings should consult local floodplain management, building, or code officials.

Additional guidance can be founding in:

- *Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings*, FEMA 259 (1995).

- The IBC 2000 and IRC 2000.

- FEMA's NFIP Technical Bulletin Series.

COASTAL A ZONES AND V ZONES

NFIP regulations do not differentiate between coastal and non-coastal A zones. Because coastal A zones may be subject to the types of hazards present in V zones—wave effects, velocity flows, erosion, scour, and high winds—the *Coastal Construction Manual* recommends that **buildings in coastal A zones should meet the NFIP regulatory requirements for V-zone buildings,** including the performance requirements concerning:

- Resistance to flotation, collapse, and lateral movement.
- Prescriptive requirements concerning:
  - Elevation.
  - Foundation type.
  - Engineering certification of design and construction.
  - Enclosures below the BFE.
  - Use of structural fill.

Recommended Good Practices: Coastal A and V Zones

To provide a greater level of protection against the hazards in coastal A zones and V zones, the following are recommended as good practice for the siting, design, and construction of buildings in those zones:

- **Siting.** The building should be located landward of both the long-term erosion setback and the limit of 100-year storm erosion (rather than simply landward of the reach of mean high tide).

- **Elevation.** The bottom of the lowest horizontal structural member should be elevated **above** (rather than to) the BFE. That is, **freeboard** should be provided (see Fig. 5-4).

- **Space Below the BFE.** Open latticework or screening should be used in lieu of breakaway walls in the space below the elevated building, or—at a minimum—the use of solid breakaway wall construction should be minimized.

- **Orientation.** In V zones, the lowest horizontal structural members should be oriented perpendicular to the expected wave crest.

Recommendation for exceeding NFIP minimum elevation. The bottom of the lowest horizontal structural member should be <u>above</u> the BFE.
In V zones, the lowest horizontal structural members should be <u>perpendicular</u> to the expected wave crest.

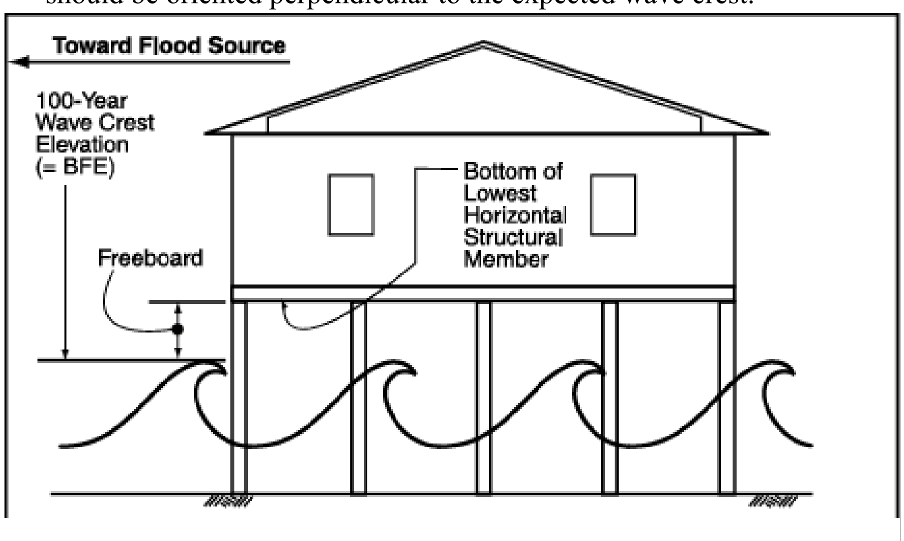


Table 5.1. Summary of NFIP Regulatory Requirements and Recommendations for Exceeding the Requirements

	Guidance[a]		
	V Zone	**Coastal A Zone**	**A Zone**
General Requirements			
Design	**Requirement:** Building and its foundation must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement from **simultaneous wind and water loads.**	**Requirement:** Building must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy. **Recommendation:** Same as a V zone.	**Requirement:** Building must be designed, constructed, and anchored to prevent flotation, collapse, and lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.
Materials	**Requirement:** Structural and nonstructural building materials at or below the BFE must be flood-resistant.	**Requirement:** Structural and nonstructural building materials at or below the BFE must be flood-resistant.	**Requirement:** Structural and nonstructural building materials at or below the BFE must be flood-resistant.
Construction	**Requirement:** Building must be constructed with methods and practices that minimize flood damage.	**Requirement:** Building must be constructed with methods and practices that minimize flood damage.	**Requirement:** Building must be constructed with methods and practices that minimize flood damage.
Siting	**Requirement:** All new construction shall be landward of mean high tide; alteration of sand dunes and mangrove stands that increases potential flood damage is prohibited. **Recommendation:** Site new construction landward of the long-term erosion setback and landward of the area subject to erosion during the 100-year coastal flood event.	**Requirement:** Encroachments into the SFHA are permitted as long as they do not increase the BFE by more than 1 foot.[b] Encroachments into the floodway are prohibited. **Recommendation:** Same as V zone.	**Requirement:** Encroachments into the SFHA are permitted as long as they do not increase the BFE by more than 1 foot.[b] Encroachments into the floodway are prohibited.

Notes:

[a] “Prohibited” and “Allowed” refer to the minimum NFIP regulatory requirements; individual States and communities may enforce more stringent requirements that supersede those summarized here. **Exceeding minimum NFIP requirements will provide increased flood protection and may result in lower flood insurance premiums.**

[b] Some communities may allow encroachments to cause a 1-foot rise in the flood elevation, while others may allow no rise.

Table 5.1 (Continued)

	Guidance		
	V Zone	**Coastal A Zone**	**A Zone**
Foundation			
Structural Fill	**Prohibited**	**Allowed, but not recommended** Compaction required where used; protect against scour and erosion.[c]	**Allowed** Compaction required where used; protect against scour and erosion.[c]
Solid Foundation	**Prohibited**	**Allowed, but not recommended** [c]	**Allowed**[c]
Open Foundation	**Required**	**Not required, but recommended**[c]	**Allowed**[c]
Lowest Floor Elevation	**Not applicable**[d]	**Requirement:** Top of floor must be at or above BFE.[e] **Recommendation:** Elevate bottom of lowest horizontal structural member to or above BFE[e] (see next category below); orient member perpendicular to wave crest.	**Requirement:** Top of floor must be at or above BFE.[e]
Bottom of Lowest Horizontal Structural Member	**Requirement:** Bottom must be at or above BFE.[e]	**Allowed below BFE[e], but not recommended.** **Recommendation:** Same as V zone.	**Allowed below BFE[e], but not recommended** **Recommendation:** Same as V zone.
Orientation of Lowest Horizontal Structural Member	**No requirement** **Recommendation:** Orient perpendicular to wave crest.	**No requirement**	**No requirement**
Freeboard	**Not required,[e] but recommended**	**Not required,[e] but recommended**	**Not required,[e] but recommended**

Notes:
[c] Some coastal communities require open foundations in A zones.
[d] Bottom of lowest horizontal structural member must be at or above the BFE.
[e] State or community may regulate to a higher elevation (DFE).

Table 5.1 (Continued)

	Guidance		
	V Zone	**Coastal A Zone**	**A Zone**
Enclosures Below the BFE			
(Also see Certification)	**Prohibited,** except for breakaway walls, open lattice, and screening.[f] **Recommendation:** If constructed, use open lattice or screening instead of breakaway walls.	**Allowed, but not recommended** If an area is fully enclosed, the enclosure walls must be equipped with openings to equalize hydrostatic pressure. Size, location, and covering of openings governed by regulatory requirements. **Recommendation:** If enclosure is constructed, use breakaway walls, open lattice, or screening (as required in V zone).[f,g]	**Allowed** If an area is fully enclosed, the enclosure walls must be equipped with openings to equalize hydrostatic pressure. Size, location, and coverings of openings governed by regulatory requirements.[f,g]
Nonstructural Fill			
	Allowed for minor landscaping and site drainage as long as the fill does not interfere with the free passage of flood waters and debris beneath the building or cause changes in flow direction during coastal storms that could result in damage to buildings.	**Allowed**[h] **Recommendation:** Same as V zone.	**Allowed**
Use of Space Below the BFE[i]			
	Allowed only for parking, building access, and storage.	**Allowed only** for parking, building access, and storage.	**Allowed only** for parking, building access, and storage.
Utilities[i]			
	Requirement: Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.	**Requirement:** Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.	**Requirement:** Must be designed, located, and elevated to prevent flood waters from entering and accumulating in components during flooding.

Notes:

f Some coastal communities prohibit breakaway walls and allow only open lattice or screening.

g If an area below the BFE in an A-zone building is fully enclosed by breakaway walls, the walls must meet the requirement for openings that allow equalization of hydrostatic pressure.

h Placement of nonstructural fill adjacent to buildings in coastal AO zones is not recommended.

I There are some differences between what is permitted under floodplain management regulations and what is covered by NFIP flood insurance. Building designers should be guided by floodplain management requirements, not by flood insurance policy provisions.

Table 5.1 (Continued)

	Guidance		
	V Zone	**Coastal A Zone**	**A Zone**
Certification			
Structure	**Required:** Registered engineer or architect must certify that the design and methods of construction are in accordance with accepted standards of practice for meeting the design requirements described under **General Requirements**.	**Recommendation:** Same as V zone.	**Recommendation:** Same as V zone.
Breakaway Walls (Also see Enclosures Below the BFE)	**Required:** Either of the following: (1) Walls must be designed to provide a safe loading resistance of between 10 lb/ft^2 and 20 lb/ft^2 OR (2) a registered engineer or architect must certify that the walls will collapse under a water load associated with the base flood and that the elevated portion of building and its foundation will not be subject to collapse, displacement, or lateral movement under simultaneous wind and water loads.[f,g]	**Not required, but recommended**[f,g]	**Not required**[f,g]
Openings in Below-BFE Walls (Also see Enclosures Below the BFE)	**Not applicable**[j]	**Required:** Unless number and size of openings meets regulatory requirements, registered engineer or architect must certify that openings are designed to automatically equalize hydrostatic forces on walls by allowing the automatic entry and exit of flood waters.	**Required:** Unless number and size of openings meets regulatory requirements, registered engineer or architect must certify that openings are designed to automatically equalize hydrostatic forces on walls by allowing the automatic entry and exit of flood waters.

Notes:

[f] Some coastal communities prohibit breakaway walls and allow only open lattice or screening.

[g] If an area below the BFE in an A-zone building is fully enclosed by breakaway walls, the walls must meet the requirement for openings that allow equalization of hydrostatic pressure.

[j] Walls below BFE must be designed and constructed as breakaway walls that meet the minimum requirements of the NFIP regulations.

SELF-CHECK REVIEW:
RECOMMENDATIONS FOR EXCEEDING NFIP MINIMUM REQUIREMENTS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. The *Coastal Construction Manual* recommends that. . .

   A. In coastal A and V zones, the building should be located landward of:

      a. The reach of the mean high tide
      b. The long-term erosion setback
      c. The limit of 100-year storm erosion
      d. The long-term erosion setback and the limit of 100-year storm erosion

   B. In coastal A and V zones, the bottom of the lowest horizontal structural member should be elevated:

      a. At the BFE
      b. At the stillwater elevation
      c. Above the BFE
      d. At the wave crest elevation

   C. In V zones, the lowest horizontal structural members should be oriented __________________ to the expected wave crest.

2. According to *Coastal Construction Manual* recommendations for A and V zone construction, which of the following would be most desirable in the space below the BFE?

   a. Space enclosed by solid, weight-bearing walls
   b. Enclosed space with openings
   c. Breakaway walls
   d. Open latticework or screening

ANSWER KEY

1. The *Coastal Construction Manual* recommends that. . .

   A. In coastal A and V zones, the building should be located landward of:

      d. The long-term erosion setback and the limit of 100-year storm erosion

   B. In coastal A and V zones, the bottom of the lowest horizontal structural member should be elevated:

      c. Above the BFE

   C. In V zones, the lowest horizontal structural members should be oriented **<u>perpendicular</u>** to the expected wave crest.

2. According to *Coastal Construction Manual* recommendations for A and V zone construction, which of the following would be most desirable in the space below the BFE?

   d. Open latticework or screening

COASTAL BARRIER RESOURCES ACT OF 1982

PURPOSE

The Coastal Barrier Resources Act (CBRA) of 1982 was enacted to:

- Protect vulnerable coastal barriers from development.
- Minimize the loss of life.
- Reduce expenditures of Federal revenues.
- Protect fish, wildlife, and other natural resources.

This law established the Coastal Barrier Resources System (CBRS), which is managed by the U.S. Department of the Interior, Fish and Wildlife Service.

HOW THE LAW WORKS

The law restricts Federal expenditures and financial assistance that could encourage development of coastal barriers. The CBRA does not prohibit privately financed development. However, it does prohibit most new Federal financial assistance, **including federally offered flood insurance**, in areas within the CBRS (also referred to as CBRA areas).

Flood insurance may not be sold for buildings in the CBRS that were constructed or substantially improved after October 1, 1983. The financial risk of building in these areas is transferred from Federal taxpayers directly to those who choose to live in or invest in these areas.

"Otherwise Protected Areas"

NOTE

Additional information about CBRS regulations and areas included in the CBRS is available at the U.S. Fish and Wildlife Service website at http://www.fws.gov/cep/cbrtable.html

The Coastal Barrier Improvement Act (CBIA), passed in 1991, tripled the size of the CBRS to over 1.1 million acres. The CBIA also designated "otherwise protected areas" that include lands that are under some form of public ownership. The CBIA prohibits the issuance of flood insurance on buildings constructed or substantially improved after November 16, 1991, for the areas added to the CBRS, including these "otherwise protected areas."

An exception is made to allow insurance for buildings located in "otherwise protected areas" that are used in a manner consistent with the purpose for which the area is protected. Examples include research buildings, buildings that support the operation of a wildlife refuge, and similar buildings.

CBRS BOUNDARIES

CBRS boundaries are shown on a series of maps produced by the Department of the Interior (DOI). In addition, FEMA has transferred CBRS boundaries to FIRMs so that insurance agents and underwriters may determine eligibility for flood insurance coverage.

Before constructing a new building, substantially improving an existing building, or repairing a substantially damaged building, the designer or property owner should review the FIRM to determine whether the property is within the CBRS. In situations where the FIRM does not allow for a definitive determination, the designer or property owner should consult local officials. In some situations, it may be necessary to request a determination from the U.S. Fish and Wildlife Service based on the DOI maps.

NOTE

Remember: Any building within a CBRS area that is constructed or substantially improved after October 1, 1983, or the date of designation for areas added to the system in 1991, is not eligible for Federal flood insurance or other Federal financial assistance. The same restriction applies to substantially damaged buildings in a CBRS area that are repaired or renovated after those dates.

COASTAL ZONE MANAGEMENT REGULATIONS

PURPOSE

The Coastal Zone Management (CZM) Act of 1972 encourages adoption of coastal zone policies by U.S. coastal States in partnership with the Federal government.

CZM regulations have been adopted by 27 coastal states and 5 island territories. Two of the three remaining coastal States—Indiana and Minnesota—are preparing CZM regulations for the Great Lakes for Federal approval.

For current information concerning the status of State and National CZM programs, refer to the website of the National Oceanic and Atmospheric Administration, National Ocean Service, Office of Coastal Resource Management, at http://wave.nos.oaa.gov/ocrm/czm

PROVISIONS

Each State's CZM program contains provisions to:

- Protect natural resources.
- Manage development in high hazard areas.
- Manage development to achieve quality coastal waters.
- Give development priority to coastal-dependent uses.
- Have orderly processes for the siting of major facilities.
- Locate new commercial and industrial development in or adjacent to existing developed areas.
- Provide public access for recreation.
- Redevelop urban waterfronts and ports, and preserve and restore historic, cultural, and aesthetic coastal features.
- Simplify and expedite governmental decisionmaking actions.
- Coordinate State and Federal actions.
- Give adequate consideration to the views of Federal agencies.
- Ensure that the public and local government have a say in coastal decisionmaking.
- Plan for and manage living marine resources.

VARIATIONS Coastal zone regulations vary greatly. The following are examples of these variations.

- Many States, such as Washington, Oregon, and Hawaii, provide guidelines for development but **leave the enactment of specific regulatory requirements up to county and local governments.**
- Most State coastal zone regulations **control construction seaward of a defined boundary line**, such as a dune or road.
- Many States—though not all—**regulate or prohibit construction seaward of a second line based on erosion**. Some of these lines are updated when new erosion mapping becomes available. (Lines that follow physical features such as dune lines are not fixed; they "float" as the physical feature shifts over time.)
- Some States have requirements concerning the placement or prohibition of **shore protection structures** and the **protection of dunes**.
- Some States not only control new construction, but also **regulate renovations and repairs of substantially damaged buildings** to a greater degree than required by the NFIP. These regulations help limit future damage in coastal areas by requiring that older buildings be brought up to current standards when they are renovated or repaired.
- In addition to regulating the construction of buildings near the coast, many jurisdictions **regulate the construction of accessory structures**, **roads and infrastructure**, and other development-related activities.

NOTE

To determine whether State coastal zone management regulations apply to a specific property, consult community officials or the appropriate State coastal zone management agency.

SELF-CHECK REVIEW: CBRA AND CZM

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. The CBRA restricts Federal expenditures and financial assistance that could encourage

   ____.

2. The CBRA prohibits privately financed development.

   True False

3. The Coastal Barrier Improvement Act designated _____________________________________, which include lands under some form of public ownership.

4. CBRS boundaries __are / are not__ shown on FIRMs. (Circle one.)

5. Give an example of the kinds of issues addressed by State Coastal Zone Management regulations.

   ____

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. The CBRA restricts Federal expenditures and financial assistance that could encourage

   development of coastal barriers.

2. The CBRA prohibits privately financed development.

   False.
   It restricts Federal expenditures and financial assistance, including federally offered flood insurance.

3. The Coastal Barrier Improvement Act designated **"otherwise protected areas",** which include lands under some form of public ownership.

4. CBRS boundaries **are** shown on FIRMs.

5. Give an example of the kinds of issues addressed by State Coastal Zone Management regulations.

   Any of the following:
   - **Protection of natural resources**
   - **Management of development in high hazard areas**
   - **Maintenance of coastal water quality**
   - **Development priorities (i.e., for coastal-dependent uses)**
   - **Siting of major facilities**
   - **Location of new commercial and industrial development**
   - **Public access for recreation**
   - **Redevelopment of urban waterfronts and ports**
   - **Preservation of historic, cultural, and aesthetic coastal features**
   - **Simplification of governmental decisionmaking**
   - **Coordination of State and Federal actions**
   - **Shared coastal decisionmaking (Federal, local, public)**
   - **Management of living marine resources**

UNIT V EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit V. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit VI.

1. Land use regulations can be rendered obsolete by a natural hazard event.

   True False

2. Building codes may apply both to new construction and to existing buildings that are being rebuilt, rehabilitated, or modified.

   True False

3. When a local jurisdiction adopts a model building code, it must adopt the entire code, as is.

   True False

4. Few coastal States have adopted a model building code and/or specific requirements concerning the construction of buildings in coastal flood and wind hazard areas.

   True False

5. A community that adopts the IBC 2000 and the IRC 2000 will be compliant with the regulatory building requirements of the NFIP and the recommended provisions of the NEHRP.

   True False

6. The NFIP requires the purchase of flood insurance as a condition of receiving Federal financial assistance for the construction of buildings in SFHAs.

   True False

7. Hazards in coastal A zones are:

   a. The same as those in non-coastal A zones.
   b. More severe than those in V zones.
   c. The same as those in V zones.
   d. Greater than those in non-coastal A zones.

8. The NFIP operates through a partnership between (1) ______________________________,

   (2) ________________________________ , and (3) ___________________________________.

9. NFIP minimum requirements cover the type of foundation allowed. List two other aspects of coastal construction that are covered by NFIP requirements.

   (1) ____.

   (2) ____.

10. If the foundation of a coastal residence lies half in the A zone and half in the V zone, the building must comply with ___________ requirements.

    a. A zone
    b. V zone
    c. Coastal A zone
    d. Either A or V zone (builder's choice)

11. The NFIP regulations require that buildings be designed and anchored to prevent flotation, collapse, and lateral movement of the building resulting from hydrodynamic and hydrostatic loads. This requirement applies to buildings in:

    a. A zones only.
    b. V zones only.
    c. The SFHA.
    d. The CBRS.

12. The *Coastal Construction Manual* recommends that buildings in coastal A zones be designed and constructed to _________________________ requirements.

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT V EXERCISE — ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Land use regulations can be rendered obsolete by a natural hazard event.

   True

2. Building codes may apply both to new construction and to existing buildings that are being rebuilt, rehabilitated, or modified.

   True

3. When a local jurisdiction adopts a model building code, it must adopt the entire code, as is.

   False. A model code may be adopted unaltered or with amendments and revisions.

4. Few coastal States have adopted a model building code and/or specific requirements concerning the construction of buildings in coastal flood and wind hazard areas.

   False. Most coastal States have done so.

5. A community that adopts the IBC 2000 and the IRC 2000 will be compliant with the regulatory building requirements of the NFIP and the recommended provisions of the NEHRP.

   True

6. The NFIP requires the purchase of flood insurance as a condition of receiving Federal financial assistance for the construction of buildings in SFHAs.

   True

7. Hazards in coastal A zones are:

   d. Greater than those in non-coastal A zones

8. The NFIP operates through a partnership between (1) **the Federal Government**, (2) **the States**, and (3) **individual communities.**

9. NFIP minimum requirements cover the type of foundation allowed. List two other aspects of coastal construction that are covered by NFIP requirements.

   Any of the following:
   - **Required height of the lowest floor**
   - **Installation of building utility systems**
   - **Use of flood-resistant materials**
   - **Use of the area below the lowest floor**

10. If the foundation of a coastal residence lies half in the A zone and half in the V zone, the building must comply with ___________ requirements.

    b. V zone

11. The NFIP regulations require that buildings be designed and anchored to prevent flotation, collapse, and lateral movement of the building resulting from hydrodynamic and hydrostatic loads. This requirement applies to buildings in:

    c. The SFHA

12. The *Coastal Construction Manual* recommends that buildings in coastal A zones be designed and constructed to **V zone** requirements.

UNIT VI: IDENTIFYING HAZARDS (PART I)

IDENTIFYING HAZARDS (PART I)

INTRODUCTION

In coastal areas, proper siting and design require an accurate assessment of the vulnerability of any proposed structure. That assessment must include the nature and extent of coastal hazards. Failure to properly identify and design against coastal hazards can lead to severe consequences—most often building damage or destruction.

This unit is the first of two units presenting a broad array of information on hazard identification. In this unit, you will learn about:

- **Hazard-producing events** that strike coastal areas, including tropical cyclones, coastal storms, and tsunamis.

- **Natural hazards** that affect coastal residential buildings and building sites, including:
  - Coastal flooding.
  - High winds.

  In the next unit, you will learn more about natural hazards, including:
  - Erosion.
  - Earthquakes.
  - Other hazards.

  The next unit will also present information about coastal hazard zones and procedures for translating hazard information into practice.

UNIT OBJECTIVES

After completing this unit, you should be able to:

6.1 Identify hazard-producing events and their potential effects on U.S. coastal areas.
6.2 Describe the potential effects of coastal flooding on coastal residential structures.
6.3 Describe the potential effects of high winds on coastal residential structures.

NATURAL HAZARDS AFFECTING COASTAL AREAS

To assess the risk associated with building in a given coastal area, we must understand the types of hazards that may impact coastal areas and the effects these hazards may produce.

The most significant natural hazards that affect the coastlines of the United States and its territories can be divided into five general categories:

- Coastal flooding.
- High winds.
- Erosion.
- Earthquakes.
- Other hazards.

Before we discuss each of these natural hazards, let's begin with a brief look at three types of events that are significant sources of several of these hazards:

- Tropical cyclones.
- Other coastal storms.
- Tsunamis.

TROPICAL CYCLONES AND COASTAL STORMS

Tropical cyclones and coastal storms include all storms associated with circulation around an area of atmospheric low pressure. When the storm origin is **tropical** in nature and when the **circulation is closed**, tropical storms, hurricanes, or typhoons result.

Tropical cyclones and coastal storms are capable of generating a wide array of effects (see Fig. 6-1):

- High winds.
- Coastal flooding.
- High-velocity flows.
- Damaging waves.
- Significant erosion.
- Intense rainfall.
- Large quantities of waterborne sediments and floating debris.

Consequently, the risk to improperly sited, designed, or constructed coastal buildings can be great.

Figure 6-1.
Hurricane Frederic (1979). Storm surge and waves overtopping a coastal barrier island in Alabama.

Classification

Tropical storms have sustained winds averaging 39–74 mph. When sustained winds intensify to greater than 74 mph, the resulting storms are called ***hurricanes*** (in the North Atlantic basin or in the Central or South Pacific basins east of the International Date Line) or ***typhoons*** (in the western North Pacific basin).

- Hurricanes are divided into five classes according to the Saffir-Simpson hurricane scale (see Table 6.1), which uses wind speed and central pressure as the principal parameters to categorize storm damage potential.

- Typhoons are divided into two categories: ***typhoons*** (sustained winds less than 150 mph) and ***super typhoons*** (sustained winds 150 mph or greater).

NOTE

One parameter that is not taken into account in these storm classifications—**storm coincidence with spring tides or higher than normal water levels**—also plays a major role in determining storm impacts and property damage.

If a tropical cyclone or other coastal storm coincides with abnormally high water levels or with the highest monthly, seasonal, or annual tides, the flooding and erosion effects of the storm are magnified by the higher water levels upon which they are added.

Table 6.1 Saffir-Simpson Hurricane Scale

Scale Number (Category)	Central Pressure (in) [mb]	Wind Speed (mph) Sustained & (3-sec Gust)	Surge Height (ft)	Property Damage	Recent Examples
1	≥ 28.94 [≥980]	74 – 95 (93 – 119)	4 – 5	**Minimal**	**Agnes** (1972 – FL; NE U.S.) **Juan** (1985 – LA) **Earl** (1998 – FL)
2	28.49 – 28.93 [965 – 979]	96 – 110 (120 – 138)	6 – 8	**Moderate**	**Bob** (1991 – MA) **Marilyn** (1995 – U.S. Virgin Is.)
3	27.90 – 28.48 [945 – 964]	111 – 130 (139 – 163)	9 – 12	**Extensive**	**Frederic** (1979 – AL) **Alicia** (1983 – TX) **Fran** (1996 – NC)
4	27.17 – 27.89 [920 – 944]	131 – 155 (164 – 194)	13 – 18	**Extreme**	**Hugo** (1989 – SC) **Andrew** (1992 – FL)
5	< 27.17 [< 920]	>155 (> 194)	> 18	**Cata-strophic**	**FL Keys** (1935) **Camille** (1969 – MS)

NOTE

The Saffir-Simpson scale is a generalization, and **classification of actual storms may be inconsistent.** For example, the classification of a hurricane based on wind speed may differ from the classification based on storm surge or central pressure.

Tropical Cyclone Landfall

Approximately one in four named storms (tropical storms and hurricanes) in the North Atlantic basin makes landfall along the Atlantic or Gulf of Mexico coast of the United States (approximately 2.6 landfalling storms per year).

However, landfalls are not evenly distributed on a geographic basis. In fact, there is a wide variation in the incidence of landfalls—as illustrated in Figure 6-2. The figure shows the total number of direct and indirect impacts of landfalling hurricanes between 1900 and 1994. (Generally speaking, a ***direct impact*** occurs when the eye makes landfall in the county of interest, and an ***indirect impact*** occurs when the eye makes landfall in an adjacent county.)

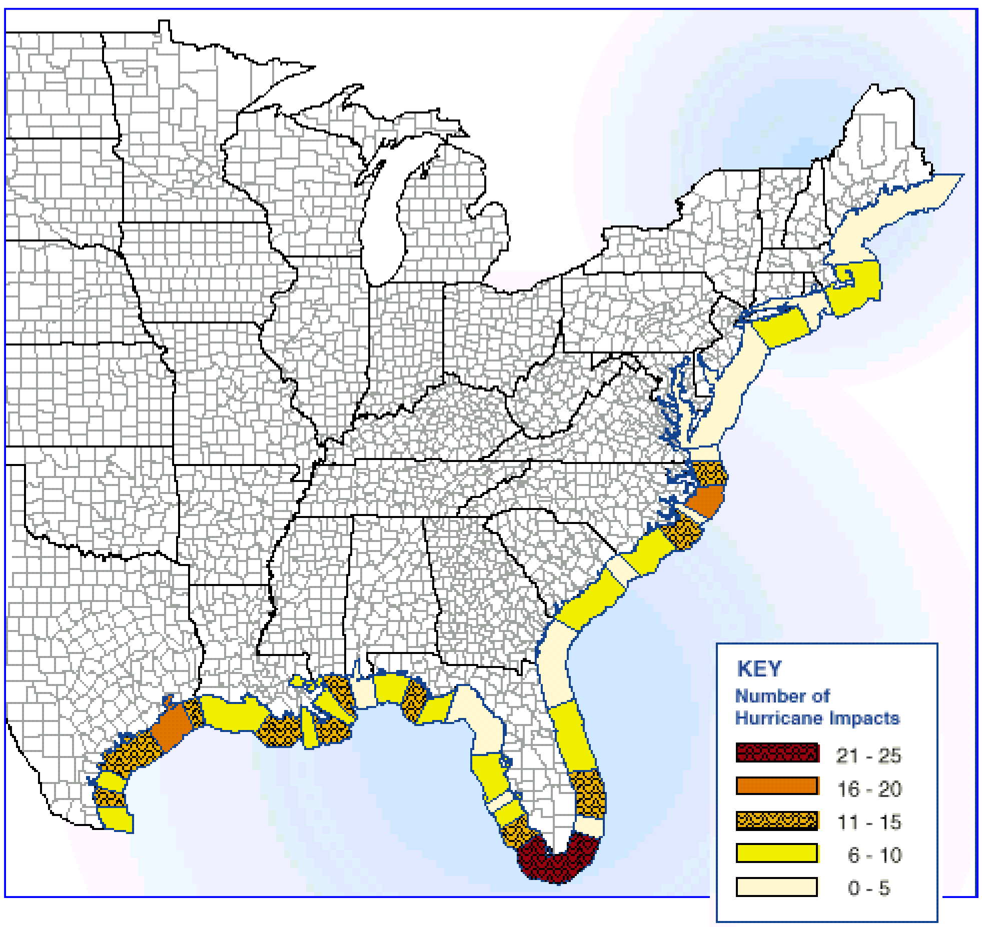


Figure 6-2. Landfalling Hurricanes. Total number of direct and indirect impacts by landfalling hurricanes for coastal counties from Texas to Maine, 1900–1994.

Mean Return Period

Table 6.2 shows the ***mean return period***—the average time (in years) between landfall or nearby passage of a tropical storm or hurricane.

Over short periods of time, the actual number and timing of tropical cyclone passage or landfall may deviate substantially from the long-term statistics. Some years see little tropical cyclone activity with no landfalling storms; other years see many storms with several landfalls. A given area may not feel the effects of a tropical cyclone for years or decades, and then be affected by several storms in a single year.

Table 6.2. Mean Return Periods for Landfall or Nearby Passage of Tropical Cyclones

Mean Return Period (years)			
Area	Passage of All Tropical Cyclones Within 50 Miles[a]	Landfall of All Hurricanes (Category 1–5)[b]	Landfall of All Major Hurricanes (Category 3–5)[b]
U.S. (Texas to Maine)	–	0.6	1.5
Texas	1.4	2.7	6.5
South	–	7.5	16
Central	–	16	49
North	–	5.7	14
Louisiana	1.6	39	8.1
Mississippi	2.7	12	16
Alabama	2.7	9.7	19
Florida	0.8	1.7	4.0
Northwest	–	4.0	14
Southwest	–	5.4	11
Southeast	–	3.7	8.8
Northeast	–	11	#
Georgia	2.0	19	#
South Carolina	2.3	6.9	24
North Carolina	1.7	3.9	8.8
Virginia	4.0	24	97
Maryland	4.2	97	#
Delaware	4.7	#	#
New Jersey	4.7	97	#
New York	3.7	11	19
Connecticut	4.2	19	32
Rhode Island	4.2	19	32
Massachusetts	3.7	16	49
New Hampshire	7.8	49	#
Maine	7.2	19	#
Virgin Islands[a]	2.0	~	~
Puerto Rico[a]	2.4	8	~
Hawaii[a]	7.1	~	~
Guam[a]	1.0	~	~

[a] Based on National Weather Service (NWS) data for period 1899–1992, from FEMA Hurricane Program, 1994.
[b] For period 1900–1996, from National Oceanic Atmospheric Administration (NOAA) Technical Memorandum NWS TPC-1, February 1997.
– No intrastate breakdown by FEMA Hurricane Program.
Number not computed (no storms of specified intensity made landfall during 1900–1996).
~ Island; landfall statistics alone may understate hazard.

OTHER COASTAL STORMS

Other coastal storms include storms lacking closed circulation but capable of producing strong winds. These storms usually occur during winter months and can affect the Pacific coast, the Great Lakes coast, the Gulf of Mexico coast, or the Atlantic coast. Along the Atlantic coast, these storms are known as ***extratropical storms*** or ***northeasters***.

Classification

Table 6.3 presents a classification scheme for northeasters, based on storm characteristics and typical damage to beaches, dunes, and property.

Table 6.3 Classification for Northeasters

Storm Class	Storm Description	Storm Duration	Storm Impacts on Beaches and Dunes	Property Damage
1	**Weak**	1 tidal cycle	Minor beach erosion	Little or none
2	**Moderate**	2 to 3 tidal cycles	Moderate beach erosion; dune scarping begins; minor flooding and shallow overwash in low areas, especially street ends	Undermining of seaward ends of dune walkovers; undermining of slab foundations on or near the active beach; some damage to erosion-control structures
3	**Significant**	3 to 4 tidal cycles	Significant beach erosion; dune scarping with complete loss of small dunes; increased depth of flooding and overwash in low areas	Widespread damage to dune walkovers and boardwalks; increased damage to erosion-control structures; undermining of beachfront slab foundations and shallow post or pile foundations; burial of roads and inland property by overwash
4	**Severe**	4 to 5 tidal cycles	Severe beach erosion and dune scarping; widespread dune breaching in vulnerable areas; coalescing of overwash fans; occasional inlet formation	Damage to poorly sited, elevated, or constructed coastal buildings is common; frequent damage to erosion-control structures; floodborne debris loads increase; overwash burial depths increase
5	**Extreme**	> 5 tidal cycles	Widespread and severe beach and dune loss; widespread flooding of low-lying areas; massive overwash; inlet formation is common	Widespread damage to buildings with inadequate elevations or foundations, and to buildings with inadequate setbacks from the shoreline or inlets; widespread damage to low-lying roads and infrastructure

Pacific Coast

Coastal storms along the Pacific coast of the United States are usually associated with the passage of weather fronts during the winter months. These storms produce little or no storm surge (generally 2 feet or less) along the ocean shoreline, but they are capable of generating hurricane-force winds and large, damaging waves.

Storm characteristics and patterns along the Pacific coast are strongly influenced by the occurrence of the El Nino Southern Oscillation (ENSO)—a climatic anomaly resulting in above-normal ocean temperatures and elevated sea levels along the U.S. Pacific coast. During El Nino years, sea levels along the Pacific shoreline tend to rise as much as 12 to 18 inches above normal, the incidence of coastal storms increases, and the typical storm track shifts from the Pacific Northwest to southern and central California.

The results of these effects are:

- Increased storm-induced erosion.
- Changes in longshore sediment transport (because of changes in the direction of wave approach) which results in changes in erosion or deposition patterns along the shoreline.
- Increased incidence of rainfall and landslides in coastal regions.

Great Lakes

Storms on the Great Lakes are usually associated with the passage of low-pressure systems or cold fronts. Storm effects (i.e., high winds, storm surge, and wave runup) may last a few hours or a few days. Storm surges and damaging wave conditions on the Great Lakes are a function of wind speed, direction, duration, and fetch.

If high winds occur over a long fetch for more than an hour or so, the potential for flooding and erosion exists. However, because of the sizes and depths of the Great Lakes, storm surges are usually be limited to less than 2 feet, except in embayments (2–4 feet) and on Lake Erie, where storm surges can reach 8 feet near the east and west ends of the lake.

TSUNAMIS

Tsunamis are long-period water waves generated by undersea shallow-focus earthquakes or by undersea crustal displacements, landslides, or volcanic activity.

Tsunamis can travel great distances, undetected in deep water, but shoaling rapidly in coastal waters and producing a series of large waves capable of destroying harbor facilities, shore protection structures, and upland buildings (see Fig. 6-3). Tsunamis have been known to damage some structures hundreds of feet inland and over 50 feet above sea level.

Figure 6-3.
Hilo, Hawaii—damage from the 1960 tsunami

Coastal construction in tsunami hazard zones must consider the effects of:

- Tsunami runup.
- Flooding.
- Erosion.
- Debris loads.
- "Rundown" (return of water to the sea), which can damage the landward sides of structures that withstood the initial runup.

Tsunami Effects

Tsunami effects at a particular site will be determined by four basic factors, described in Table 6.4.

Table 6.4. Factors that Determine Tsunami Effects

Factor	Description
Magnitude	The magnitude of the triggering event determines the period of the resulting waves, and generally (but not always) the tsunami magnitude and damage potential. Unlike typical wind-generated water waves with periods between 5 and 20 seconds, tsunamis can have wave periods ranging from a few minutes to over 1 hour. As wave periods increase, the potential for coastal inundation and damage also increases. Wave period is also important because of the potential for resonance and wave amplification within bays, harbors, estuaries, and other semi-enclosed bodies of coastal water.
Location	The location of the triggering event has two important consequences: (1) The distance between the point of tsunami generation and the shoreline determines the maximum available warning time. Tsunamis generated at a remote source will take longer to reach a given shoreline than locally generated tsunamis. (2) The point of generation will determine the direction from which a tsunami approaches a given site. Direction of approach can affect tsunami characteristics at the shoreline, because of the sheltering or amplification effects of other land masses and offshore bathymetry.
Configuration	The configuration of the continental shelf and shoreline affect tsunami impacts at the shoreline through wave reflection, refraction, and shoaling. Variations in offshore bathymetry and shoreline irregularities can focus or disperse tsunami wave energy along certain shoreline reaches, increasing or decreasing tsunami impacts.
Upland Topography	Upland elevations and topography will also determine tsunami impacts at a site. Low-lying tsunami-prone coastal sites will be more susceptible to inundation, tsunami runup, and damage than sites at higher elevations.

Areas Subject to Tsunamis

Table 6.5 lists areas that are subject to tsunami events, and the sources of those events.

Table 6.5. Areas Subject to Tsunami Events

	Principal Source of Tsunamis	
Area	**Locally Generated Events[a]**	**Remote-Source Earthquakes**
Alaska		
North Pacific coast	x	
Aleutian Islands	x	x
Gulf of Alaska coast	x	x
Bering Sea coast[b]		
Hawaii		x
American Samoa		x
Oregon	x	x
Washington	x	x
California	x	x
Puerto Rico	x	
U.S. Virgin Islands	x	

[a]Landslides, subduction, submarine landslides, volcanic activity.
[b]Not considered threatened by tsunamis.

SELF-CHECK REVIEW: NATURAL HAZARD EVENTS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Hurricanes and typhoons are tropical storms.

   True False

2. List three potential effects of tropical cyclones and coastal storms.

   (1) ____

   (2) ____

   (3) ____

3. What is the Saffir-Simpson scale?

4. Tropical cyclone landfalls can be expected to follow a consistent pattern, geographically, along the Atlantic and Gulf of Mexico coasts.

   True False

5. Over short periods of time the actual number and timing of tropical cyclone passage and landfall may deviate substantially from long-term mean return periods.

   True False

6. Northeasters:

   a. Are tropical storms.
   b. Affect primarily the Pacific coast.
   c. Have closed circulation.
   d. Affect the Atlantic coast, usually in winter.

7. The impact of a tsunami at a particular site may be affected by both the configuration of the continental shelf and shoreline and the upland topography.

   True False

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Hurricanes and typhoons are tropical storms.

   True

2. List three potential effects of tropical cyclones and coastal storms.

   Any three of the following:
   - **High winds**
   - **Coastal flooding**
   - **High-velocity flows**
   - **Damaging waves**
   - **Significant erosion**
   - **Intense rainfall**
   - **Large quantities of waterborne sediments and floating debris**

3. What is the Saffir-Simpson scale?

   A scale used to classify the storm damage potential of hurricanes according to wind speed and central pressure.

4. Tropical cyclone landfalls can be expected to follow a consistent pattern, geographically, along the Atlantic and Gulf of Mexico coasts.

   False. There is wide variation in incidence of landfalls.

5. Over short periods of time the actual number and timing of tropical cyclone passage and landfall may deviate substantially from long-term mean return periods.

   True

6. Northeasters:

   d. Affect the Atlantic coast, usually in winter.

7. The impact of a tsunami at a particular site may be affected by both the configuration of the continental shelf and shoreline and the upland topography.

   True

COASTAL FLOODING

Coastal flooding can originate from a number of sources. Tropical cyclones, other coastal storms, and tsunamis generate the most significant coastal flood hazards. These hazards usually take the form of:

- Hydrostatic forces.
- Hydrodynamic forces.
- Wave effects.
- Floodborne debris effects.

NOTE

Regardless of the source of coastal flooding, a number of flood parameters must be investigated at a coastal site to correctly characterize potential flood hazards:

- Origin of flooding.
- Flood frequency.
- Flood depth.
- Flood velocity.
- Flood direction.
- Flood duration.
- Wave effects.
- Erosion and scour.
- Sediment overwash.
- Floodborne debris.

HYDROSTATIC FORCES

Standing water or slowly moving water can induce **horizontal** hydrostatic forces against a structure, especially when floodwater levels on different sides of the structure are not equal. Flooding can also cause **vertical** hydrostatic forces, or ***flotation*** (see Fig. 6-4).

Figure 6-4. Hurricane Hugo (1989), Garden City, South Carolina. Intact houses were floated off their foundations and carried inland.

HYDRODYNAMIC FORCES

Hydrodynamic forces on buildings are created when coastal floodwaters move at high velocities. These high-velocity flows are capable of destroying solid walls and dislodging buildings with inadequate foundations. High-velocity flows can also move large quantities of sediment and debris, which can cause additional damage.

High-velocity flows in coastal areas are usually associated with one or more of the following:

- **Storm surge** and **wave runup** flowing landward, through breaks in sand dunes or across low-lying areas (see Fig. 6-5).
- **Tsunamis.**
- **Outflow** (flow in the seaward direction) of floodwaters driven into bay or upland areas.
- **Strong currents** parallel to the shoreline, driven by the obliquely incident storm waves.

Figure 6-5.
Storm surge and wave runup across boardwalk at South Mission Beach, California, during January 1988 storm.

High-velocity flows can be created or exacerbated by the presence of manmade or natural obstructions along the shoreline and by “weak points” formed by:

- Shore-normal roads and access paths that cross dunes.
- Bridges.
- Shore-normal canals, channels, or drainage features.

EXAMPLE

Anecdotal evidence after Hurricane Opal struck Navarre Beach, Florida, in 1995 suggests that large, engineered buildings channeled flow between them (see Fig. 6-6). The channelized flow caused deep scour channels across the island, undermining a pile-supported house between the large buildings (see Fig. 6-7), and washing out roads and houses (see Fig. 6-8) situated farther landward.

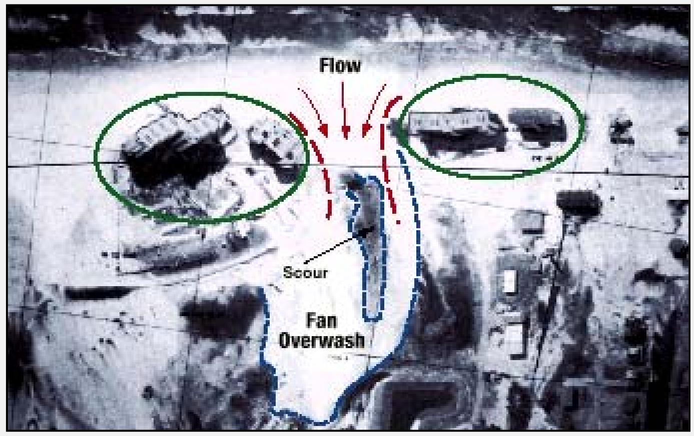


Figure 6-6.
Flow channeled between large engineered buildings (circled) scoured a deep channel across the island and damaged infrastructure and houses.

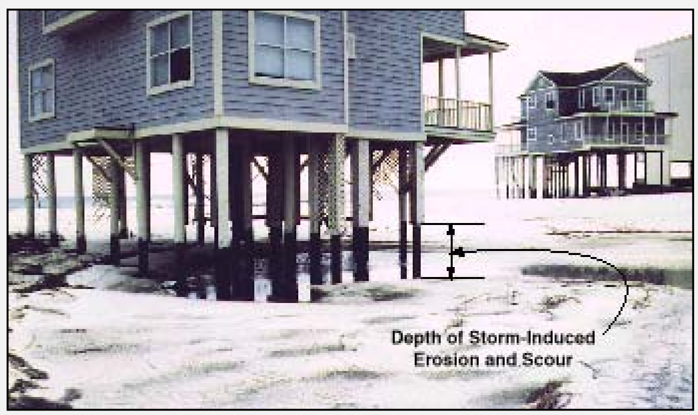


Figure 6-7.
Pile-supported house in the area of channeled flow. The building foundation and elevation prevented high-velocity flow, erosion, and scour from destroying the building.

Figure 6-8.
This house was also in an area of channeled flow. The house was undermined and washed into the bay behind the barrier island. As a result, the house is now a total loss and a threat to navigation.

WAVES Waves can affect coastal buildings by means of breaking waves, wave runup, wave reflection or deflection, and wave uplift forces.

Breaking Waves

The most severe damage is caused by breaking waves (see Fig. 6-9). The force created by waves breaking against a vertical surface is often 10 or more times higher than the force created by high winds during a storm event.

Figure 6-9.
Storm waves breaking against a seawall in front of a coastal residence at Stinson Beach, California

Wave Runup

Wave runup (see Fig. 6-10) occurs as waves break and run up beaches, sloping surfaces, and vertical surfaces. Wave runup can drive large volumes of water against or around coastal buildings, inducing fluid impact forces (although smaller than breaking wave forces), current drag forces, and localized erosion and scour.

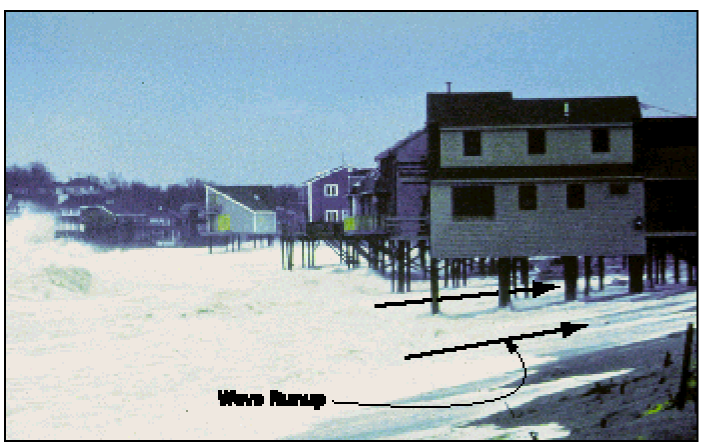


Figure 6-10.
Wave runup beneath elevated buildings at Scituate, MA, during the December 1992 northeaster. Nine homes in the area were bought with public funds and demolished following the storm.

Wave runup against a vertical wall will generally extend to a higher elevation than runup on a sloping surface and will be capable of destroying overhanging decks and porches. Figure 6-11 shows the effects of wave runup breaking against a vertical wall and adjacent building.

Figure 6-11. Damage to an oceanfront condominium in Ocean City, NJ, caused by wave runup on a timber bulkhead.

Wave Reflection or Deflection

Wave reflection or deflection from adjacent structures or objects can produce forces on a building similar to those caused by wave runup.

Wave Uplift Forces

Shoaling waves beneath elevated buildings can lead to wave uplift forces. The most common example of wave uplift damage occurs at fishing piers—where pier decks are commonly lost close to shore—when shoaling storm waves lift the pier deck from the pilings and beams. The same type of damage sometimes occurs at the lowest floor of insufficiently elevated but well-founded residential buildings and underneath slabs-on-grade below elevated buildings (see Fig. 6-12).

Figure 6-12. Hurricane Fran (1996). Concrete slab-on-grade flipped up by wave action came to rest against two foundation members, generating large unanticipated loads on the foundation.

FLOODBORNE DEBRIS

Floodborne debris produced by coastal flood events and storms typically includes:

- Decks.
- Steps.
- Ramps.
- Breakaway wall panels.
- Portions of or entire houses.
- Heating oil and propane tanks.
- Vehicles.
- Boats.
- Decks and pilings from piers (see Fig. 6-13).
- Fences.
- Destroyed erosion-control structures.
- A variety of smaller objects.

Figure 6-13. Hurricane Opal (1995). Pier pilings were carried over 2 miles by storm surge and waves before they came to rest against this elevated house in Pensacola Beach, Florida.

Floodborne debris is often capable of destroying unreinforced masonry walls (see Fig. 6-14), light wood-frame construction, and small-diameter posts and piles (and the components of structures they support).

Figure 6-14. Hurricane Fran (1996). Debris lodged beneath a Topsail Island, NC, house elevated on unreinforced masonry walls. The wall damage could have resulted from flood and wave forces, debris loads, or both.

Debris trapped by cross-bracing, closely spaced pilings, grade beams, or other components or obstructions below the BFE is also capable of transferring flood and wave loads to more massive debris, such as the drift logs shown in Figure 6-15.

Figure 6-15.
March 1975 storm. Drift logs driven into coastal houses at Sand Point, WA.

SEA-LEVEL RISE AND LAKE-LEVEL RISE

The coastal flood effects just described typically occur over a period of hours or days. However, longer-term water level changes also occur.

- Sea level tends to rise or fall over centuries or thousands of years, in response to long-term global climate changes.
- Great Lakes water levels fluctuate over decades, in response to regional climate changes.

In either case, long-term increases in water levels increase the damage-causing potential of coastal flood and storm events and often cause a permanent horizontal recession of the shoreline.

NOTE

Because coastal land masses can move up (uplift) or down (subsidence) independent of water levels, discussions of long-term water-level change must be expressed in terms of ***relative sea level*** or ***relative lake level***.

Sea-Level Rise

Tide gauge records for the **U.S. Atlantic and Gulf of Mexico coasts** show that relative sea level has been rising at long-term rates averaging 2 to 4 mm annually, with higher rates along the Louisiana and Texas coasts.

Records for the **U.S. Pacific coast** stations show that some areas have experienced rises in relative sea levels of approximately 2 mm annually, while other areas have seen relative sea levels fall. Relative sea level has fallen at rates as much as 2 mm annually in northern California and as much as 13 mm annually in Alaska.

Lake-Level Rise

NOTE

Detailed data on measured and projected water levels is available at the USACE Detroit District website: http://sparky.nce.usace.arm.mil/hmpghh.html

Great Lakes seasonal water levels typically fluctuate between 1 and 2 feet. Long-term water levels in Lakes Michigan, Huron, Erie, and Ontario have fluctuated approximately 6 feet, and water levels in Lake Superior have fluctuated approximately 4 feet.

Beach and bluff erosion rates tend to increase as long-term water levels rise. As water levels fall, erosion rates diminish. Low lake levels lead to generally stable shorelines and bluffs but make navigation through harbor entrances difficult.

SELF-CHECK REVIEW: COASTAL FLOODING

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Coastal flood hazards usually take the form of:

   (1) ________________________________

   (2) ________________________________

   (3) ________________________________

   (4) ________________________________

2. List at least five flood parameters that must be investigated at a coastal site to correctly characterize potential flood hazards.

   (1) ________________________________

   (2) ________________________________

   (3) ________________________________

   (4) ________________________________

   (5) ________________________________

3. Standing or slowly moving water can induce both horizontal and vertical hydrostatic forces.

   True   False

4. Storm surge and wave runup are typical sources of hydrodynamic forces. List three other sources.

   (1) ________________________________

   (2) ________________________________

   (3) ________________________________

5. The most severe flood damage to coastal buildings is caused by ____________________________.

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Coastal flood hazards usually take the form of:

   (1) Hydrostatic forces.
   (2) Hydrodynamic forces.
   (3) Wave effects.
   (4) Floodborne debris effects.

2. List at least five flood parameters that must be investigated at a coastal site to correctly characterize potential flood hazards.

   Any of the following:
   - **Origin of flooding**
   - **Flood frequency**
   - **Flood depth**
   - **Flood velocity**
   - **Flood direction**
   - **Flood duration**
   - **Wave effects**
   - **Erosion and scour**
   - **Sediment overwash**
   - **Floodborne debris**

3. Standing or slowly moving water can induce both horizontal and vertical hydrostatic forces.

   True

4. Storm surge and wave runup are typical sources of hydrodynamic forces. List three other sources.

   (1) Tsunamis
   (2) Outflow of floodwaters
   (3) Strong currents parallel to the shoreline

5. The most severe flood damage to coastal buildings is caused by **breaking waves.**

HIGH WINDS

High winds can originate from a number of events; tropical cyclones, other coastal storms, and tornadoes generate the most significant coastal wind hazards.

The most current design wind speeds are given by the national load standard, *ASCE 7-98* (American Society of Civil Engineers, 1998). Figure 6-16, taken from *ASCE 7-98*, shows the geographic distribution of design wind speeds for the continental United States and Alaska. Design wind speeds for Hawaii, Puerto Rico, Guam, American Samoa, and the Virgin Islands are also listed.

NOTE

Basic wind speeds shown in Figure 6-16 correspond to:

- A wind with a recurrence interval between 50 and 100 years in **hurricane-prone regions** (Atlantic and Gulf of Mexico coasts with a basic wind speed greater than 90 mph, and Hawaii, Puerto Rico, Guam, the U.S. Virgin Islands, and American Samoa).

- A recurrence interval of 50 years in **non-hurricane-prone areas.**

Figure 6-16. ASCE 7-98 wind speed map (continued on the next page)

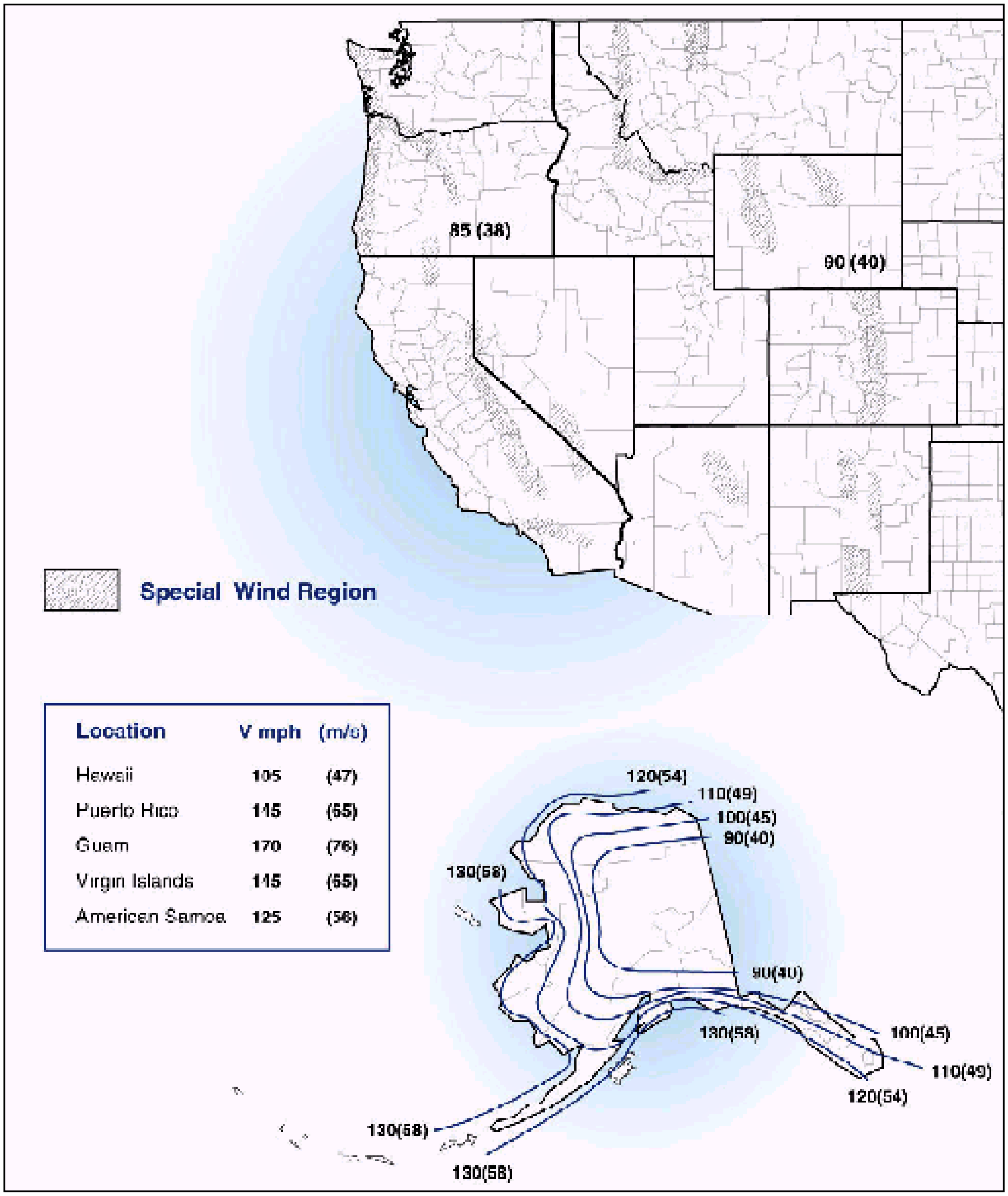
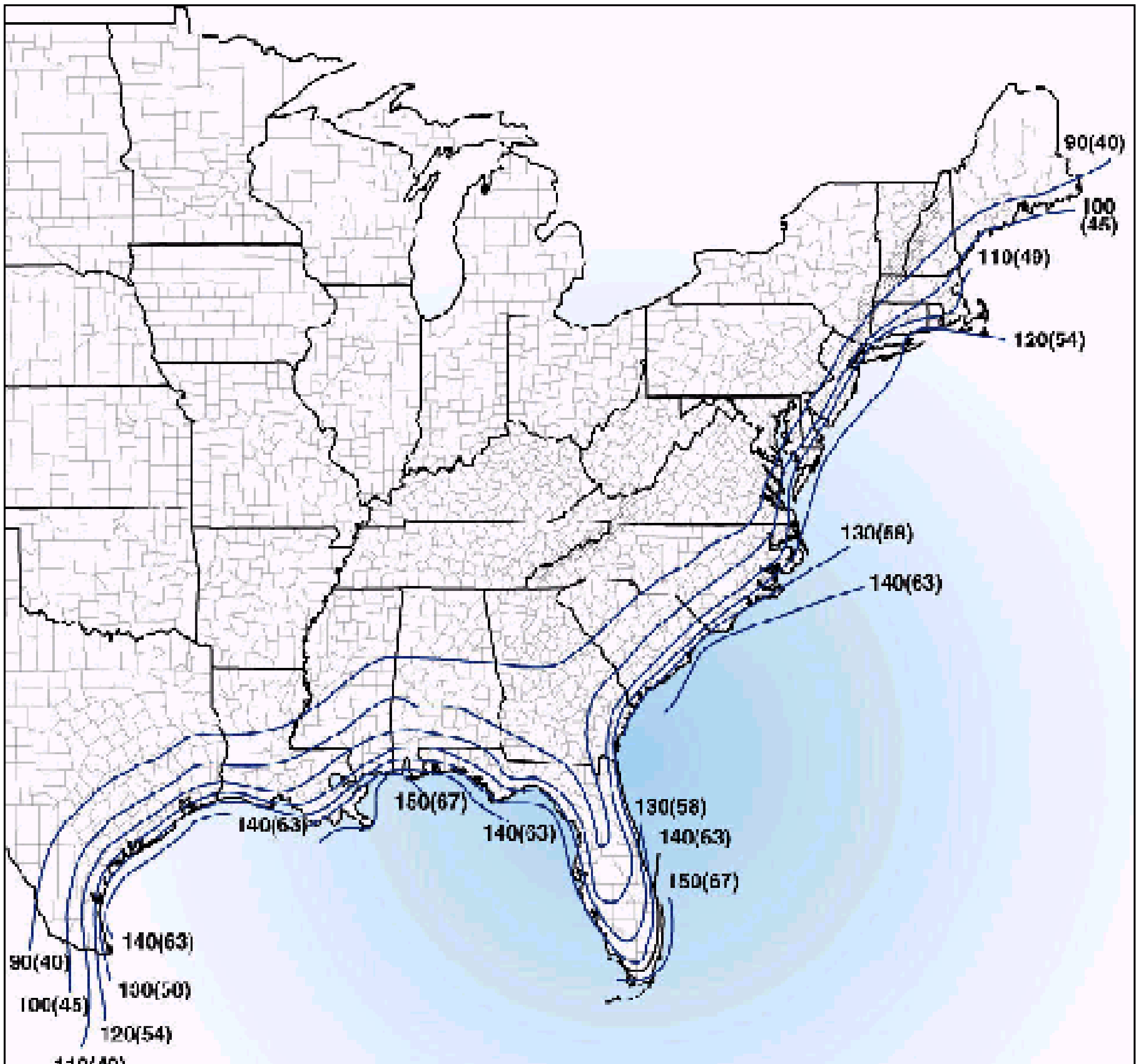


Figure 6-16. ASCE 7-98 wind speed map (continued)



Notes:

1. Values are nominal design 3-sec gust wind speeds in miles per hour (mph) at 33 ft (10 m) above ground for Exposure Category C.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

Source: *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-98.

EFFECTS OF HIGH WINDS

High winds are capable of imposing large lateral (horizontal) and uplift (vertical) forces on buildings. Residential buildings can suffer extensive wind damage when they are improperly designed and constructed and when wind speeds exceed design levels (see Figs. 6-17 and 6-18).

Wind Effect Factors

The effects of high winds on a building will depend on several factors:

- Wind speed (sustained and gusts) and duration of high winds.
- Height of building above ground.
- Exposure or shielding of the building (by topography, vegetation, or other buildings) relative to wind direction.
- Strength of the structural frame, connections, and envelope (walls and roof).
- Shape of the building and building components.
- Number, size, location, and strength of openings (e.g., windows, doors, vents).
- Presence and strength of shutters or opening protection.
- Type, quantity, and velocity of windborne debris.

WARNING

Proper design and construction of residential structures—particularly those close to open water or near the coast—demand that every one of these factors be investigated and addressed carefully. Failure to do so may ultimately result in building damage or destruction by wind.

Figure 6-17. Hurricane Andrew (1992). End-wall failure of typical first-floor masonry/second-floor wood-frame building in Dade County, Florida.

Figure 6-18. Hurricane Iniki (1992), Kauai County, Hawaii. Loss of roof sheathing from improper nailing design and schedule.

SPEEDUP OF WINDS FROM TOPOGRAPHIC EFFECTS

Speedup of winds resulting from topographic effects can occur wherever **mountainous areas, gorges, and ocean promontories** exist. Thus, the potential for increased wind speeds should be investigated for any construction on or near the crests of high coastal bluffs, cliffs, or dunes, or in gorges and canyons. *ASCE 7-98* provides guidance on calculating increased wind speeds in such situations.

Designers should also consider the **effects of long-term erosion** on the wind speeds a building may experience over its lifetime.

For example, a building sited atop a tall bluff, but away from the bluff edge, will not be prone to wind speedup initially, but long-term erosion may move the bluff edge closer to the building and expose the building to increased wind speeds from topographic effects.

WINDBORNE DEBRIS AND RAINFALL PENETRATION

Wind loads and windborne debris are both capable of causing damage to a building envelope. Even small failures in the building envelope will, at best, lead to interior damage by rainfall penetration and winds. At worst, they will lead to internal pressurization of the building, roof loss, and complete structural disintegration.

As the insured wind losses following Hurricanes Hugo and Andrew demonstrate:

- **Most wind damage** to houses is restricted to the building envelope.

- **Rainfall** entering a building through envelope failures causes the dollar value of direct building damage to be magnified by a factor of two (at lower wind speeds) to nine (at higher wind speeds).

- **Lower levels of damage magnification** are associated with interior damage by water seeping through exposed roof sheathing (e.g., following loss of shingles or roof tiles).

- **Higher levels of damage magnification** are associated with interior damage by rain pouring through areas of lost roof sheathing and through broken windows and doors.

COST CONSIDERATION

Even minor damage to the building envelope can lead to large economic losses.

TORNADOES

A tornado is a rapidly rotating vortex or funnel of air extending groundward from a cumulonimbus cloud. Tornadoes are spawned by severe thunderstorms and by hurricanes. Tornadoes often form in the right forward quadrant of a hurricane, far from the hurricane eye.

The strength and number of tornadoes are not related to the strength of the hurricane that generates them. In fact, the weakest hurricanes often produce the most tornadoes.

Damage from Tornadoes

Tornadoes can lift and move huge objects, move or destroy houses, and siphon large volumes from bodies of water.

Tornadoes also generate large amounts of debris, which then become windborne shrapnel that causes additional damage.

Implications for Design

It is generally beyond the scope of most building designs to account for a direct strike by a tornado (the *ASCE 7-98* wind map in Figure 6-16 excludes tornado effects). However, use of wind-resistant design techniques will reduce damage caused by a tornado passing nearby.

NOTE

Additional information about tornadoes and tornado hazards is presented in *Taking Shelter from the Storm: Building a Safe Room Inside Your House*, FEMA 320 (1999).

SELF-CHECK REVIEW: HIGH WINDS

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Proper design and construction of coastal buildings requires that all pertinent wind factors be investigated and addressed. Mark all factors below that affect the impact of high winds on a building.

   ___ Wind speed and duration
   ___ Building height
   ___ Exposure of the building relative to wind direction
   ___ Strength of structural frame, connections, and envelope
   ___ Shape of the building and its components
   ___ Number, size, location, and strength of openings
   ___ Protection for openings
   ___ Type, quantity, and velocity of windborne debris

2. Speedup of winds from topographic effects is most common in large, flat expanses where wind can rapidly pick up speed (e.g., plains or long beaches).

   True False

3. As long as damage to the building envelope is minor, it is not a concern—economically speaking.

   True False

4. Wind damage in combination with _________________ accounts for much of the insured wind losses in hurricanes.

5. The strength and number of tornadoes are directly related to the strength of the hurricane that generates them.

   True False

6. Most well-designed coastal buildings are designed to withstand a direct strike by a tornado.

   True False

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Proper design and construction of coastal buildings requires that all pertinent wind factors be investigated and addressed. Mark all factors below that affect the impact of high winds on a building.

   <u>x</u> Wind speed and duration
   <u>x</u> Building height
   <u>x</u> Exposure of the building relative to wind direction
   <u>x</u> Strength of structural frame, connections, and envelope
   <u>x</u> Shape of the building and its components
   <u>x</u> Number, size, location, and strength of openings
   <u>x</u> Protection for openings
   <u>x</u> Type, quantity, and velocity of windborne debris

2. Speedup of winds from topographic effects is most common in large, flat expanses where wind can rapidly pick up speed (e.g., plains or long beaches).

   False. It occurs in the vicinity of mountainous areas, gorges, and ocean promontories.

3. As long as damage to the building envelope is minor, it is not a concern—economically speaking.

   False. Even minor damage to the building envelope can lead to large economic losses.

4. Wind damage in combination with **<u>rain</u>** accounts for much of the insured wind losses in hurricanes.

5. The strength and number of tornadoes are directly related to the strength of the hurricane that generates them.

   False. The weakest hurricanes often produce the most tornadoes.

6. Most well-designed coastal buildings are designed to withstand a direct strike by a tornado.

   False. It is generally beyond the scope of most building designs to account for a direct strike, but use of wind-resistant design techniques will reduce damage caused by a tornado passing nearby.

UNIT VI EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit VI. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit VII.

1. Match the coastal events on the left with the descriptions on the right.

____	Tropical storm	a.	Rapidly rotating vortex of wind.
____	Hurricane	b.	Western North Pacific storm, winds 100 mph.
____	Typhoon	c.	North Atlantic storm, winds 100 mph.
____	Super typhoon	d.	Earthquake-induced long-period water wave.
____	Class 5 (catastrophic) hurricane	e.	North Atlantic storm, winds 175 mph.
____	Northeaster	f.	Western North Pacific storm, winds 175 mph.
____	Tsunami	g.	North Atlantic winter storm lacking closed circulation.
____	Tornado	h.	Closed circulation, winds 50 mph.

2. Tropical cyclone landfalls __are / are not__ evenly distributed on a geographic basis. (Circle one.)

3. The average number of landfalling hurricanes would probably be LOWEST in:

   a. Maine
   b. South Carolina
   c. Oregon
   d. Florida

4. A tsunami has the greatest likelihood of striking:

   a. Alaska
   b. North Carolina
   c. Louisiana
   d. New England

5. What effect does coinciding with seasonal high tides have on a storm's potential impact?

   a. No effect.
   b. Magnifies the impact.
   c. Lessens the impact.
   d. Eliminates the impact.

6. Match terms on the left with phrases on the right.

___ Hydrostatic forces	a. Sloping surfaces
___ Hydrodynamic forces	b. Standing or slowly moving water
___ Breaking waves	c. Separate pier decks from pilings
___ Wave runup	d. High velocity flows
___ Wave uplift forces	e. Vehicles, boats, and propane tanks
___ Floodborne debris	f. Cause most severe damage

7. Great Lakes water levels:

   a. Do not fluctuate.
   b. Have seasonal and long-term fluctuations.
   c. Fluctuate over hundreds or thousands of years.
   d. Fluctuate daily by as much as 20 feet.

8. Standing or slowly moving water:

   a. Can induce only horizontal hydrostatic forces.
   b. Cannot induce hydrostatic or hydrodynamic forces.
   c. Can induce horizontal and vertical hydrostatic forces.
   d. Can induce extreme hydrodynamic forces.

9. Which of the following wave effects typically causes the most severe damage?

   a. Wave runup
   b. Wave deflection
   c. Breaking waves
   d. Wave uplift forces

10. The shape of a building affects the impact of high winds on the building.

    True False

11. A house atop a 100-foot bluff may be at risk for:

    a. Wind speedup.
    b. Floodborne debris.
    c. Storm surge.
    d. A higher mean return period.

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT VI EXERCISE—ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Match the coastal events on the left with the examples on the right.

h	Tropical storm	a.	Rapidly rotating vortex of wind.
c	Hurricane	b.	Western North Pacific storm, winds 100 mph.
b	Typhoon	c.	North Atlantic storm, winds 100 mph.
f	Super typhoon	d.	Earthquake-induced long-period water wave.
e	Class 5 (catastrophic) hurricane	e.	North Atlantic storm, winds 175 mph.
g	Northeaster	f.	Western North Pacific storm, winds 175 mph.
d	Tsunami	g.	North Atlantic winter storm lacking closed circulation.
a	Tornado	h.	Closed circulation, winds 50 mph.

2. Tropical cyclone landfalls **are not** evenly distributed on a geographic basis. (Circle one.)

3. The average number of landfalling hurricanes would probably be LOWEST in:

   c. Oregon

4. A tsunami has the greatest likelihood of striking:

   a. Alaska

5. What effect does coinciding with seasonal high tides have on a storm's potential impact?

   b. Magnifies the impact.

6. Match terms on the left with phrases on the right.

b	Hydrostatic forces	a.	Sloping surfaces
d	Hydrodynamic forces	b.	Standing or slowly moving water
f	Breaking waves	c.	Separate pier decks from pilings
a	Wave runup	d.	High velocity flows
c	Wave uplift forces	e.	Vehicles, boats, and propane tanks
e	Floodborne debris	f.	Cause most severe damage

7. Great Lakes water levels:

   b. Have seasonal and long-term fluctuations.

8. Standing or slowly moving water:

   c. Can induce horizontal and vertical hydrostatic forces.

9. Which of the following wave effects typically causes the most severe damage?

   c. Breaking waves

10. The shape of a building affects the impact of high winds on the building.

    True

11. A house atop a 100-foot bluff may be at risk for:

    a. Wind speedup.

UNIT VII: IDENTIFYING HAZARDS (PART II)

IDENTIFYING HAZARDS (PART II)

INTRODUCTION

In coastal areas, proper siting and design require an accurate assessment of the vulnerability of any proposed structure, including the nature and extent of coastal hazards.

In the previous unit, you learned about hazard-producing events that strike coastal areas and about natural hazards that affect coastal residential buildings and building sites, including:

- Coastal flooding
- High winds

In this unit, you will learn about:

- Additional **natural hazards that affect coastal residential buildings and building sites**, including:
  - Erosion.
  - Earthquakes.
  - Other hazards.

- **Coastal hazard zones**, procedures used by FEMA to establish these zones, and the importance of these zones in risk assessment.

- **Translating hazard information into practice**—how designers put hazard data to use when designing residential coastal buildings.

UNIT OBJECTIVES

After completing this unit, you should be able to:

7.1 Identify causes of erosion.
7.2 Describe the potential effects on coastal residential structures of:
  - Erosion.
  - Earthquakes.
  - Other natural hazards (including subsidence and uplift, landslides and ground failures, salt spray and moisture, rain, hail, snow, ice, wood decay and termites, and wildfires).

7.3 Explain how coastal hazard zone mapping procedures can affect design decisions.
7.4 Identify key issues to be considered when using NFIP data in hazard assessments.

EROSION

WHAT IS EROSION?

Erosion is the wearing or washing away of coastal lands. The term *erosion* is commonly used to refer to the horizontal recession of the shoreline (i.e., ***shoreline erosion***), but it can apply to other types of erosion as well.

For example, ***seabed or lakebed erosion*** (also called *downcutting*) occurs when fine-grained sediments in the nearshore zone are eroded and carried into deep water. These sediments are lost permanently—resulting in a lowering of the seabed or lakebed. This process has several important consequences:

- Increased local water depths.
- Increased wave heights reaching the shoreline.
- Increased shoreline erosion.
- Undermining of erosion-control structures.

Downcutting has been documented along some ocean-facing shorelines and much of the Great Lakes shoreline (which is largely composed of fine-grained glacial deposits).

Although the concept of erosion is simple, erosion is one of the most complex hazards to understand and predict at a given site.

WARNING

This section reviews basic concepts related to coastal erosion, but it does not provide a comprehensive treatment of the many aspects of erosion that should be considered in planning, siting, and designing coastal residential buildings.

It is recommended that designers develop an understanding of erosion fundamentals, but **rely upon coastal erosion experts** (at Federal, State, and local agencies; universities; and private firms) for specific guidance regarding erosion potential at a site.

IMPACTS OF EROSION

Erosion is capable of threatening coastal residential buildings in a number of ways:

- Destroying dunes or other natural protective features (see Fig. 7-1).
- Destroying erosion-control devices (see Fig. 7-2).

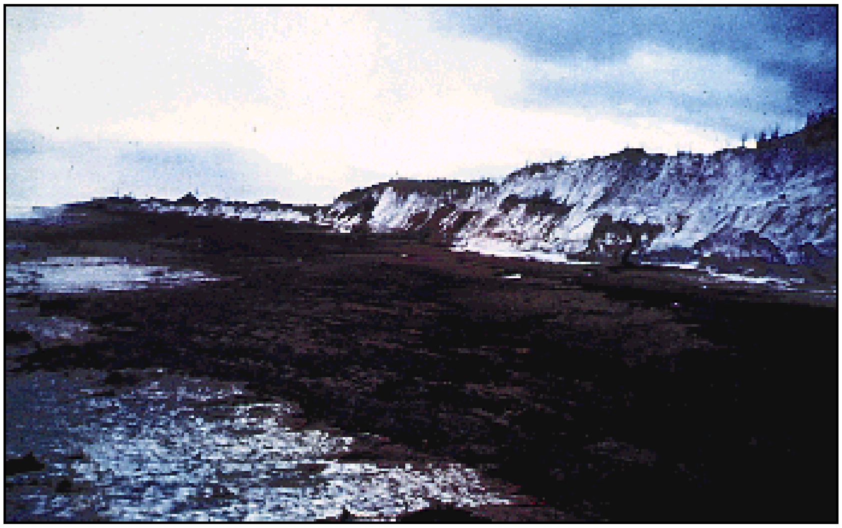


Figure 7-1. Hurricane Eloise (1975). Dune erosion in Walton County, Florida.

Figure 7-2. Hurricane Opal (1995). Failure of seawall in Bay County, Florida, led to undermining and collapse of the building behind the wall.

- Lowering ground elevations, undermining shallow foundations, and reducing penetration of deep foundations such as piles (see Fig. 7-3).

- Supplying overwash sediments that can bury structures farther landward (see Fig. 7-4).

Figure 7-3.
Erosion undermining a coastal residence. Cape Shoalwater, WA (1992).

Figure 7-4.
Removal of Hurricane Opal overwash from road at Pensacola Beach, FL. Sand that was washed landward from the beach buried the road, adjacent lots, and some at-grade buildings to a depth of 3–4 feet.

- Breaching low-lying coastal barrier islands, destroying structures at the site of the breach (see Fig. 7-5), and sometimes exposing structures on the mainland to increased flood and wave effects. (See Figure 4-5 in Unit IV).
- Eroding coastal bluffs that provide support to buildings outside the floodplain itself (see Fig. 7-6).

Figure 7-5.
Hurricane Fran (1996). Breach and building damage at North Topsail Beach, North Carolina.

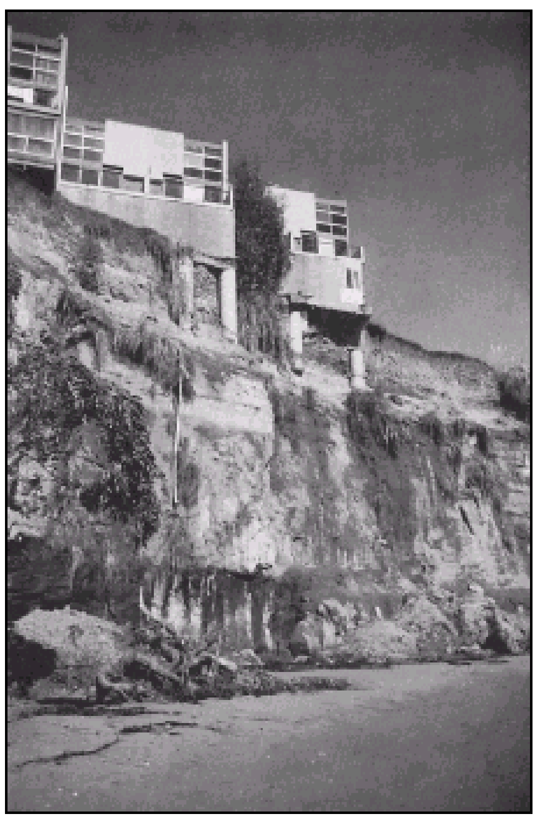


Figure 7-6.
Bluff failure by a combination of marine, terrestrial, and seismic processes led to progressive undercutting of blufftop apartments at Capitola, CA. Six of the units were demolished after the 1989 Loma Prieta earthquake.

- Washing away low-lying coastal landforms (Figs. 7-7 and 7-8).

Figure 7-7.
Cape San Blas, Gulf County, FL, in November 1984 (before Hurricane Elena).

Figure 7-8.
Same location in November 1985 (after Hurricane Elena).

DESCRIBING AND MEASURING EROSION

Erosion should be considered part of the larger process of shoreline change:

- When more sediment leaves a shoreline segment than moves into it, ***erosion*** results.

- When more sediment moves into a shoreline segment than leaves it, ***accretion*** results.

- When the amounts of sediment moving into and leaving a shoreline segment balance, the shoreline is said to be ***stable***.

NOTE

Use care in classifying a particular shoreline as erosional, stable, or accretional. A shoreline classified as "erosional" may experience periods of stability or accretion. Likewise, a shoreline classified as "stable" or "accretional" may be subject to periods of erosion. Actual shoreline behavior will depend on the time period of analysis and on prevailing and extreme coastal processes during that period.

Short-Term vs. Long-Term Changes

We classify shoreline changes as short-term changes and long-term changes.

- **Short-term** changes occur over periods ranging from a few days to a few years. They can be highly variable in direction and magnitude.

- **Long-term** changes occur over a period of decades, over which short-term changes tend to average out to the underlying erosion or accretion trend.

Both short-term and long-term shoreline changes should be considered in siting and design of coastal residential construction.

Erosion Rates

Erosion is usually expressed as a rate, in terms of:

- **Linear retreat** (e.g., feet of shoreline recession per year)

  or

- **Volumetric loss** (e.g., cubic yards of eroded sediment per foot of shoreline frontage per year).

NOTE

In this discussion of erosion, **erosion rates** are cited as positive numbers, with corresponding shoreline change rates as negative numbers (e.g., an erosion rate of 2 feet/year is equivalent to a shoreline change rate of –2 feet/year). **Accretion rates** are stated as positive numbers, with corresponding shoreline change rates as positive numbers (e.g., an accretion rate of 2 feet/year is equivalent to a shoreline change rate of 2 feet/year).

Variability of Erosion Rates

Shoreline erosion rates are usually computed and cited as long-term, average annual rates. However, erosion rates are **not** uniform in time or space. Erosion rates can vary substantially:

- From one location along the shoreline to another, even when the two locations are only a short distance apart.
- Over time at a single location.
- Seasonally.

NOTE

It is not uncommon for short-term erosion rates to exceed long-term rates by a factor of 10 or more.

EXAMPLES

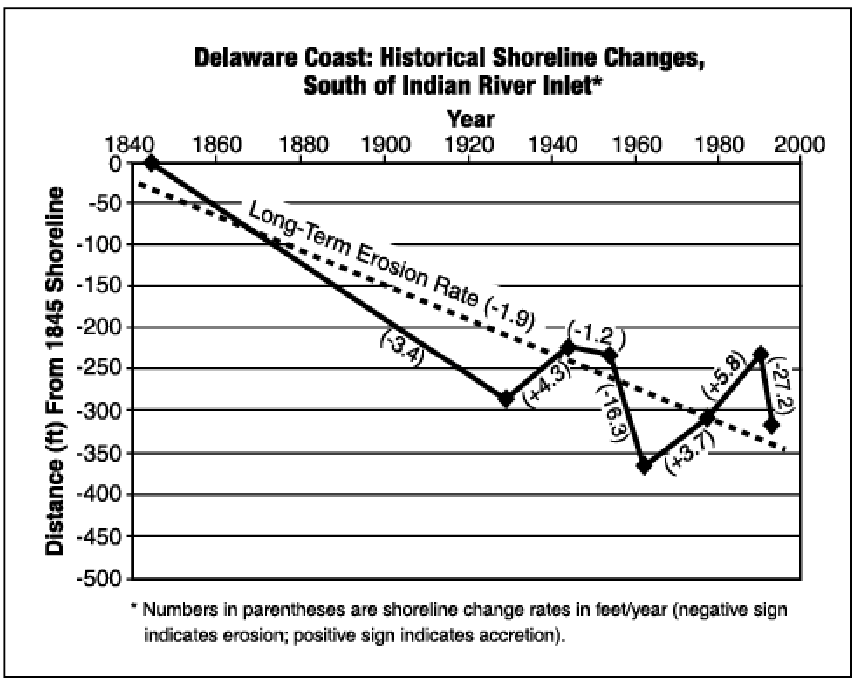
Delaware coastline: Long-term, average annual shoreline change rates for the period 1845–1993 varied from approximately –1 foot/year to –10 feet/year, over a distance of less than 5 miles.

East coast of the United States: The dominant trend is one of erosion (72 percent of the stations have experienced long-term erosion), with shoreline change rates averaging –3.0 feet/year (i.e., 3 feet/year of erosion). However, there is considerable variability along the shoreline. A few locations have experienced more than 20 feet/year of erosion. Over one-fourth of the stations have experienced accretion.

Pacific County, Washington: Erosion rates as high as 150 feet/year contrast with accretion rates as high as 18 feet/year.

Indian River Inlet, Delaware: Although the long-term, average annual shoreline change rate is approximately –2 feet/year, short-term shoreline change rates vary from –27 feet/year (erosion resulting from severe storms) to +6 feet/year (accretion associated with post-storm recovery of the shoreline). (See Fig. 7-9.)

Figure 7-9.
Shoreline changes through time at a location approximately 1.5 miles south of Indian River Inlet, Delaware.



Seasonal Fluctuations

Some shorelines experience large seasonal fluctuations in beach width and elevation (see Fig. 7-10). These changes—a result of seasonal variations in wave conditions and water levels—should not be taken as indicators of long-term shoreline changes. For this reason, shoreline change calculations at beaches subject to large seasonal fluctuations should be based on shoreline measurements taken at approximately the same time of year.

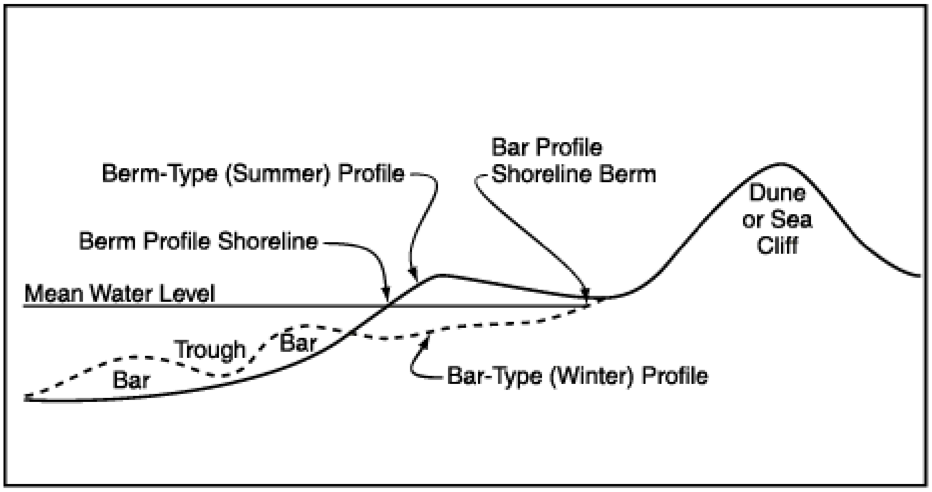


Figure 7-10.
Seasonal fluctuations in beach width and elevation

Use Caution

Erosion rates have been calculated by many States and communities for the establishment of regulatory construction setback lines. These rates are typically calculated from measurements made with aerial photographs, historical charts, or beach profiles.

A number of potential errors are associated with measurements and calculations using each of these data sources—particularly the older data. Some studies have estimated that errors in most computed erosion rates are at least 1 foot/year.

Therefore, the *Coastal Construction Manual* recommends that the siting of coastal residential structures not be based on smaller erosion rates—unless there is compelling evidence to support small erosion rates or to support accretion. **Siting decisions should be based upon erosion rates greater than or equal to 1 foot/year.**

CAUSES OF EROSION

Erosion can result from a variety of natural or manmade causes, including the following:

- Erosion caused by **storms and coastal flood events—**usually rapid and dramatic (also called ***storm-induced*** erosion).
- Erosion caused by natural changes associated with **tidal inlets, river outlets, and entrances to bays** (e.g., interruption of littoral transport by jetties and channels, migration or fluctuation of channels and shoals, formation of new inlets).
- Erosion induced by **manmade structures and human activities** (e.g., certain shore protection structures; damming of rivers; dredging; mining sand from beaches and dunes; alteration of vegetation, surface drainage, or groundwater at coastal bluffs).
- **Long-term erosion**—gradual erosion that occurs over a period of decades as a result of the cumulative effects of many factors, including changes in sea or lake level, sediment supply, and those factors mentioned above.
- **Localized scour** around structural elements, including piles and foundation elements.

Erosion can affect all coastal landforms except highly resistant geologic formations. Low-lying beaches and dunes are vulnerable to erosion, as are most coastal bluffs, banks, and cliffs.

Improperly sited buildings—even those situated atop coastal bluffs and outside the floodplain—and buildings with inadequate foundation support are especially vulnerable to the effects of erosion.

Storm-Induced Erosion

Storm-induced erosion can take place along open-coast shorelines (i.e., Atlantic, Pacific, Gulf of Mexico, and Great Lakes shorelines) and along shorelines of smaller enclosed or semi-enclosed bodies of water. If a body of water is subject to increases in water levels and generation of damaging wave action during storms, storm-induced erosion can occur.

Erosion during storms can be dramatic and damaging. Although the event is usually short-lived, the resulting erosion can be equivalent to decades of long-term erosion.

Effects on Dunes. During severe storms or coastal flood events, it is not uncommon for large dunes to be eroded 25–75 feet or more and for small dunes to be complete destroyed.

The amount of erosion during a storm determines the level of protection that a dune or similar coastal landform will provide to buildings. The mere presence of a dune does not guarantee protection during a storm. Figure 7-11 illustrates this point:

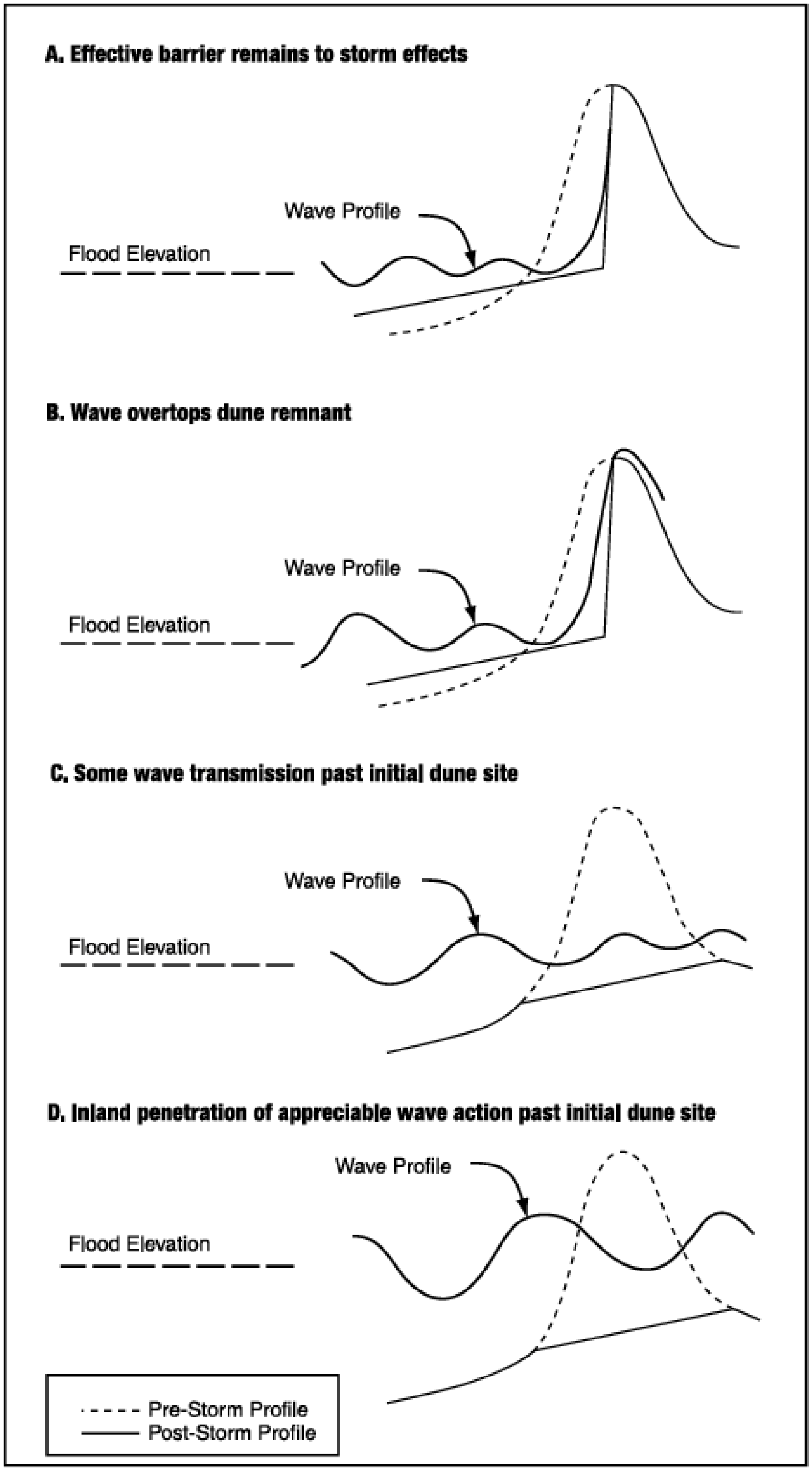
- Profile A: Areas experiencing **dune or bluff retreat** will form an effective barrier to storm effects.

- Profile B: Areas experiencing **wave overtopping and overwash** may be subject to shallow flooding.

- Profile C: Areas experiencing **dune disintegration** will transmit—but attenuate—storm waves landward of the former dune location.

- Profile D: Areas experiencing **dune flooding or submergence** will not attenuate storm waves appreciably and will allow inland penetration of storm waves.

Figure 7-11.
Flood protection offered by eroded dunes



Storms also exploit weaknesses in dune systems. A dune that is not covered by well-established vegetation (i.e., in place for two or more growing seasons) will be more vulnerable to wind and flood damage. A dune crossed by a road or pedestrian path will offer a weak point that storm waves and flooding will exploit.

Erosion Volume. The volume of sediment eroded during a storm is controlled by the following parameters:

- Storm tide elevation relative to upland elevation.
- Storm duration.
- Storm wave characteristics.
- Beach width and condition.
- Whether or not the area has been left vulnerable by the effects of other recent storms. (The cumulative effects of two or more closely spaced minor storms can often exceed the effects of a single, more powerful storm.)

Erosion-Control Devices. Erosion during storms sometimes occurs despite the presence of erosion-control devices such as seawalls, revetments, and toe protection. Storm waves frequently overtop, damage, or destroy poorly designed, constructed, or maintained erosion-control devices. Land and buildings situated behind such devices are not necessarily safe from coastal flood forces and storm-induced erosion.

Other Land Features. Narrow sand spits and low-lying coastal lands can be breached by tidal channels and inlets—often originating from the buildup of water on the back side—or washed away entirely. (See Figs. 7-7 and 7-8.)

Storm-induced erosion damage to unconsolidated cliffs and bluffs typically takes the form of large-scale collapse, slumping, and landslides, with concurrent recession of the top of the bluff. (See Fig. 1-12 in Unit I.)

Siting and Design Implications. When siting and designing structures to be built on coastal dunes, spits, or bluffs—or any other subject to storm-induced erosion—it is important to consider the potential for significant loss of supporting soil during storms.

- Buildings in low-lying coastal areas must have deep, well-designed, and well-constructed pile or column foundations.

- Buildings constructed atop dunes and bluffs, and outside the floodplain, can still be subject to erosion. Designers therefore must account for the possibility of loss of supporting soil, using methods such as the following:
  - **Setbacks** from the dune or bluff edge sufficient to offer protection over the expected life of the building.
  - **Dune or bluff toe protection** designed to withstand the base flood event. (Many States and communities, however, restrict or prohibit the construction of dune protection and erosion-control structures.
  - Design of a **moveable building,** which can be lifted off its foundation and moved landward onto a new foundation.
  - Construction of a **deep foundation**. (Note that this method could result in a building standing high above the beach following a storm. It would probably be uninhabitable and require landward relocation.)
  - A **combination** of these methods.

WARNING

Ground elevations in some V zones lie above the BFE (as a result of mapping procedures that account for storm erosion). V-zone requirements for a pile or column foundation capable of resisting flotation, collapse, and lateral movement still apply, even if the current ground level lies above the BFE.

Erosion from Tidal Inlets or Harbor, Bay, and River Entrances

Many miles of coastal shoreline are situated on or adjacent to connections between two bodies of water. These connections can take the form of tidal inlets (i.e., short, narrow hydraulic connections between oceans and inland waters), harbor entrances, bay entrances, and river entrances.

WARNING

The location of a tidal inlet or harbor, bay, or river entrance can be stabilized by jetties or other structures, but the shorelines in the vicinity can still fluctuate in response to storms, waves, and other factors.

Governing Factors. The size, location, and adjacent shoreline stability of these connections are usually governed by five factors:

- Tidal and freshwater flows through the connection.
- Wave climate.
- Sediment supply.
- Local geology.
- Jetties or stabilization structures.

Temporary or permanent changes in any of these governing factors can cause the connection to migrate, change size, or change configuration. They can also cause sediment transport patterns in the vicinity of the inlet to change, thereby altering flood hazards in nearby areas.

Stabilization. Construction of jetties or similar structures at a tidal inlet or a bay, harbor, or river entrance often results in accretion on one side and erosion on the other, with a substantial shoreline offset. This offset results from the jetties trapping the *littoral drift* (i.e., wave-driven sediment moving along the shoreline) and preventing it from moving to the downdrift side.

EXAMPLE

At Ocean City Inlet, Maryland, formation of the inlet in 1933 by a hurricane and construction of inlet jetties in 1934–35 have led to approximately 800 feet of accretion against the north jetty at Ocean City and approximately 1,700 feet of erosion on the south side of the inlet along Assateague Island (see Fig. 7-12).

Figure 7-12. Ocean City Inlet, MD (1992). Note extreme shoreline offset and downdrift erosion resulting from inlet stabilization.

The downdrift erosion is ongoing. Post-inlet shoreline change rates on Assateague Island have been documented between –30 feet/year and –40 feet/year. Pre-inlet shoreline change rates were approximately –4 feet/year.

It should be noted that erosion and accretion patterns at stabilized inlets and entrances sometimes differ from this classic pattern.

- In some instances, accretion occurs immediately adjacent to both jetties, with erosion beyond.
- In some instances, erosion and accretion patterns near a stabilized inlet change over time.

Channel Migration. Development in the vicinity of a tidal inlet or bay, harbor, or river entrance is often affected by lateral migration of the channel and associated changes in sand bars—which may focus waves and erosion on particular shoreline areas.

Often, these changes are cyclic in nature and can be identified and forecast through a review of historical aerial photographs and bathymetric data. When considering a building site near a tidal inlet or a bay, harbor, or river entrance, thoroughly investigate the following:

- The history of the connection.
- Associated shoreline fluctuations.
- Migration trends.
- Impacts of any stabilization structures.

Failure to do so could result in increased building vulnerability or building loss to future shoreline changes.

WARNING

Many State and local siting regulations allow residential development in areas where erosion is likely to occur. **Do not assume that a building sited in compliance with minimum State and local requirements will be safe from future erosion.**

Erosion from Human Intervention

Human actions along the shoreline can both reduce and increase flood hazards. For example—

- In some instances, structures built or actions taken to facilitate navigation will cause erosion elsewhere.

- In some cases, structures built or actions taken to halt erosion and reduce flood hazards at one site will increase erosion and flood hazards at nearby sites.

Therefore, when evaluating a potential coastal building site, it is important to consider the effects of both natural and human-induced shoreline changes, including:

- Shore protection structures.
- Dredging of navigation channels.
- Sand mining from beaches.
- Alteration of vegetation, drainage, or groundwater.
- Damming of rivers.

EFFECTS OF SHORE PROTECTION STRUCTURES

NOTE

This is not an indictment of all erosion-control structures: many provide protection against erosion and flood hazards. But there is the potential for adverse impacts.

In performing their intended function, shore protection structures can lead to or increase erosion on nearby properties. Potential impacts will vary from site to site and structure to structure. They can sometimes be mitigated by *beach nourishment* (the placement of additional sediment on the beach) in the vicinity of the erosion-control structure.

- **Groins.** Groins (see Fig. 4-3 in Unit IV) are short, shore-perpendicular structures designed to trap available littoral sediments. They can cause erosion to downdrift beaches if the groin compartments are not filled with sand and maintained in a full condition.

- **Offshore Breakwaters.** Offshore breakwaters (see Fig. 7-13) can trap available littoral sediments and reduce the sediment supply to nearby beaches. This adverse effect should be mitigated by combining breakwater construction with beach nourishment.

Figure 7-13. Trapping of littoral sediments behind offshore breakwaters. Presque Isle, Pennsylvania.

- **Seawalls, Bulkheads, and Revetments.** These devices are shore-parallel structures built—usually along the shoreline or at the base of a bluff—to act as retaining walls and to provide some degree of protection against high water levels, waves, and erosion. The degree of protection they afford depends on their design, construction, and maintenance.

  They do not prevent erosion of the beach; in fact, they can exacerbate ongoing erosion of the beach. The structures can:

  - Impound upland sediments that would otherwise erode and nourish the beach.
  - Lead to *passive erosion*—eventual loss of the beach as a structure prevents landward migration of the beach profile.
  - Lead to *active erosion*—localized scour waterward of the structure and on unprotected property at the ends of the structure.

The vast majority of privately financed seawalls, revetments, and erosion control devices fail during 100-year—or lesser—events. Either they are heavily damaged or destroyed, or they withstand the storm but fail to prevent flood damage to lands and buildings they are intended to protect (see Fig. 7-2).

Reliance on these devices to protect upland sites and residential buildings is not a good substitute for proper siting and foundation design.

NOTE

Some communities distinguish between erosion control structures built to protect existing development and those constructed to create a buildable area on an otherwise unbuildable site. Designers should investigate any local or state regulations and requirements pertaining to erosion control structures before undertaking building site selection and design.

EFFECTS OF DREDGING NAVIGATION CHANNELS

NOTE

It has been estimated that these two activities account for three-fourths of the beach erosion along the east coast of Florida.

Dredging navigation channels can interrupt the natural bypassing of littoral sediments across tidal inlets and bay entrances, altering natural sediment transport and erosion/accretion patterns.

Disposal of beach-compatible dredged sediments into deepwater will result in a permanent loss to the littoral system and may ultimately lead to shoreline erosion.

Dredging across natural barriers (e.g., inlet shoals, protective reefs, sand bars, and nearshore shoals) can also modify wave and current patterns and cause shoreline changes nearby. This activity has been cited as a cause of shoreline erosion in Hawaii and in many other locations.

EFFECTS OF SAND MINING FROM BEACHING

Sand mining from beaches and dune areas is not permitted in most States and communities because it causes an immediate and direct loss of littoral sediments. However, the practice is allowed in some situations where shoreline trends are accretional.

EFFECTS OF ALTERATION OF VEGETATION, DRAINAGE, OR GROUNDWATER

Altering vegetation, drainage, or groundwater can sometimes make a site more vulnerable to coastal storm or flood events. For example, removal of grasses, ground covers, and trees at a site can make the soil more prone to erosion by wind, rain, and flood forces.

Altering natural drainage patterns and groundwater flow can increase erosion potential, especially on steep slopes and coastal bluffs. Irrigation and septic systems often contribute to bluff instability.

EFFECTS OF DAMMING RIVERS

Damming of rivers can reduce natural sediment loads transported to open coast shorelines. Most rivers carry predominantly fine sediments (i.e., silts and clays), but some rivers may carry higher percentages of sand, and some large rivers may yield significant quantities of sand.

Although the exact shoreline impacts from damming rivers may be difficult to discern, the reduced sediment input may ultimately translate into shoreline erosion in some areas. It has been postulated that river damming and reduced sediment loads are responsible for the shift from long-term accretion to recent erosion along the portion of the Washington coast shown in Figure 7-14.

Figure 7-14. Buildings threatened by erosion at Ocean Shores, WA (1998). The rock revetments were built in response to shoreline erosion along an area adjacent to a jetty and thought to be accretional.

Long-Term Erosion

Causes. Observed long-term erosion at a site represents the net effect of a combination of factors, which may include:

- Rising sea levels (or subsidence of uplands).
- Rising lake levels or lakebed erosion (in the case of the Great Lakes).
- Reduced sediment supply to the coast.
- Construction of jetties, other structures, or dredged channels that impede littoral transport of sediments along the shoreline.
- Increased incidence or intensity of storms.
- Alteration of upland vegetation, drainage, or groundwater flows (especially in coastal bluff areas).

Effects. Regardless of the cause, long-term shoreline erosion can increase the vulnerability of coastal construction in a number of ways, depending on local shoreline characteristics, construction setbacks, and structure design. In essence, **long-term erosion shifts flood hazard zones landward.**

For example, a site that was at one time mapped accurately as an A zone will become exposed to V-zone conditions. A site that was at one time accurately mapped as outside the 100-year floodplain may become exposed to A-zone or V-zone conditions.

LONG-TERM EROSION AND FIRMs

Coastal FIRMs (even recently published coastal FIRMs) do not incorporate the effects of long-term erosion. Mapped V zones and A zones in areas subject to long-term erosion will underestimate the extent and magnitude of actual flood hazards that a coastal building may experience over its lifetime.

FEMA has undertaken a series of studies to determine whether and how long-term erosion can be incorporated into coastal floodplain mapping. The studies mapped erosion in 27 coastal counties in 18 States and (for 18 of the mapped counties) inventoried structures within the erosion hazard areas.

Results are being used to estimate future erosion and flood damage as part of economic impact and cost/benefit analyses and to determine whether it is economically and technically justified for FEMA to map and insure against erosion hazards through the NFIP.

Sources of Data. Despite the fact that FIRMs do not incorporate long-term erosion, there are other sources of long-term erosion data available for much of the country's shorelines. These data usually take the form of historical shoreline maps or erosion rates published by individual States or specific reports (from Federal or State agencies, universities, or consultants) pertaining to counties or other small shoreline reaches.

There may be more than one source of long-term erosion rate data available for a given site, and the different sources may report different erosion rates because of:

- Different study periods.
- Different data sources (e.g., aerial photographs vs. maps vs. ground surveys).
- Different study methods.

Where multiple sources and long-term erosion rates exist for a given site, designers should **use the highest long-term erosion rate** in siting decisions, unless they conduct a detailed review of the erosion rate studies and conclude that a lower erosion rate is more appropriate for forecasting future shoreline positions.

Localized Scour

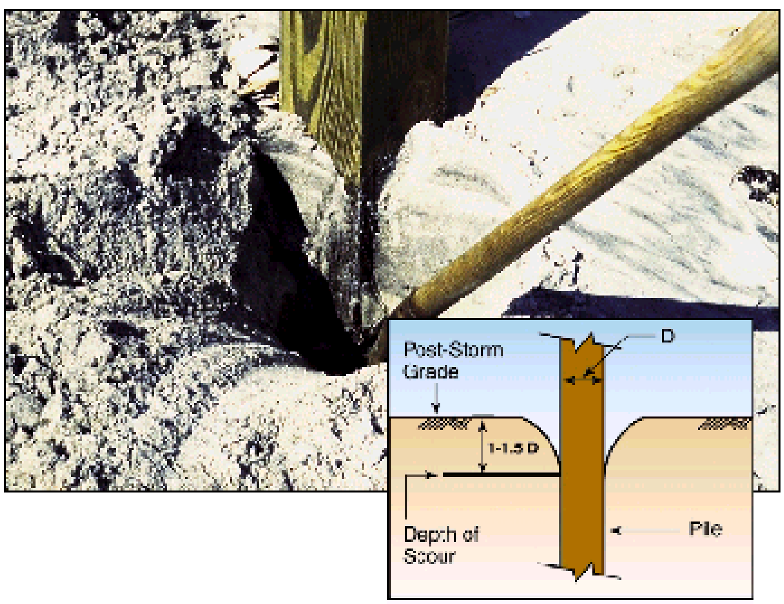
Cause. Localized scour can occur when water flows at high velocities past an object embedded in or resting on erodible soil. Localized scour can also be caused or exacerbated by waves interacting with the object.

Flow moving past a fixed object must accelerate, often forming eddies or vortices and scouring loose sediment from the immediate vicinity of the object.

The scour is not caused by the flood or storm event, per se, but by the distortion of the flow field by the object. Localized scour occurs only around the object itself and is in addition to storm- or flood-induced erosion that occurs in the general area.

Effects. Localized scour around piles and similar objects (see Fig. 7-15) is generally limited to small, cone-shaped depressions less than 2 feet deep and several feet in diameter.

Figure 7-15. Determination of localized scour from changes in sand color, texture, and bedding. Hurricane Fran (1996).



Localized scour is capable of undermining slabs and grade-supported structures. In severe cases, the depth and lateral extent of localized scour can lead to structural failure (see Fig. 7-16).

Designers should consider potential effects of localized scour when calculating foundation size, depth, or embedment requirements.

Figure 7-16. Extreme case of localized scour undermining a slab-on-grade house on Topsail Island, NC (Hurricane Fran, 1996). The lot was several hundred feet from the shoreline and mapped as an A zone on the FIRM prior to the storm.

Overwash and Sediment Burial

Causes. Sediment eroded during a coastal storm event must travel to one of the following locations:

- Offshore to deeper water.
- Along the shoreline.
- Inland.

Overwash occurs when low-lying coastal lands are overtopped and eroded by storm surge and waves. The eroded sediments are carried landward by floodwaters, burying uplands, roads, and at-grade structures (see Fig. 7-4). Significant overwash deposits can occur when the waves are capable of suspending sediments in the water column and flow velocities exceed 3 feet/sec).

Post-storm aerial photographs and/or videos can be used to identify likely future overwash locations.

Effects. Depths of overwash deposits can reach 3–5 feet or more near the shoreline, gradually decreasing away from the shoreline. It is not uncommon to see overwash deposits extending several hundred feet inland following a severe storm—especially in the vicinity of shore-perpendicular roads.

The physical processes required to create significant overwash deposits are also capable of damaging buildings. Thus, existing coastal buildings located in A zones (particularly the seaward portions of A zones) and built on slab or crawlspace foundations should be considered vulnerable to damage from overwash, high-velocity flows, and waves.

Windblown Sand. Some coastal areas suffer from an excess of sand rather than from erosion. The excess usually translates into accretion of the shoreline and/or significant quantities of windblown sand.

Unless this windblown sand is stabilized by vegetation or other means, it will likely be blown inland by coastal winds. Windblown sand can bury non-elevated coastal residential buildings and at-grade infrastructure—such as drainage structures and ground-mounted electrical and telephone equipment—and drift across roads (see Fig. 7-17).

Figure 7-17. Windblown sand drifting against coastal residences in Pacific City, Oregon.

SELF-CHECK REVIEW: EROSION

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Describe at least five ways that erosion threatens coastal residential buildings.

   (1) ______________________________

   (2) ______________________________

   (3) ______________________________

   (4) ______________________________

   (5) ______________________________

2. When more sediment moves into a shoreline than leaves it, ____________________ results.

3. Long-term shoreline changes tend to be highly variable in direction and magnitude.

   True False

4. Both short-term and long-term shoreline changes should be considered in siting and design of coastal residential buildings.

   True False

5. Low-lying beaches and dunes are vulnerable to erosion, but coastal bluffs, banks, and cliffs are not.

   True False

6. How can designers help avoid problems associated with errors in computed erosion rates?

7. List five main causes of erosion.

   (1) ____

   (2) ____

   (3) ____

   (4) ____

   (5) ____

8. When building atop dunes or bluffs, what strategies can be used to account for the possibility that supporting soils will be lost to erosion?

9. How would you describe the potential impact on erosion of such human interventions as shoreline protection structures and dredging of channels?

10. Long-term erosion shifts flood hazard zones:

    a. Laterally
    b. Landward
    c. Seaward

11. Where different long-term erosion rates have been published for a site, designers should generally use the ______________________ erosion rate in siting decisions.

    a. Most recent
    b. Lowest
    c. Oldest
    d. Highest

12. __________________________________ occurs when water flows at high velocities past an object that is embedded in or resting on erodible soil.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Describe at least five ways that erosion threatens coastal residential buildings.

   Any of the following:
   - **Destroying dunes or other natural protective features.**
   - **Destroying erosion control devices.**
   - **Lowering ground elevations, undermining shallow foundations, and reducing penetration of deep foundations.**
   - **Supplying overwash sediments that can bury structures farther landward.**
   - **Breaching low-lying coastal barrier islands.**
   - **Washing away low-lying coastal landforms.**
   - **Eroding coastal bluffs.**

2. When more sediment moves into a shoreline than leaves it, **accretion** results.

3. Long-term shoreline changes tend to be highly variable in direction and magnitude.

   False

4. Both short-term and long-term shoreline changes should be considered in siting and design of coastal residential buildings.

   True

5. Low-lying beaches and dunes are vulnerable to erosion but coastal bluffs, banks, and cliffs are not.

   False

6. How can designers help avoid problems associated with errors in computed erosion rates?

   By basing siting decisions upon erosion rates of at least 1 foot/year.

7. List five main causes of erosion.

   - **Storms and coastal flood events**
   - **Natural changes associated with tidal inlets, river outlets, and entrances to bays**
   - **Manmade structures and human activities**
   - **Long-term erosion**
   - **Localized scour**

8. When building atop dunes or bluffs, what strategies can be used to account for the possibility that supporting soils will be lost to erosion?

   - **Setbacks from the dune or bluff edge**
   - **Dune or bluff toe protection designed to withstand the base flood event**
   - **Designing a moveable building**
   - **Constructing a deep foundation**
   - **A combination of these strategies**

9. How would you describe the potential impact on erosion of such human interventions as shoreline protection structures and dredging of channels?

   They can both reduce and increase flood hazards, either at the site or at nearby sites.

10. Long-term erosion shifts flood hazard zones:

    b. Landward

11. Where different long-term erosion rates have been published for a site, designers should generally use the ______________________ erosion rate in siting decisions.

    d. Highest

12. **<u>Localized scour</u>** occurs when water flows at high velocities past an object that is embedded in or resting on erodible soil.

EARTHQUAKES

Earthquakes can affect coastal areas just as they can affect inland areas—through ground shaking, liquefaction, surface fault ruptures, and other ground failures. Therefore, coastal construction in seismic hazard areas must take potential earthquake hazards into account.

Proper design in seismic hazard areas must strike a balance between:

- The need to elevate buildings above flood hazards and minimize obstructions to flow and waves beneath a structure.
- The need to stabilize or brace the building against potentially violent accelerations and shaking from earthquakes.

CLASSIFICATION

Earthquakes are classified according to two parameters: magnitude and intensity.

- **Magnitude** refers to the total energy released by the event. An earthquake has a single magnitude. The Richter Scale is used to report earthquake magnitude.
- **Intensity** refers to the effects at a particular site. The intensity varies with location. The Modified Mercalli Intensity (MMI) Scale is used to report felt intensity. The MMI Scale (see Table 7.1) ranges from I (imperceptible) to XII (catastrophic).

Table 7.1. Modified Mercalli Earthquake Intensity Scale

MMI Level	Felt Intensity
I	Not felt except by a very few people under special conditions. Detected mostly by instruments.
II	Felt by a few people, especially those on upper floors of buildings. Suspended objects may swing.
III	Felt noticeably indoors. Standing automobiles may rock slightly.
IV	Felt by many people indoors, by a few outdoors. At night, some people are awakened. Dishes, windows, and doors rattle.
V	Felt by nearly everyone. Many people are awakened. Some dishes and windows are broken. Unstable objects are overturned.
VI	Felt by nearly everyone. Many people become frightened and run outdoors. Some heavy furniture is moved. Some plaster falls.
VII	Most people are alarmed and run outside. Damage is negligible in buildings of good construction, considerable in buildings of poor construction.
VIII	Damage is slight in specially designed structures, considerable in ordinary buildings, great in poorly built structures. Heavy furniture is overturned.
IX	Damage is considerable in specially designed buildings. Buildings shift from their foundations and partly collapse. Underground pipes are broken.
X	Some well-built wooden structures are destroyed. Most masonry structures are destroyed. The ground is badly cracked. Considerable landslides occur on steep slopes.
XI	Few, if any, masonry structures remain standing. Rails are bent. Broad fissures appear in the ground.
XII	Virtually total destruction. Waves are seen on the ground surface. Objects are thrown in the air.

IMPACT ON BUILDINGS

The ground motion produced by earthquakes can:

- Shake buildings (both lateral and vertical building movements are common) and cause **structural failure by excessive deflection**.

- **Cause building failures by rapid, permanent displacement of underlying soils and strata** (e.g., uplift, subsidence, ground rupture, soil liquefaction, and/or consolidation).

In coastal areas, the structural effects of ground shaking can be magnified when buildings are elevated (on piles, piers, posts, or columns in V zones or by fill in A zones) above the natural ground elevation in conformance with NFIP-compliant State and local floodplain management regulations.

SITE PARAMETERS

One of the site parameters controlling seismic-resistant design of buildings is the *maximum considered earthquake ground motion*, which has been mapped by the U.S. Geological Survey for the National Earthquake Hazard Reduction Program (NEHRP) at two levels:

- 0.2-sec spectral response acceleration (see Fig. 7-18).
- 1.0-sec spectral response acceleration. (see Fig 7-19).

Accelerations are mapped as a percent of “g,” the gravitational constant.

Figure 7-18. 1.0-sec Spectral Response Acceleration—Maximum Earthquake Ground Motion (%g) (Legend appears on the next page)

Figure 7-18 (Continued)

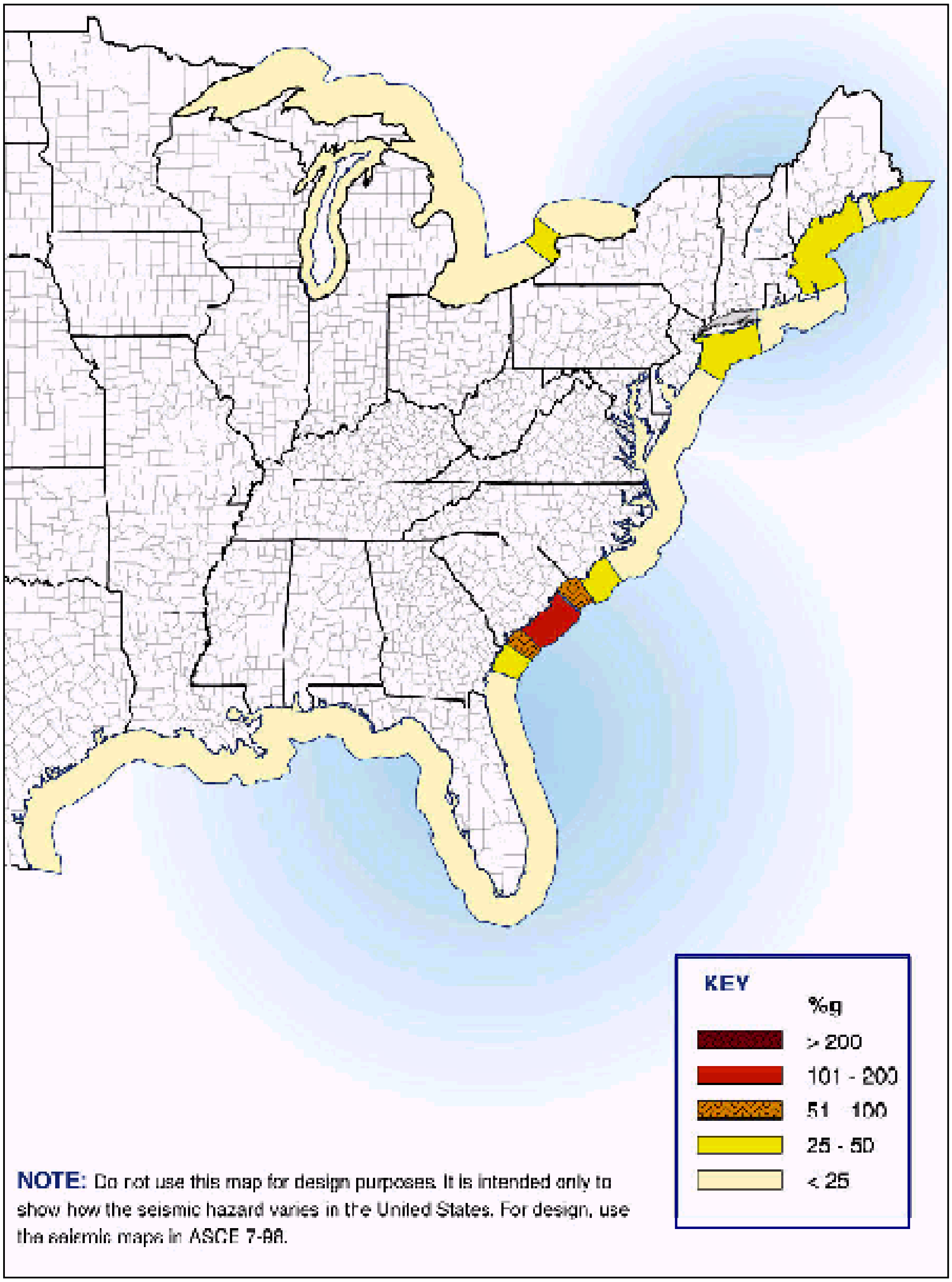
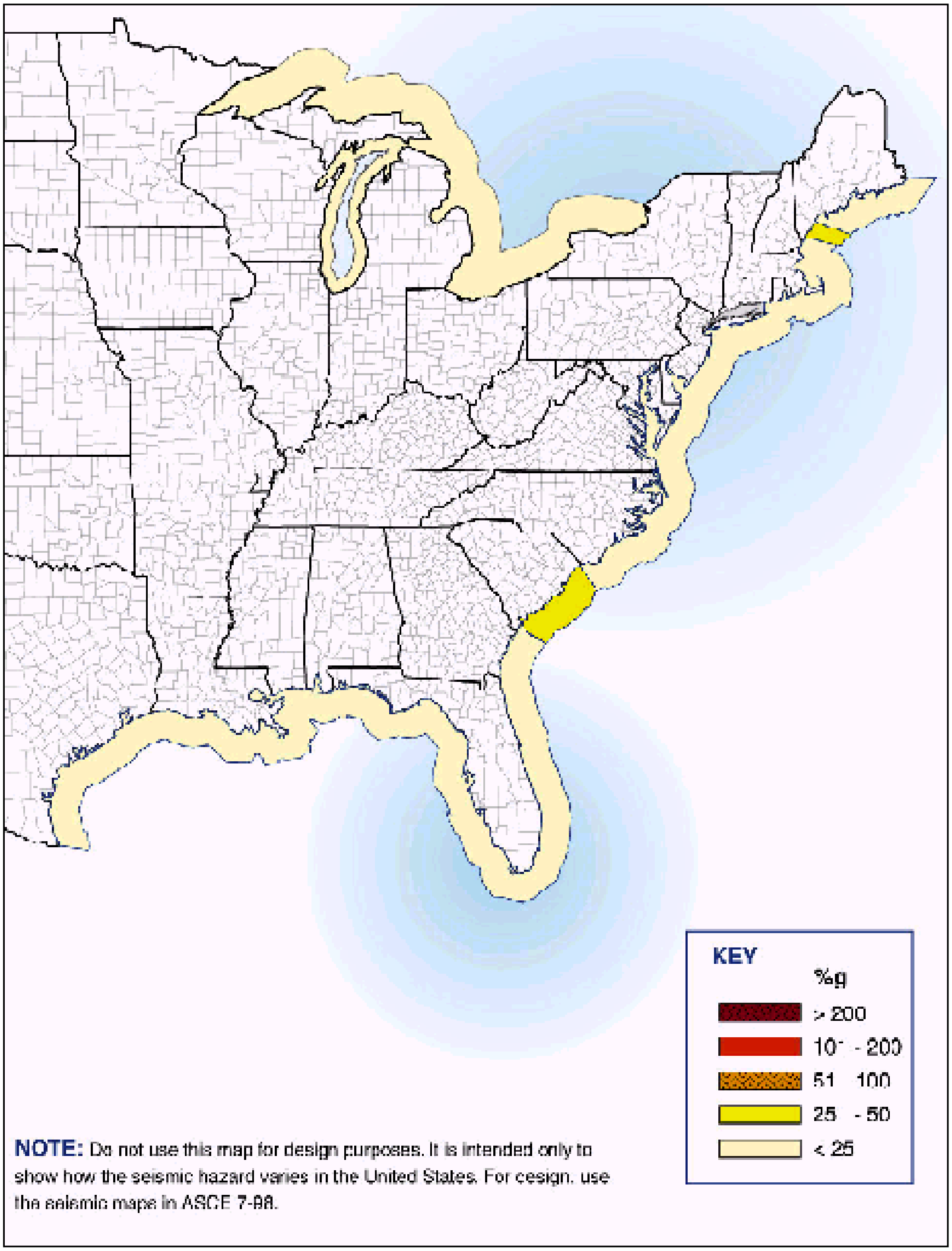


Figure 7-19. 1.0-sec Spectral Response Acceleration—Maximum Earthquake Ground Motion (%g) (Legend appears on the next page)

Figure 7-19 (Continued)



IMPLICATIONS FOR BUILDING DESIGN

The structural effects of earthquakes are a function of many factors, including:

- Soil characteristics.
- Local geology.
- Building characteristics:
    - Weight
    - Shape.
    - Height.
    - Structural system.
    - Foundation type.

Therefore, design of earthquake-resistant buildings requires careful consideration of both site and structure.

Design

In many cases, elevating a building 8–10 feet above grade on a pile or column foundation—a common practice in low-lying V zones and Z coastal zones—can result in what earthquake engineers term a “soft story” or “inverted pendulum,” a condition that requires the building be designed for a larger earthquake force.

Thus, designs for pile- or column-supported residential buildings should be verified for necessary **strength and rigidity below the first-floor level**, to account for increased stresses in the foundation members when the building starts to move and deflect during an earthquake.

Foundation

For buildings elevated on fill, earthquake ground motions can be exacerbated if the fill and underlying soils are not properly **compacted and stabilized**.

Liquefaction of the supporting soil can be another damaging consequence of ground shaking. In granular soils with high water tables (like those found in many coastal areas), the ground motion will cause an increase in the pore water pressure, which overcomes soil cohesion and can create a semi-liquid state. The soil then can temporarily lose its bearing capacity, and settlement and differential movement of buildings can result.

Construction

Seismic effects on buildings vary with structural configuration, stiffness, ductility, and strength.

- Properly designed and built **wood-frame buildings** are quite ductile, meaning that they can withstand large deformations without losing strength. Failures, when they occur in wood-frame buildings, are usually at connections.

- Properly designed and built **steel construction** is also inherently ductile but can fail at non-ductile connections.

- Modern **concrete construction** can be dimensioned and reinforced to provide sufficient strength and ductility to resist earthquakes. Older concrete structures typically are more vulnerable. Failures in concrete masonry structures are likely to occur if reinforcing and cell grouting do not meet seismic-resistant requirements.

SELF-CHECK REVIEW: EARTHQUAKES

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. What are the two main ways earthquakes affect buildings?

2. Describe the conflicting design challenges when designing a residence in a V zone vulnerable to earthquakes.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. What are the two main ways earthquakes affect buildings?

   The ground motion produced by earthquakes can:
   - **Shake buildings and cause structural failure by excessive deflection.**
   - **Cause building failures by rapid, permanent displacement of underlying soils and strata.**

2. Describe the conflicting design challenges when designing a residence in a V zone vulnerable to earthquakes.

   In V zones, buildings must be elevated above the BFE on a pile or column foundation to protect against flood damage. This kind of design results in an "inverted pendulum," which requires that the building be designed to resist the larger forces that will occur in some members.

OTHER HAZARDS AND ENVIRONMENTAL EFFECTS

Other hazards to which coastal construction may be exposed include a wide variety of hazards whose incidence and severity may be highly variable and localized. Examples include:

- Subsidence and uplift.
- Landslides and ground failures.
- Salt spray and moisture.
- Rain.
- Hail.
- Wood decay and termites.
- Wildfires.
- Floating ice.
- Snow.
- Atmospheric ice.

These hazards do not always come to mind when coastal hazards are mentioned, but like the other hazards described earlier in this unit, they can impact coastal construction and should be considered in siting, design, and construction decisions.

SUBSIDENCE AND UPLIFT

Subsidence. Subsidence is a hazard that typically affects areas where any of the following situations exist:

- Withdrawal of groundwater or petroleum has occurred on a large scale.
- Organic soils are drained and settlement results.
- Younger sediments deposit over older sediments and cause those older sediments to compact (e.g., river delta areas).
- Surface sediments collapse into underground voids (rare in coastal areas).

One consequence of coastal subsidence—even when small in magnitude—is an increase in coastal flood hazards because of an increase in flood depth.

Uplift. Differential uplift in the vicinity of the Great Lakes can lead to increased water levels and flooding. As the ground rises in response to the removal of the great ice sheet, it does so in a non-uniform fashion.

EXAMPLES

- On Lake Superior, the outlet at the eastern end of the lake is rising at a rate of nearly 10 inches per century, relative to the city of Duluth-Superior at the western end of the lake. This causes a corresponding water level rise at Duluth-Superior.

- The northern ends of Lakes Michigan and Huron are rising relative to their southern portions. On Lake Michigan, the northern outlet at the Straits of Mackinac is rising at a rate of 9 inches per century, relative to Chicago. The outlet of Lakes Michigan and Huron is rising only about 3 inches per century relative to the land at Chicago.

Landslides and Ground Failures

Landslides. Landslides occur when slopes become unstable and loose material slides or flows under the influence of gravity. Often, landslides are triggered by other events, such as erosion at the toe of a sleep slope, earthquakes, floods, or heavy rains. But they can be worsened by human actions such as destruction of vegetation or uncontrolled pedestrian access on steep slopes (see Fig. 7-20).

Figure 7-20. Unstable coastal bluff at Beacon's Beach, San Diego, California

Ground Failures. Smaller, more subtle, and gradual movements of soil under or around residential buildings can also be destructive. These movements can result from natural or development-induced factors and can result in ground movements of just a few inches.

For example, *soil creep* is the slow, downslope movement of overburden—usually in conjunction with subsurface drainage and slippage. Development on soils subject to creep may aggravate the problem. *Settlement* is the downward vertical movement of a building foundation or soil surface as a consequence of soil compression or lateral yielding.

Creep, settlement, and other ground failures can occur in granular, cohesive, and rocky soils. Coastal bluff failures can be induced by seismic activity.

SALT SPRAY AND MOISTURE

Salt spray and moisture effects frequently lead to corrosion and decay of building materials in the coastal environment. This is one hazard that is commonly overlooked or underestimated by designers. Any careful inspection of coastal buildings (even new or recent buildings) near a large body of water will reveal deterioration of improperly selected or installed materials.

For example, metal connectors, straps, and clips used to improve a building's resistance to high winds and earthquakes will often show signs of corrosion (see Fig. 7-21).

Figure 7-21. Example of corrosion, and resulting failure, of metal connectors

Corrosion is affected by many factors, but the primary difference between coastal and inland areas is the presence of salt spray, tossed into the air by breaking waves and blown onto land by onshore winds. Salt spray accumulates on metal surfaces, accelerating the electrochemical processes that cause rusting and other forms of corrosion—particularly in the humid conditions common along the coast.

Factors affecting the rate of corrosion include:

- Humidity.
- Wind direction and speed.
- Seasonal wave conditions.
- Distance from the shoreline.
- Elevation above the ground.
- Orientation of the building to the shoreline.
- Rinsing by rainfall.
- Shelter and air flow in and around the building.
- Materials used to make the component.

RAIN

Rain presents two principal hazards to coastal residential construction:

- Penetration of the building envelope during high wind events.
- Vertical loads from rainfall ponding on the roof.

Ponding usually occurs on flat or slow-slope roofs where a parapet or other building element causes rainfall to accumulate, and where the roof drainage system fails. Every inch of accumulated rainfall causes a downward-directed load of approximately 5 lb/ft^2. Excessive accumulation can lead to progressive deflection and instability of roof trusses and supports.

HAIL

Hailstorms develop from severe thunderstorms and generate balls or lumps of ice capable of damaging agricultural crops, buildings, and vehicles. Severe hailstorms can damage roofing shingles and tiles, metal roofs, roof sheathing, skylights, glazing, and other building components. Accumulation of hail on flat or low-slope roofs—like accumulation of rain—can lead to significant vertical loads and progressive deflection of roof trusses and supports.

WOOD DECAY AND TERMITES

Decay of wood products and infestation by termites are common in coastal areas subject to high humidity and frequent and heavy rains. Improper preservative treatments, improper design and construction, and even poor landscaping practices, can all contribute to decay and infestation problems.

One or more of the following can be used to protect against decay and termites:

- Use of pressure-treated wood products (including field treatment of notches, holes, and cut ends).
- Use of naturally decay-resistant and termite-resistant wood species.
- Chemical soil treatment.
- Installation of physical barriers to termites (e.g., metal or plastic termite shields).

WILDFIRE

Wildfires occur virtually everywhere in the United States and can threaten buildings constructed in coastal areas. The three principal factors that impact wildfire hazards include:

- Topography.
- Availability of vegetative fuel.
- Weather.

NOTE

Reducing the wildfire hazard and the vulnerability of structures to wildfire hazards are discussed in *Wildfire Mitigation in the 1998 Florida Wildfires*, Wildfire Report FEMA-1223-DR-FL (FEMA 1998).

One of the most effective ways of preventing loss of buildings to wildfire is to replace highly flammable vegetation around the buildings with minimally flammable vegetation.

Clearing of vegetation around some buildings may be appropriate, but this action can lead to slope instability and landslide failures on steeply sloping land. Siting and construction on steep slopes requires careful **consideration of multiple hazards** with sometimes conflicting requirements.

FLOATING ICE

Some coastal areas of the United States are vulnerable to problems caused by floating ice. These problems can take the form of:

- Erosion and gouging of coastal shorelines.
- Flooding resulting from ice jams.
- Lateral and vertical ice loads on shore protection structures and coastal buildings.

On the other hand, the presence of floating ice along some shorelines will reduce erosion from winter storms and wave effects. Designers should investigate potential adverse and beneficial effects of floating ice in the vicinity of their building site.

SNOW

The principal hazard associated with snow is its accumulation on roofs and the subsequent deflection and potential failure of roof trusses and supports. Calculation of snow loads is more complicated than rain loads because snow can drift and be distributed non-uniformly across a roof. Drainage of trapped and melted snow, like the drainage of rain water, must be addressed by the designer.

ATMOSPHERIC ICE

Ice can sometimes form on structures as a result of certain atmospheric conditions or processes (e.g., freezing rain or drizzle or in-cloud icing—accumulation of ice as supercooled clouds or fog come into contact with a structure). The formation and accretion of this ice is termed atmospheric.

Typical coastal residential buildings are not considered ice-sensitive structures and are not subject to structural failures resulting from atmospheric ice. However, they may be affected by the failure of ice-sensitive structures, such as utility towers and utility lines.

SELF-CHECK REVIEW: OTHER HAZARDS

Instructions: Answer the following question. Then turn the page to check your answer. If you answered incorrectly, you should review the related material before continuing.

1. Identify three hazards (other than coastal flooding, high winds, erosion, and earthquakes) and describe their main effects on coastal residential structures.

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Your answer may be slightly different, but it should include the same main points.

1. Identify three hazards (other than coastal flooding, high winds, erosion, and earthquakes) and describe their main effects on coastal residential structures.

Any of the following:

- **Subsidence/differential uplift: Increased flood hazards from increased flood depth.**
- **Landslides/ground failures: Loss of supporting soil.**
- **Salt spray/moisture: Corrosion and decay of building materials.**
- **Rain: Penetration of building envelope; vertical loads on roof, which cause deflection of roof supports.**
- **Hail: Damage to roofing materials; vertical loads on roof, which cause deflection of roof supports.**
- **Wood decay/termites: Failure of building components.**
- **Wildfire: Destruction of building.**
- **Floating ice: Erosion, flooding, damage to shore protection structures.**
- **Snow: Vertical loads on roof, which cause deflection of roof supports.**
- **Atmospheric ice: Failure of ice-sensitive utilities.**

COASTAL HAZARD ZONES

FACTORS TO CONSIDER

Assessing risk to coastal buildings and building sites requires the identification or delineation of hazardous areas. This, in turn, requires that the following factors be considered:

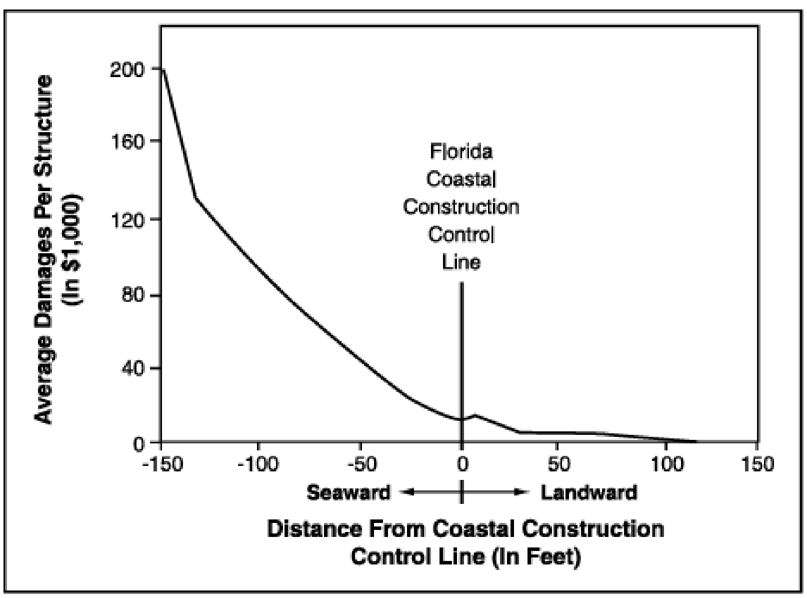
- Types of hazards known to affect the region.
- Geographic variations in hazard occurrence and severity.
- Methods and assumptions underlying any existing hazard identification maps or products.
- Concept of "acceptable level" of risk.
- Consequences of using (or not using) certain siting, design, and construction practices.

Geographic Variations

Geographic variations in coastal hazards occur, both along the coastline and relative (perpendicular) to the coastline. Hazards affecting one region of the country may not affect another. Hazards affecting construction close to the shoreline will, usually, have a lesser effect (or no effect) farther inland.

For example, Figure 7-22 shows how building damage caused by Hurricane Eloise in 1975 was greatest at the shoreline but diminished rapidly in the inland direction. This damage pattern is typical of storm damage patterns in most coastal areas.

Figure 7-22. Average damage per structure vs. distance from the Florida Coastal Construction Control Line. Hurricane Eloise, Bay County, Florida (damage in thousands of 1975 dollars).



Acceptable Level of Risk

FEMA provides reasonably detailed coastal flood hazard information via its FIS reports and FIRMs. However, these products do not consider a number of other hazards affecting coastal areas. Other Federal agencies and some States and communities have completed additional coastal hazard studies and delineations.

When reviewing hazard maps and delineations, designers should be aware of the fact that coastal hazards are often mapped at different levels of risk. Thus, the concept of **consistent and acceptable level of risk** (i.e., the level of risk judged appropriate for a particular structure) should be considered early in the planning and design process.

NFIP HAZARD ZONES

Understanding the methods and assumptions underlying NFIP FISs and FIRMs is beneficial—especially when the effective FIRM for a site is over a few years old and updated flood hazard determination is desired.

FEMA relies on four basic items in determining flood hazards at a given site:

- Flood conditions (stillwater level and wave conditions) during the base flood event.
- Shoreline type.
- Topographic and bathymetric information.
- Computer models to calculate flood hazard zones and BFEs.

NOTE

Current guidelines and standards for coastal flood hazard zone mapping along the Atlantic and Gulf of Mexico coasts are described in *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping* (FEMA 1995). At the time the *Coastal Construction Manual* went to print, draft guidelines and standards for V zone mapping along the Great Lakes coast had been developed, and guidelines and standards for V zone mapping along the Pacific coast were under development.

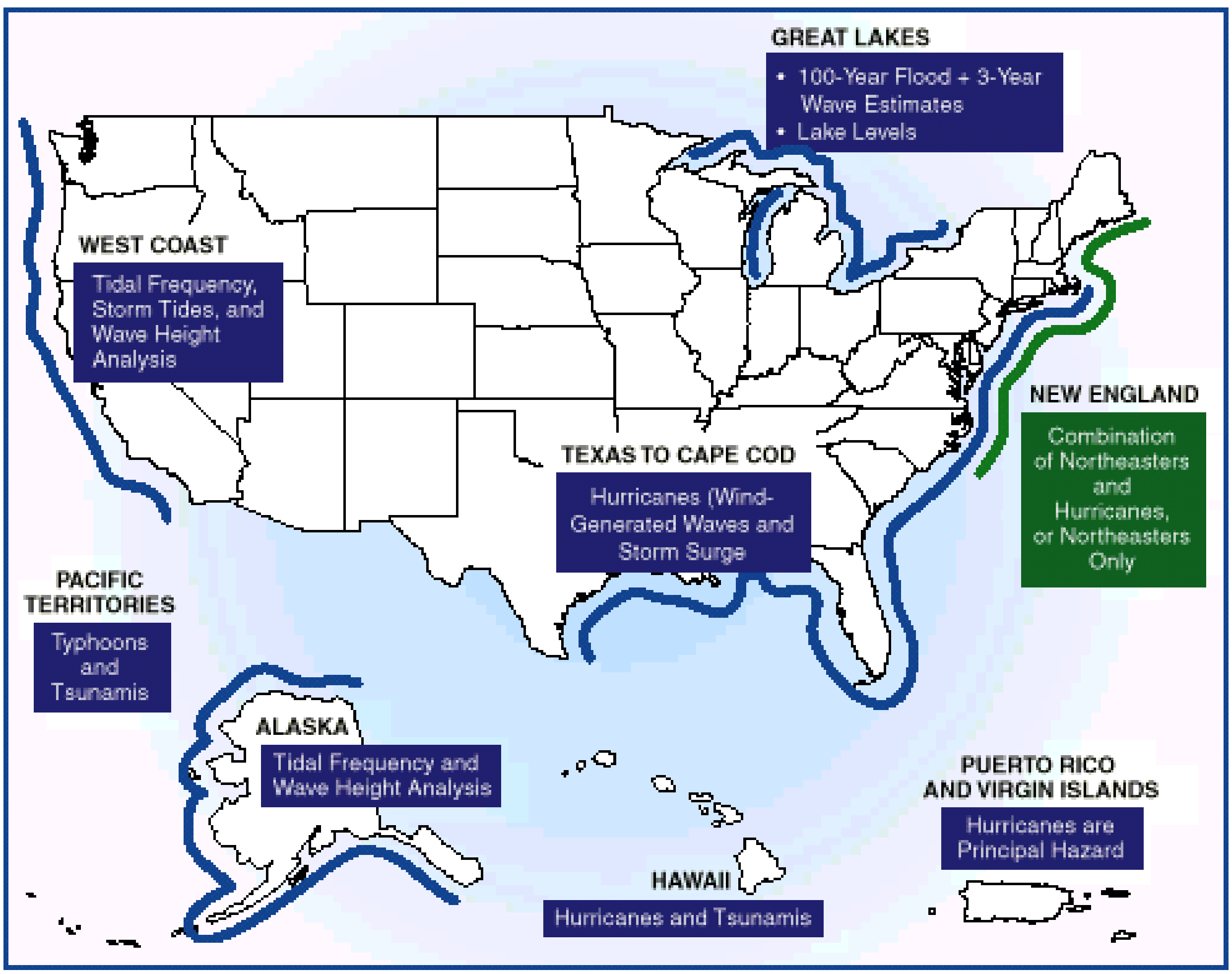
Flooding Sources Considered by the NFIP

FEMA currently considers five principal sources of coastal flooding to establish BFEs in coastal areas:

- Tropical cyclones such as hurricanes and typhoons.
- Extratropical cyclones such as northeasters.
- Tsunamis.
- Tidal frequency analysis.
- Lake levels (Great Lakes).

Figure 7-23 shows the flood sources used by FEMA to determine flood elevations along specific areas of the Nation's coastline.

Figure 7–23. BFE Determination Criteria for Coastal Hazard Areas in the United States



NOTE

Information presented here regarding the applicability and use of FEMA models is provided as background. Seek the assistance of qualified coastal engineers if a detailed or updated flood hazard analysis is needed at a site.

Models and Procedures Used by the NFIP

In addition to storm surge models (or other means of determining stillwater elevations), FEMA currently uses three distinct flood hazard delineation techniques in its FISs, depending on local conditions and expected flood effects:

- An erosion assessment procedure. (This procedure accounts for storm-induced erosion but does not take long-term erosion into account.)
- A wave runup model.
- A wave height transformation model (WHAFIS).

Table 7.2 shows which techniques are applied by FEMA to different shoreline types.

Table 7.2. FIS Model/Procedure Selection by Shoreline Type (Atlantic and Gulf of Mexico Coasts)

	Model/Procedure to Be Applied		
Type of Shoreline	**Erosion***	**Runup***	**WHAFIS***
Rocky bluffs		x	x
Sandy bluffs, little beach	x	x	x
Sandy beach, small dunes	x		x
Sandy beach, large dunes	x	x	x
Open wetlands			x
Protected by rigid structure		x	x

*Variations of these models and procedures may be used for Great Lakes, New England, and Pacific Coasts.

In applying these techniques, FEMA follows the procedure summarized below and illustrated in Figure 7-24.

1. Draw analysis transect(s) perpendicular to the shoreline at the site or region of interest.

2. Determine the type of shoreline (e.g., rocky bluff, sandy beach, rigid structure) at each transect.

3. Along each transect, determine profile bathymetry (ground elevations below the waterline) and topography (ground elevations above the waterline).

4. Determine the flood stillwater elevation and incident wave conditions during the base flood event.

5. If a shore protection structure is present on a transect, determine whether it has the structural capacity to survive the base flood event, and whether its crest elevation lies above the flood level.

   - If not, neglect the structure in further analyses.
   - If so, apply the Runup and WHAFIS models.

6. If no shore protection structure exists on the transect, or if the structure fails the tests described in step 5, determine whether the shoreline type is erodible.

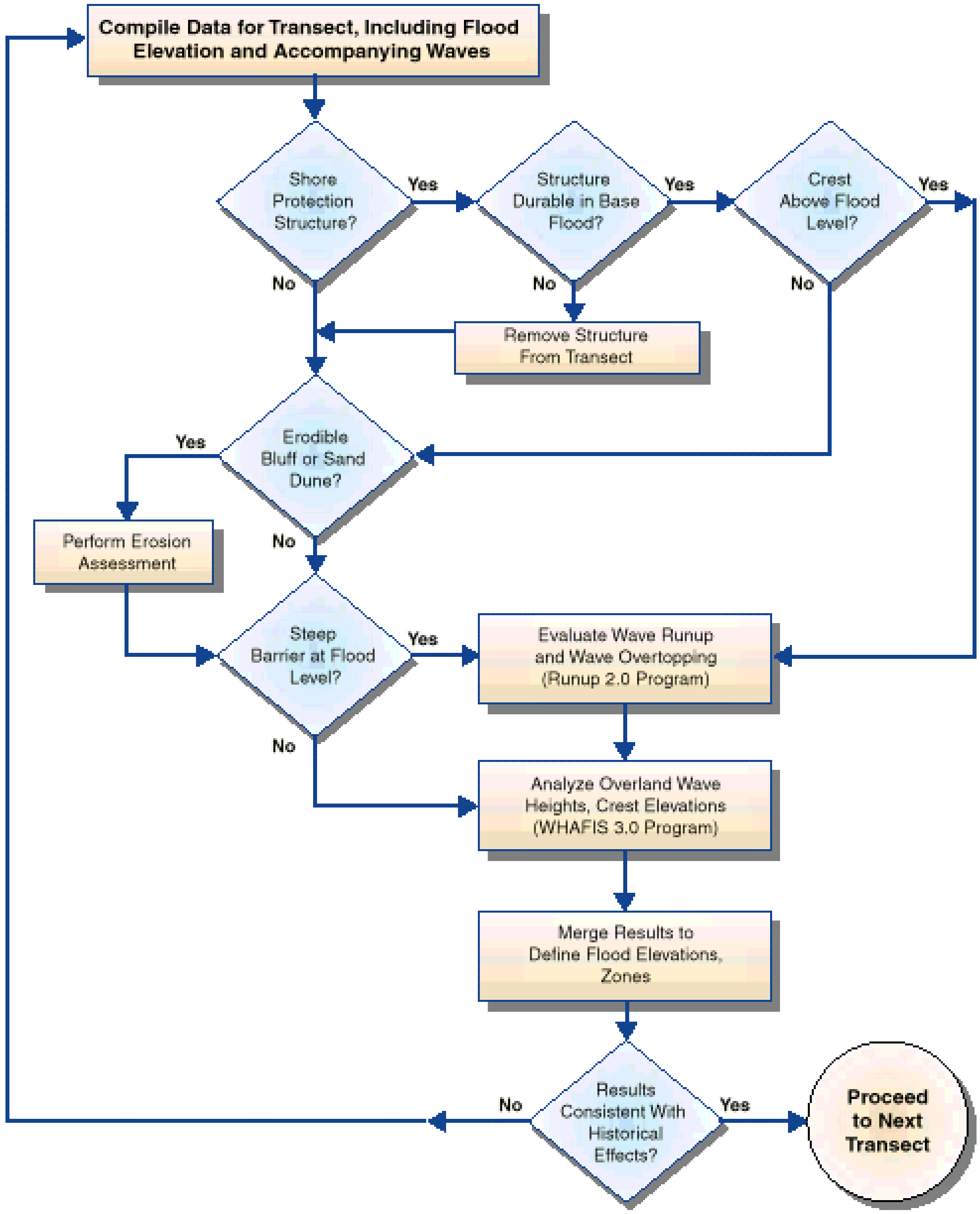
   - If not erodible, apply the Runup and WHAFIS models.
   - If erodible, apply the erosion assessment procedure, then apply the Runup and WHAFIS models on the eroded profile.

7. Determine BFEs along the transect(s) using the higher of the flood elevations calculated by the Runup and WHAFIS models. Merge the results between transects to define flood hazard zones over the area of interest.

NOTE

The storm erosion calculation procedures recommended in the *Coastal Construction Manual* differ from FEMA's current procedures in two important ways: by (1) increasing the dune reservoir volume required to prevent dune removal and (2) accounting for future shoreline erosion.

Figure 7-24. Procedural flowchart for defining coastal flood hazards



Evolution of FEMA's Flood Hazard Mapping Procedures

FEMA's flood hazard mapping procedures have evolved over the years. Thus, a FIRM produced today might differ from an earlier FIRM—not only because of physical changes at the site, but also because of changes in FEMA hazard zone definitions, revised models, and updated storm data.

WARNING

Many FIRMs (especially those produced before approximately 1989) may understate present-day flood hazards. **Before a FIRM is used for siting and design purposes, review the accompanying FIS report to determine whether the study procedures used to produce the FIRM are consistent with the latest study procedures.**

Major milestones in the evolution of FEMA flood hazard mapping procedures—which can render early FIRMs obsolete—are listed on the next page.

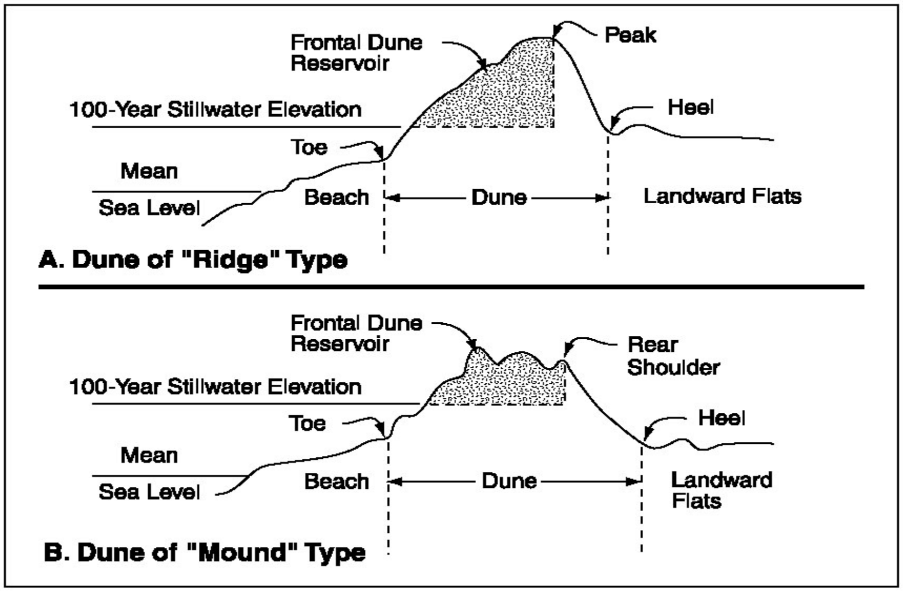
MILESTONES IN FEMA FLOOD HAZARD MAPPING PROCEDURES

Approximate Date	Milestone
Revised Coastal Water Level and Storm Data	
1979	A FEMA **storm surge model** replaced NOAA tide frequency data as the source of storm tide stillwater elevations for the Atlantic and Gulf of Mexico coasts.
1988	**Coastal tide frequency data** from the New England District of the USACE replaced earlier estimates of storm tide elevations for New England.
1988	**Return periods** for Great Lakes water levels from the Detroit District of the USACE replaced earlier estimates of lake level return periods.
1995 (FL); varies locally	**Localized changes** in flood elevations have been made. For example, following Hurricane Opal (1995), a revised analysis of historical storm tide data in the Florida panhandle raised 100-year stillwater flood elevations and BFEs several feet.
Changes in the BFE Definition	
Early 1980s	Prior to Hurricane Frederic in 1979, **BFEs** in coastal areas were set at the storm surge stillwater elevation, not at the wave crest elevation. Since that time, FIRMs have been produced with V zones, using the WHAFIS model and the 3-foot wave height as the landward limit of V zones.
Changes in Coastal Flood Hazard Zone Mapping Procedures	
1980, 1995	Since about 1980, **tsunami hazard zones** on the Pacific coast have been mapped using procedures developed by the USACE. These procedures were revised around 1995 for areas subject to both tsunami and hurricane effects.
May 1988	Before this time, flood hazard mapping for the Atlantic and Gulf of Mexico coasts resulted in V-zone boundaries being drawn near the crest of the primary frontal dune, based solely on ground elevations and without regard for erosion that would occur during the base flood event. 1988 changes in mapping procedures have accounted for **storm-induced dune erosion** and have shifted many V-zone boundaries to the landward limit of the primary frontal dune.
1989	FIRMs used a revised **WHAFIS model**, a **runup model**, and **wave setup considerations** to map flood hazard zones.
1989	**Great Lakes wave runup** methodology came into use.
1989	A standardized procedure for evaluating **coastal flood protection structures** is used.

FRONTAL DUNE RESERVOIR

FEMA's dune erosion assessment procedure is largely based on studies that found that the volume of sediment contained in the dune or bluff above the 100-year storm tide stillwater level (SWL) is a key parameter in predicting the degree of storm-induced erosion. In the case of dunes, this volume of sediment is termed the ***frontal dune reservoir*** (see Fig. 7-25).

Figure 7-25. Definition sketch for frontal dune reservoir



NOTE

For beach/dune areas, the *Coastal Construction Manual* considers **frontal dune reservoir volume** the single most important parameter used to estimate post-storm eroded profile shapes and elevations.

Some studies have found the median dune erosion volume above the 100-year SWL to be 540 ft^2 per linear foot of dune, with significant variability about the median value. Other studies have found wide variability in dune erosion volumes from one location to another, with maximum erosion volume ranging from 1.5 to 6.6 times the median volume.

FEMA's 540 ft² Rule

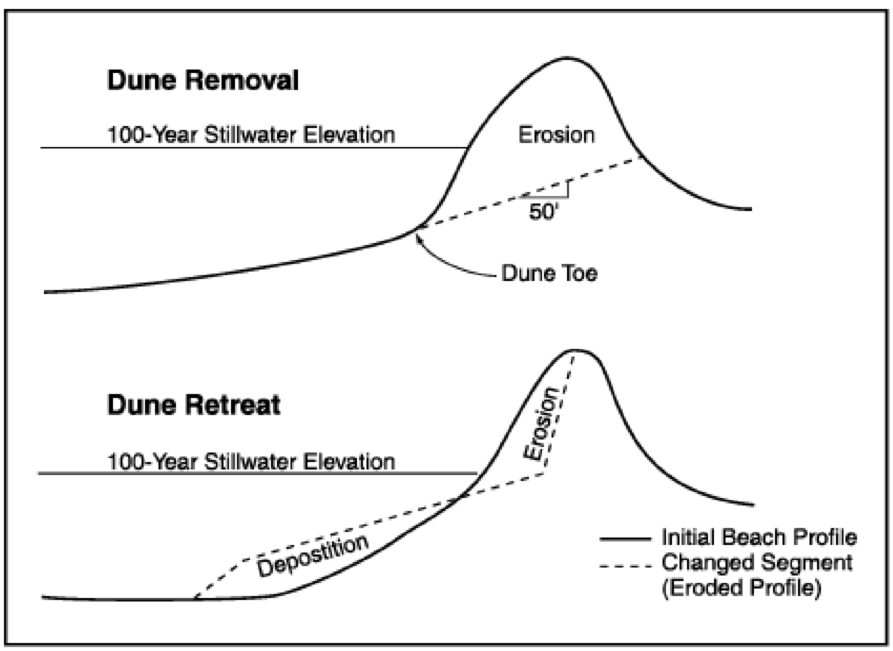
FEMA's current V-zone mapping procedures require that a dune have a minimum frontal dune reservoir of 540 ft^2 (i.e., median erosion volume) to be considered substantial enough to withstand erosion during a base flood event. According to this view:

- A frontal dune reservoir less than 540 ft^2 will result in dune removal (dune disintegration).
- A frontal dune reservoir greater than or equal to 540 ft^2 will result in dune retreat (see Fig. 7-26).

Note that FEMA also considers the **dune origin and condition** in its assessment. If the dune being evaluated was artificially constructed and does not have a well-established and long-standing vegetative cover, dune removal will be assumed even in cases where the frontal dune reservoir exceeds 540 ft^2.

FEMA's current procedure for calculating the post-storm profile in the case of dune removal is relatively simple: a straight line is drawn from the pre-storm dune toe landward at an upward slope of 1 on 50 (vertical to horizontal) until it intersects the pre-storm topography landward of the dune (Fig. 7-26). Any sediment above the line is assumed to be eroded.

Figure 7-26.
Current FEMA treatment of dune retreat and dune removal



1,100 ft^2 Recommendation

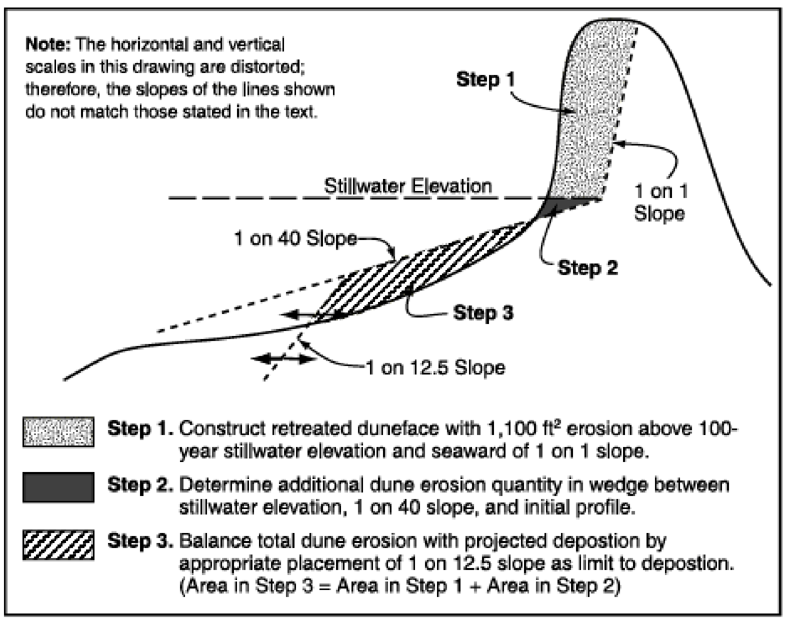
The *Coastal Construction Manual* recommends that the size of the frontal dune reservoir used by designers to prevent dune removal during a 100-year storm be increased to 1,100 ft^2 (see Fig. 7-27). This recommendation is made for three reasons:

- FEMA's 540 ft^2 rule reflects dune size at the time of mapping and does not account for **future conditions**, when beaches and dunes may be compromised by long-term erosion.

- FEMA's 540 ft^2 rule does not account for the **cumulative effects of multiple storms** that may occur within short periods of time—such as occurred in 1996, when Hurricanes Bertha and Fran struck the North Carolina coast within 2 months of each other.

- Even without long-term erosion and multiple storms, use of the median frontal dune reservoir will **underestimate** dune erosion 50 percent of the time.

Figure 7-27. Procedure for calculating dune retreat profile. Recommended in the *Coastal Construction Manual.*



Present-day beach and dune topography alone should not be used to determine whether dune retreat or dune removal will occur at a site. **The most landward shoreline and beach/dune profile expected over the lifetime of a building or development should be calculated and used as the basis for dune retreat/dune removal determinations.** The most landward shoreline should be based on long-term erosion and observed shoreline fluctuations at the site.

Dune erosion calculations at a site should also take **dune condition** into account. A dune that is not covered by well-established vegetation will be more vulnerable to wind and flood damage than one with well-established vegetation. A dune crossed by a road or pedestrian path will offer a weak point that storm waves and flooding will exploit. Post-storm damage inspections frequently show that dunes are breached at these weak points and that structures landward of them are more vulnerable to erosion and flood damage.

SELF-CHECK REVIEW: COASTAL HAZARD ZONES

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. FEMA's flood hazard mapping procedures have remained essentially unchanged since the early 1970s.

   True False

2. According to the *Coastal Construction Manual*, a dune must have a frontal dune reservoir of ________________ to be considered substantial enough to withstand erosion during a base flood event.

   a. 540 ft^2
   b. 1,100 ft^2

3. Dune condition:

   a. Should have no bearing on dune erosion calculations.
   b. Is the most important predictor of dune erosion.
   c. Should be considered in dune erosion calculations.

4. Frontal dune reservoir is:

   a. The volume of water trapped behind a dune.
   b. The volume of sediment in a dune above the SWL.
   c. The volume of sediment held in reserve behind a dune.
   d. The volume of water in front of a dune.

ANSWER KEY

1. FEMA's flood hazard mapping procedures have remained essentially unchanged since the early 1970s.

   False

2. According to the *Coastal Construction Manual*, a dune must have a frontal dune reservoir of ________________ to be considered substantial enough to withstand erosion during a base flood event.

   b. 1,100 ft^2

3. Dune condition:

   c. Should be considered in dune erosion calculations.

4. Frontal dune reservoir is:

   b. The volume of sediment in a dune above the SWL.

TRANSLATING HAZARD INFORMATION INTO PRACTICE

In this unit and the previous one, you have reviewed a wide array of hazard information. How do you translate this information into practice when assessing hazards at a site?

- At a minimum, collect the most up-to-date published hazard data and use it to assess the vulnerability of the site, following the steps outlined in Unit IV (see "*Evaluating Hazards and Potential Vulnerability,*" page IV-22).

- Where there is reason to believe that physical site conditions have changed significantly over time, or that published hazard data are obsolete or not representative of a site, conduct an updated or more detailed hazard assessment.

- Where there is reason to believe that physical site conditions *will* change significantly over the expected life of a structure or development at the site, conduct a revised hazard assessment.

- After completing a suitable hazard assessment, review siting and design options available to address and mitigate those hazards.

The remainder of this unit focuses on procedures for completing and applying updated or more detailed flood hazard assessments (which may include erosion hazards).

EVALUATING THE EXISTING INFORMATION

Evaluating the existing information to determine if updated or revised hazard assessments are needed involves asking two questions:

- Does the FIRM accurately depict present flood hazards?

- Will expected shoreline erosion render the flood hazard zones shown on the FIRM obsolete during the projected life of the building or development at the site?

Does the FIRM Accurately Depict Present Flood Hazards?

NOTE

The date of the newest FIRM for a community can be determined on FEMA's website under the heading "Community Status Book," at http://www.FEMA.gov/FEMA/CSB.htm

This question can be answered with a brief review of the FIRM, the accompanying FIS report, and site conditions. To undertake this review, complete the following steps:

1. **Check dates.** Obtain copies of the latest FIRM and FIS report for the site. If the effective date precedes the milestones listed on page VII-59, an updated flood hazard assessment may be required.

2. **Check revisions and study methods.** Review the legend on the FIRM to determine the history of the panel (and revisions to it), and review the study methods described in the FIS. If the revisions and study methods are not consistent with current methods, an updated flood hazard assessment may be required.

3. **Check dune erosion calculation.** If the FIS calculated dune erosion using the 540 ft^2 rule and placed the V-zone boundary on top of the dune, check the dune cross-section to see if it has a frontal dune reservoir of at least 1,100 ft^2 above the 100-year SWL. If not, consider shifting the V-zone boundary to the landward limit of the dune and revising other flood hazard zones as needed.

WARNING

Some sites lie outside flood hazard areas shown on FIRMs but may be subject to current or future flood and erosion hazards. These sites, like those within mapped flood hazard areas, should be evaluated carefully.

4. **Check flood event history.** Review the description in the FIS report of the storm, water level, and flood source data used in the FIS to generate the 100-year stillwater elevation and BFEs. If significant storms or flood events have affected the area since the FIS report and FIRM were completed, the source data may need to be revised and an updated flood hazard assessment may be required.

5. **Check for physical changes.** Determine whether there have been significant physical changes to the site since the FIS and FIRM were completed (e.g., erosion of dunes, bluffs, or other features; modifications to drainage, groundwater, or vegetation on coastal bluffs; construction or removal of shore protection structures; filling or excavation of the site). If so, an updated and more detailed flood hazard assessment may be required.

6. **Check adjacent properties.** Determine whether there has been significant alteration of adjacent properties since the FIS and FIRM were completed (e.g., development, construction, excavation, etc., that could affect, concentrate, or redirected flood hazards on the site). If so, an updated and more detailed flood hazard assessment may be required.

Will Long-Term Erosion Render a FIRM Obsolete?

The answer to this question depends on whether or not the site is experiencing long-term shoreline erosion. If the shoreline at the site is stable and does not experience long-term erosion, then the FIRM will not require revision for erosion considerations.

However, FIRMs are currently produced without regard to long-term erosion. Therefore, if a shoreline fluctuates or experiences long-term erosion, the FIRM will cease to provide the best available data at some point in the future (if it has not already), and a revised flood hazard assessment will be required.

The following steps should be completed to determine whether a FIRM is likely to become obsolete as a result of long-term erosion considerations, and whether a revised flood hazard assessment is required.

1. **Check for erosion rate information or construction setback lines.** Check with local or State coastal zone management agencies for any information on long-term erosion rates or construction setback lines.

   If such rates have been calculated, or if construction setback lines have been established from historical shoreline changes, long-term erosion considerations may require a revised flood hazard assessment.

2. **Check the current shoreline against the FIRM.** If no long-term erosion rates have been published, and no construction setback lines have been established based on historical shoreline movements, determine whether the current shoreline has remained in the same approximate location as that shown on the FIRM (e.g., has there been any significant shoreline erosion, accretion, or fluctuation?).

   If there has been significant change in the shoreline location or orientation since the FIS and FIRM were completed, the local floodplain administrator should require a revised flood hazard assessment.

UPDATED OR REVISED FLOOD HAZARD ASSESSMENTS

Updating or revising an existing flood hazard assessment—for siting and design purposes—can be fairly simple or highly complex, depending on the particular situation.

- A simple change might involve shifting an A zone or X zone boundary, based on topographic data better than those used to generate the FIRM.
- A complex change might involve a detailed erosion assessment and significant changes to mapped flood hazard zones.

Parameters

The analyses should be directed at defining three important parameters:

- Most landward shoreline location expected during the life of a building or development.
- Lowest expected ground elevation at the base of a building during its life.

Highest expected BFE at the building during its life, and associated flood forces.

Recalculation of Flood Depths and Wave Conditions

If an assessment requires recalculation of local flood depths and wave conditions on a site, the FEMA models (Erosion, Runup, WHAFIS) can be run at the site (bearing in mind the recommended 1,100 ft^2 rule). FEMA has also issued its Coastal Hazard Modeling Program (CHAMP) to facilitate the use of standard FEMA models for flood hazard mapping.

Reassessment of Shoreline Erosion

If an assessment requires careful consideration of shoreline erosion, the checklist, flowchart, and diagram shown in Figures 7-28, 7-29, and 7-30 can serve as a guide. However, a qualified coastal professional should be consulted.

Much of the information and analyses described in the checklist and flowchart will probably have been developed and carried out previously by others and should be available in reports about the area. Check with the community. Cases where information is unavailable and where at least basic analyses have not been completed will be rare.

NOTE

Where a new FIRM exists (i.e., one based on the most recent FEMA study procedures and topographic data), long-term erosion considerations can be approximated by shifting all flood hazard zones landward a distance equal to the long-term annual erosion rate multiplied by the life of the building or development (use 50 years as the minimum life). The shift in the flood hazard zones results from a landward shift of the profile (see Fig. 7-29).

Figure 7-28. Erosion Hazard Checklist

General Information
• Property location and dimensions • Land use at site and adjacent properties • Historical flood and erosion damage descriptions at site and nearby
Coastal Flood Conditions—Observed and Predicted
• Flood elevations from tides, storm surge, tsunami, or seiche • Wave conditions at shoreline (height, period, direction) • Erosion of beach, dune, and/or bluff • Sediment overwash • Breaching or inlet formation
Local Soils and Geology
• Soils, geology, and vegetation—site and region • Site drainage—potential for erosion from surface water or groundwater • Coastal morphology and coastal processes • Wave climate • Presence and influence of nearby inlets, harbors, coastal structures • Littoral sediment supply and sediment budget • Topography of nearshore, beach, dune, bluff, uplands • Relative sea-level changes or lake-level changes—sand subsidence or uplift
Shoreline History
• Shoreline change maps and historical aerial photographs • Published erosion rates—long-term and short-term • Spatial variability in erosion rates • Temporal variability in erosion rates (seasonal, annual, long-term) • Erosion/accretion cycles—magnitude and periodicity • Most landward historical shoreline (most landward shoreline in past 5–70 years) • Errors and uncertainties associated with erosion rates
Harbor/Inlet Navigation Projects; Erosion Control Projects
• Navigation projects (jetties, dredged channels) affecting the site • Shore protection structures, on property or nearby • Dune/bluff stabilization projects, on property or nearby • Beach/dune nourishment projects—completed or planned
Other Erosion/Sediment Considerations
• Erosion by wind • Erosion by ice • Burial by storm overwash or windborne sand • Erosion from channeling of flow between buildings or obstructions • Local scour potential and presence of terminating strata

Figure 7-29. Flowchart for estimating maximum likely flood hazards at a site over the life of a building or development.

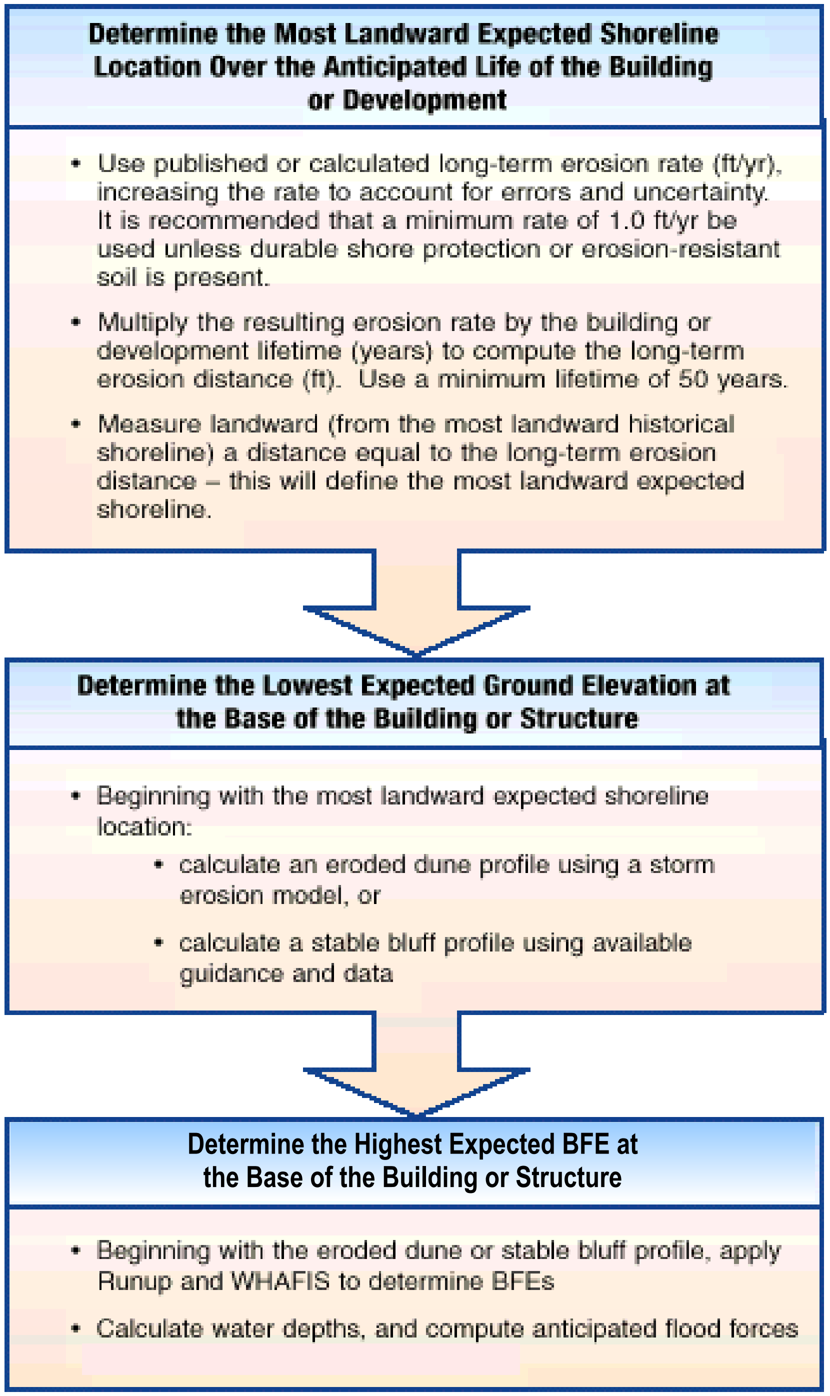
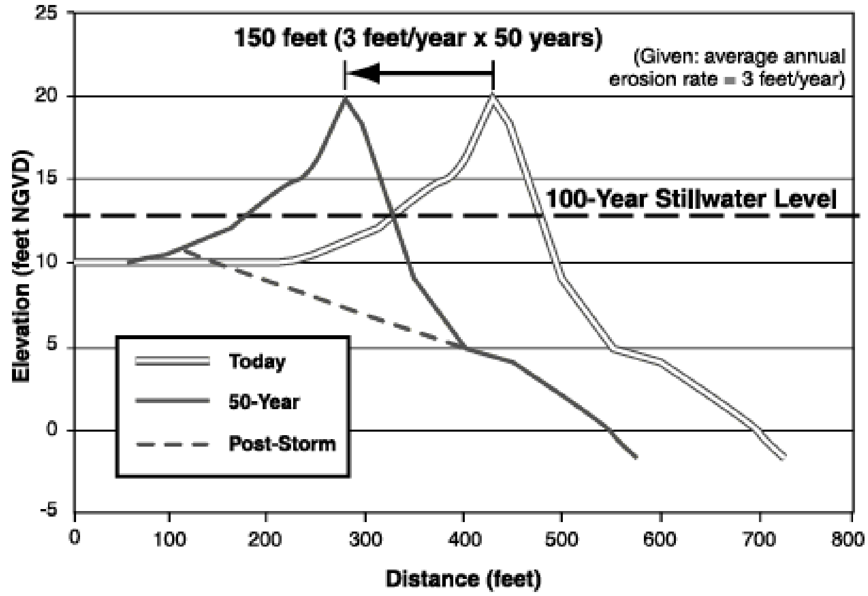


Figure 7-30. Accounting for future shoreline erosion



Shift the present-day profile landward (to account for long-term or inlet erosion), then apply the Primary Frontal Dune erosion assessment to estimate the lowest expected ground elevation at a site. This procedure also results in a landward translation of flood hazard zones.

Results

The final result should be a determination of the greatest flood hazards, resulting from a 100-year coastal flood event, that the site will be exposed to over the anticipated life of a building or development.

The determination should account for short- and long-term erosion, bluff stability, shoreline fluctuations, and storm-induced erosion. In other words, both chronic and catastrophic flood and erosion hazards should be considered.

SELF-CHECK REVIEW: TRANSLATING HAZARD INFORMATION INTO PRACTICE

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. When reviewing a FIRM, what factors might indicate the need for a revised or updated flood hazard assessment?

2. Identify three possible indicators that long-term erosion may render a FIRM obsolete:

   (1) ____

   (2) ____

   (3) ____

3. Fill in the blanks using words listed on the right.

   Updated or revised flood hazard assessments should be directed at defining:

   - The __________________ shoreline expected during the life of the building.
   - The __________________ expected ground elevation.
   - The __________________ expected BFE at the building during its life and the associated flood forces.

   a. Lowest
   b. Highest
   c. Most landward
   d. Most seaward

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Your answers may be slightly different, but they should include the same main points.

1. When reviewing a FIRM, what factors might indicate the need for a revised or updated flood hazard assessment?

   Any of the following:
   - **The FIRM predates changes in FEMA's mapping procedures.**
   - **The FIRM and FIS methods are not consistent with current methods.**
   - **Dune erosion was calculated using the 540 ft^2 rule.**
   - **Major storms or flood events have occurred since the FIRM was completed.**
   - **Significant physical changes to the site have occurred since the FIRM was completed.**
   - **Significant alteration of adjacent property has occurred since the FIRM was completed.**

2. Identify three possible indicators that long-term erosion may render a FIRM obsolete:

   (1) **Long-term erosion rates have been established.**

   (2) **Construction setback lines have been established.**

   (3) **Significant changes in the shoreline location or orientation have occurred.**

3. Updated or revised flood hazard assessments should be directed at defining:

   - The **most landward** shoreline expected during the life of the building.
   - The **lowest** expected ground elevation.
   - The **highest** expected BFE at the building during its life and the associated flood forces.

UNIT VII EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit VII. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit VIII.

1. List three ways that erosion threatens coastal residential buildings.

2. Identify three causes of erosion.

3. Short-term erosion rates tend to be the same as long-term erosion rates.

   True False

4. Seasonal fluctuations in beach width and elevation are a good indicator of long-term shoreline changes.

   True False

5. Because storms are short-lived, the amount of erosion induced by storms tends to be minor.

   True False

6. During coastal storms in dune-protected areas, areas experiencing ___________________________ will form an effective barrier to storm effects.

   a. Dune or bluff retreat
   b. Wave overtopping and overwash
   c. Dune disintegration
   d. Dune flooding or submergence

7. Seawalls, bulkheads, and revetments prevent erosion of the beach.

   True False

8. FIRMs __do / do not__ incorporate long-term erosion. (Circle one.)

9. One of the ways that earthquakes damage coastal structures is through structural failure by excessive deflection.

   True False

10. In an earthquake, a building elevated on pilings may be subject to an "inverted pendulum" effect. This condition requires that the building be designed:

    a. For a smaller earthquake force.
    b. For a larger earthquake force.
    c. To withstand earthquakes instead of flooding.
    d. On a solid foundation.

11. Match the "other hazards" on the left with effects on the right.

___ Subsidence	a. Corrosion
___ Salt spray and moisture	b. Loss of supporting soil
___ Rain	c. Damage to roofing materials
___ Hail	d. Increased flood depth
___ Landslides	e. Penetration of building envelope

12. Before basing siting decisions on FIS and FIRM information, it is important to consider the methods that were used in conducting the study.

    True False

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT VII EXERCISE—ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. List three ways that erosion threatens coastal residential buildings.

   Any of the following:
   - **Destroying dunes or other natural protective features.**
   - **Destroying erosion control devices.**
   - **Lowering ground elevations, undermining shallow foundations, and reducing penetration of deep foundations.**
   - **Supplying overwash sediments that can bury structures farther landward.**
   - **Breaching low-lying coastal barrier islands.**
   - **Washing away low-lying coastal landforms.**
   - **Eroding coastal bluffs.**

2. Identify three causes of erosion.

   Any of the following:
   - **Storms and coastal flood events.**
   - **Natural changes associated with tidal inlets, river outlets, and entrances to bays.**
   - **Manmade structures and human activities.**
   - **Long-term erosion.**
   - **Localized scour.**

3. Short-term erosion rates tend to be the same as long-term erosion rates.

   False

4. Seasonal fluctuations in beach width and elevation are a good indicator of long-term shoreline changes.

   False

5. Because storms are short-lived, the amount of erosion induced by storms tends to be minor.

   False

6. During coastal storms in dune-protected areas, areas experiencing ___________________________ will form an effective barrier to storm effects.

   a. Dune or bluff retreat

7. Seawalls, bulkheads, and revetments prevent erosion of the beach.

   False

8. FIRMs **do not** incorporate long-term erosion.

9. One of the ways that earthquakes damage coastal structures is through structural failure by excessive deflection.

   True

10. In an earthquake, a building elevated on pilings may be subject to an "inverted pendulum" effect. This condition requires that the building be designed:

    b. For a larger earthquake force.

11. Match the "other hazards" on the left with effects on the right.

d	Subsidence	a. Corrosion
a	Salt spray and moisture	b. Loss of supporting soil
e	Rain	c. Damage to roofing materials
c	Hail	d. Increased flood depth
b	Landslides	e. Penetration of building envelope

12. Before basing siting decisions on FIS and FIRM information, it is important to consider the methods that were used in conducting the study.

    True

UNIT VIII: SITING

SITING

INTRODUCTION

Siting residential buildings to minimize their vulnerability to coastal hazards is one of the most important aspects of the development (or redevelopment) process.

Unfortunately, prudent siting has often been overlooked or ignored in the past as properties have been developed close to the shoreline, near bluff edges, and atop steep coastal ridges. There are literally hundreds, if not thousands, of examples where residential buildings have been constructed with little regard for coastal hazards, only to suffer what could have been preventable damage or loss.

Today, there are few places along our shorelines where we lack sufficient information to make rational, informed siting decisions. Following the lessons and procedures described in this course will help designers, purchasers, developers, and community officials identify those locations where coastal residential development and buildings can be sited so that the risks associated with coastal hazards are minimized.

Ignoring siting and hazard identification issues only increases the likelihood that structures will be damaged, destroyed, or left standing—but inhabitable—by flooding, erosion, landslides, or other coastal hazards.

In Unit IV we discussed the process of identifying and evaluating site alternatives. In this unit we will continue that discussion—especially with regard to siting a building on a given coastal property.

UNIT OBJECTIVES

After completing this unit, you should be able to:

8.1 Identify recommended siting practices for raw land development.
8.2 Identify recommended siting practices for infill development.
8.3 Describe the influence of beach nourishment and dune restoration on siting decisions.

SITING CONSIDERATIONS

A variety of factors must be considered in selecting a specific site and locating a building on that site:

- Regulatory requirements.
- Presence and location of infrastructure.
- Previous development and/or subdivision of property.
- Physical and natural characteristics of the property.
- Vulnerability of the property to coastal hazards.

CONSTRAINTS

A thorough review of these factors will sometimes show that minimum regulatory requirements and/or previous subdivision/infrastructure decisions allow or constrain future development on sites that will be highly vulnerable to the effects of coastal hazards. In other words, **regulatory controls do not necessarily result in prudent siting of coastal buildings** (see Fig. 8-1). Likewise, constraints imposed by previous lot creation and infrastructure construction sometimes drive development to more hazardous locations.

Figure 8-1. Hurricane Opal (1995). Damage to new construction in a mapped A zone. The flood and debris damage could have been avoided had the site been considered a coastal A zone and had the structure been elevated on an open foundation.

TIMING OF SITING DECISIONS

Although these situations should have been discovered when the property was first evaluated for its suitability for purchase, development, or redevelopment, it is common practice for property owners to undertake detailed studies only after property has been acquired. This is especially true in the case of the development of raw land—where planning, engineering, architectural, and site development costs can be substantial.

MINIMIZING RISKS

Designers should recognize situations in which poor siting is allowed or encouraged and should work with property owners to minimize risks to coastal buildings. Depending on the scale of the project, this could involve one or more of strategies listed below.

SITING STRATEGIES FOR MINIMIZING RISK

- Locating development on the least hazardous portion of the site.
- Rejecting the site and finding another.
- Transferring development rights to another parcel better able to accommodate development.
- Combining lots or parcels.
- Reducing the footprint of the proposed building, and shifting the footprint away from the hazard.
- Shifting the location of the building on the site by modifying or eliminating ancillary structures and development.
- Seeking variances to lot line setbacks along the landward and side property lines (in the case of development along a shoreline).
- Moving roads and infrastructure.
- Modifying the building design and site development to facilitate future relocation of the building.
- Altering the site to reduce its vulnerability.
- Constructing protective structures (if allowed by the jurisdiction).

RAW LAND DEVELOPMENT: INFRASTRUCTURE AND LOT LAYOUT

GENERAL GUIDELINES

Large, undeveloped parcels available for coastal development generally fall into two classes:

- **Parcels well-suited to development.** These parcels may be vacant because of the desires of a former owner, lack of access, or lack of demand for their development (see Fig. 8-2).
- **Parcels that are difficult to develop.** These parcels may have:
  - Extensive areas of sensitive or protected resources.
  - Topography or site conditions requiring extensive alteration.
  - Other special site characteristics that make development expensive relative to other nearby parcels (see Fig. 8-3).

Figure 8-2.
Example of coastal development well-suited to the land. Deep lots, generous setbacks, and avoidance of dune areas should afford protection against erosion and flood events for years to come.

Figure 8-3.
Example of parcels that are problematic to develop. Increasingly, coastal residences are being built as part of mixed-use developments, such as this marina/ townhouse development. These projects can involve a new set of environmental and regulatory issues, as well as more difficult geotechnical conditions and increased exposure to flood hazards.

Proper development will be much easier for the former, and much harder for the latter. Nevertheless, development in both instances should satisfy the planning and site development guidelines listed below.

DEVELOPMENT OF RAW LAND IN COASTAL AREAS: SITE PLANNING AND SUBDIVISION GUIDELINES

DO's	DON'Ts
1. **DO …** Determine whether the parcel is suitable for subdivision or should remain a single parcel.	1. **DON'T …** Rely on engineering solutions to correct poor planning decisions.
2. **DO …** Ensure that the proposed land use is consistent with local, regional, and State planning and zoning requirements.	2. **DON'T …** Rely on relocation or restoration efforts to replace resources impacted by poor planning decisions.
3. **DO …** Ensure that all aspects of the proposed development consider and integrate topographic and natural features into the design and layout.	3. **DON'T …** Assume that omissions in planning can be corrected during site development.
4. **DO …** Avoid areas that require extensive grading to ensure stability.	4. **DON'T …** Overlook the effects of infrastructure location on the hazard vulnerability of building sites and lots.
5. **DO …** Study the parcel thoroughly for all possible resource and hazard concerns.	5. **DON'T …** Overlook the effects of modifications to the parcel on surface and groundwater hydrology.
6. **DO …** Identify and avoid, or set back from, all sensitive resources and prominent land features.	6. **DON'T …** Plan development: ▪ On beaches or dunes. ▪ On ridge lines. ▪ On top of prominent topographic features. ▪ On steep slopes. ▪ In or adjacent to streams.
7. **DO …** Consider combining subdivision elements, such as access, utilities, and drainage.	7. **DON'T …** Forget to consider future site and hazard conditions on the parcel.
8. **DO …** Account for all types of erosion (e.g., long-term erosion, storm-induced erosion, erosion from inlets) and governing erosion-control policies when laying out lots and infrastructure near a shoreline.	8. **DON'T …** Assume that engineering and architectural practices can mitigate all hazards.
9. **DO …** Consider existing public access to shoreline and resource areas.	
10. **DO …** Incorporate setbacks from identified high-hazard areas.	
11. **DO …** Use a multi-hazard approach to planning and design.	
12. **DO …** Involve a team of experts with local knowledge, and a variety of technical expertise and backgrounds.	

Planning for the Future. Development of raw land in coastal areas must consider the effects of all hazards known to exist and should not ignore the effects of those hazards on future property owners.

Likewise, development of raw land in coastal areas should consider any local, State, or Federal policies, regulations, or plans that will affect the abilities of future property owners to protect, transfer, or redevelop their properties—such as those dealing with:

- Erosion control.
- Coastal setback lines.
- Post-disaster redevelopment.
- Landslides.
- Geologic hazards.

PRACTICES TO AVOID AND RECOMMENDED ALTERNATIVES

A review of previous coastal development patterns and resulting damages suggests there are several subdivision and lot layout practices to avoid.

Shore-Parallel Road

In the case of an eroding shoreline, placing a road close to the shoreline and creating small lots between the road and the shoreline results in buildings, roadway, and utilities being extremely vulnerable to erosion and storm damage. It can also lead to future conflicts over shore protection and buildings occupying public beaches (see Fig. 8-4).

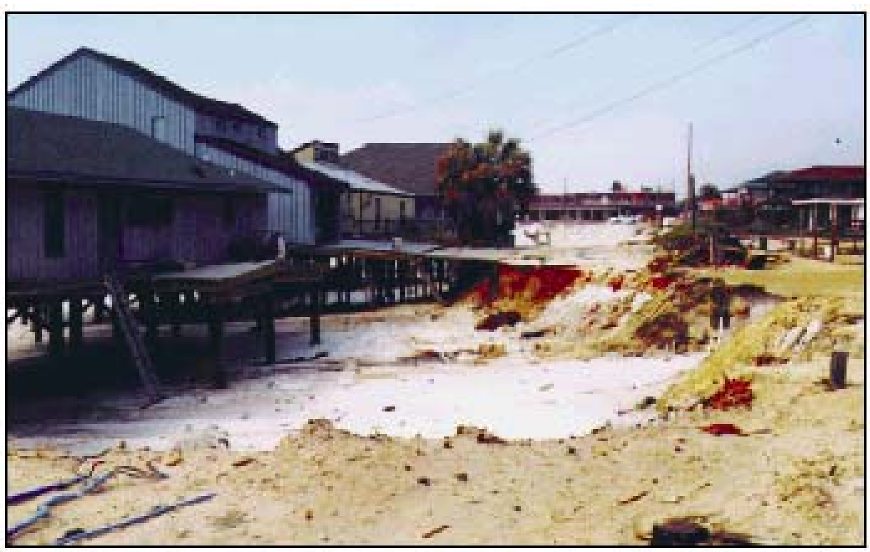
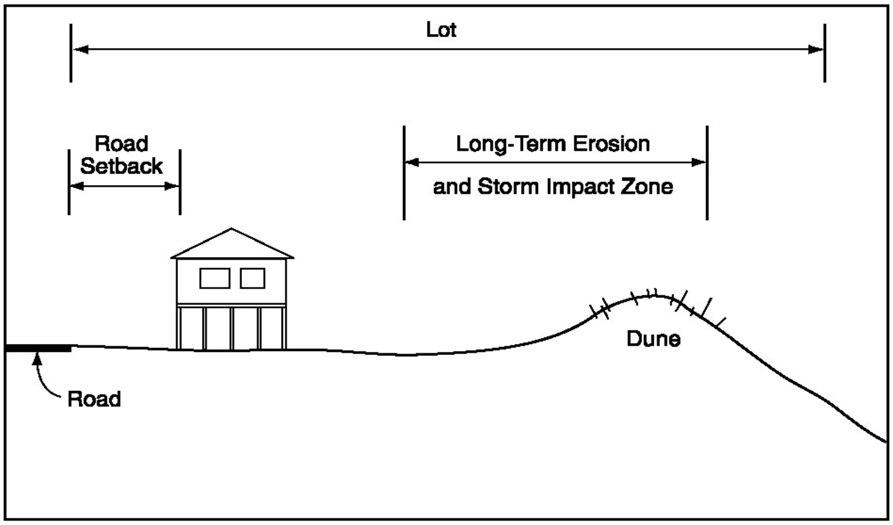


Figure 8-4.
View along a washed-out, shore-parallel road in Bay County, FL, after Hurricane Opal. Homes to the left are standing on the beach and have lost upland access. Some homes to the right have also lost their roadway access.

Recommended Alternative. Figure 8-5 shows a recommended lot layout that provides sufficient space to comply with State and/or local setback requirements and avoid damage to dunes.

Figure 8-5.
Recommended lot layout.

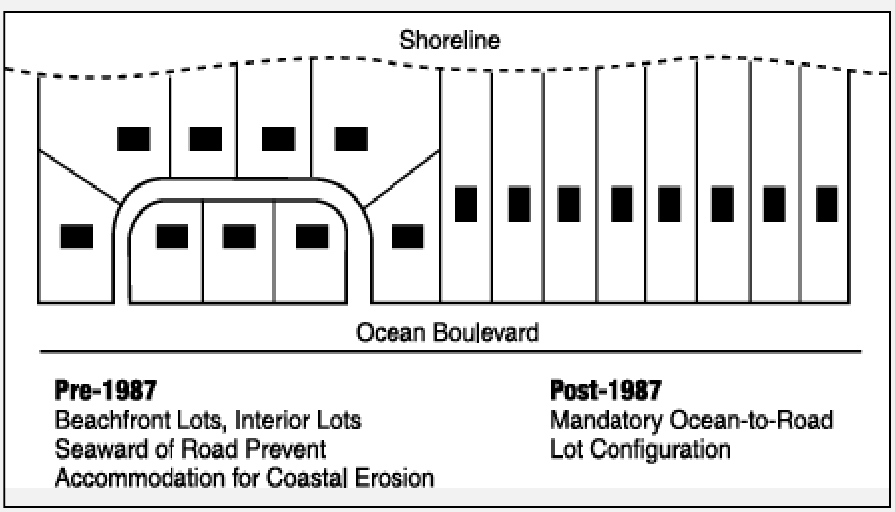


Some communities have land development regulations that help achieve this goal, as shown in the following example.

EXAMPLE

The Town of Nags Head, North Carolina, modified its subdivision regulations in 1987 to require all new lots to extend from the ocean to the major shore-parallel highway. Figure 8-6 compares lots permitted in Nags Head prior to 1987 with those required after 1987. The town also has policies and regulations governing the combination of nonconforming lots.

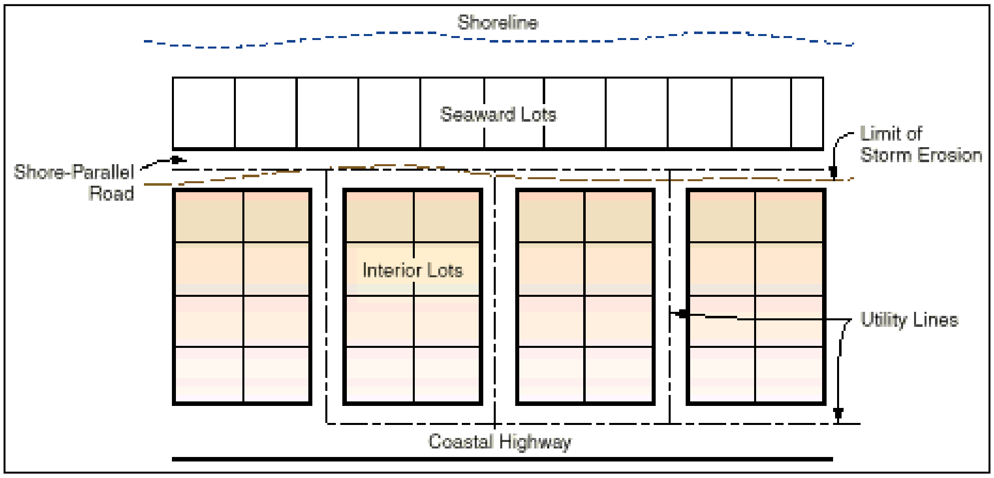
Figure 8-6.
Comparison of Nags Head, NC, oceanfront lot layouts permitted before 1987 and post-1987 oceanfront lot requirements.



Shore-Parallel Utility Lines

A second problem associated with a shore-parallel road close to the shoreline is storm erosion damage to the road and associated utilities (see Fig. 8-7).

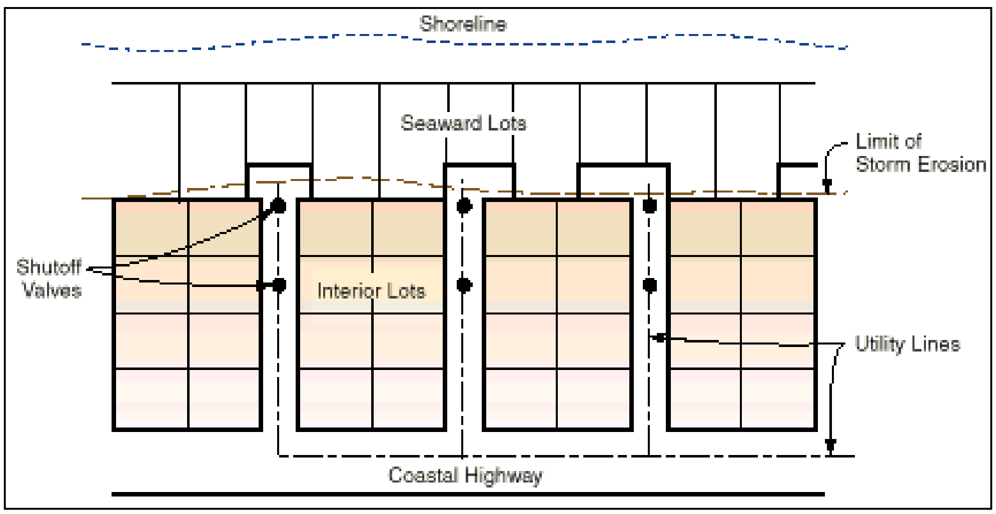
Figure 8-7. Layout not recommended: Shore-parallel roadways and utilities vulnerable to storm effects and erosion.



Some infrastructure damage can be avoided by:

- Reconfiguring the seaward lots (so they all have access from shore-perpendicular roads).
- Eliminating the shore-parallel road.
- Eliminating the shore-parallel utility lines (see Fig. 8-8).

Figure 8-8. Recommended alternative: Lots and infrastructure created without the shore-parallel road; shutoff valves installed on water and sewer lines.



Flag or Key Lots

Another type of lot layout not recommended for vulnerable or eroding coastal shorelines is the "flag" lot or "key" lot illustrated in Figure 8-9. This layout is used to provide more lots with direct access to the shoreline. However, it limits the ability of half of the property owners to respond to coastal flood hazards and erosion by constructing or relocating their buildings farther landward.

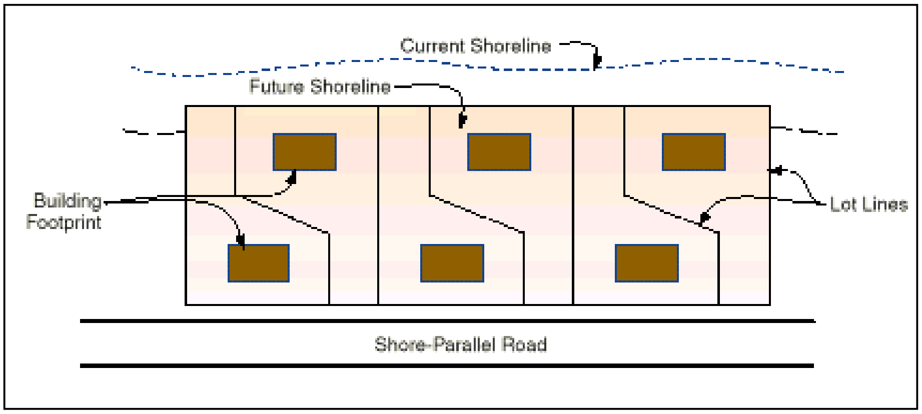


Figure 8-9. Layout not recommended for use along eroding shorelines: Typical layout of "flag" lots or "key" lots.

Again, the recommended alternative is to **locate the shore-parallel road sufficiently landward** to accommodate coastal flooding and future erosion and to create all lots so that their full width extends from the shoreline to the road.

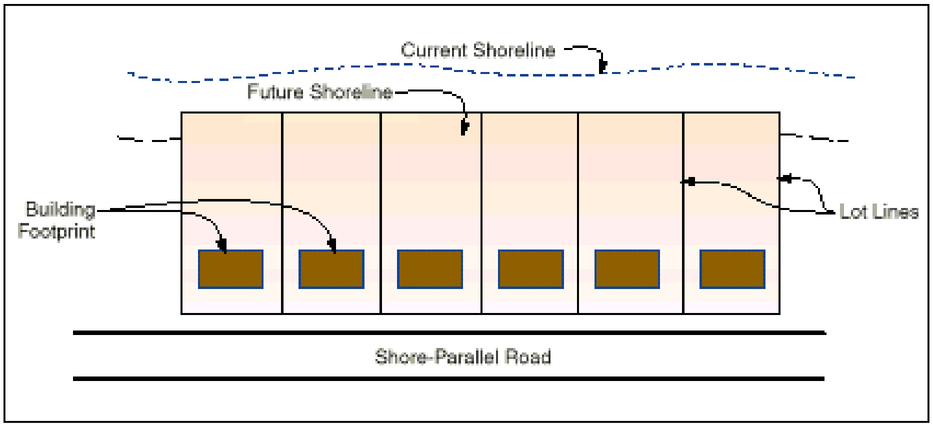


Figure 8-10. Recommended alternative layout

Lots on Narrow Sand Spits

Creation of lots along narrow sand spits and low-lying landforms (see Fig. 8-11) is not recommended—especially if the shoreline is eroding. Any buildings constructed there will be routinely subject to coastal storm effects, overwash, and other flood hazards.

Figure 8-11.
Not recommended. Construction along this narrow, low-lying area of St. Johns County, FL, is routinely subjected to coastal storm effects. The lots and buildings are landward of a previous State highway location, now abandoned.

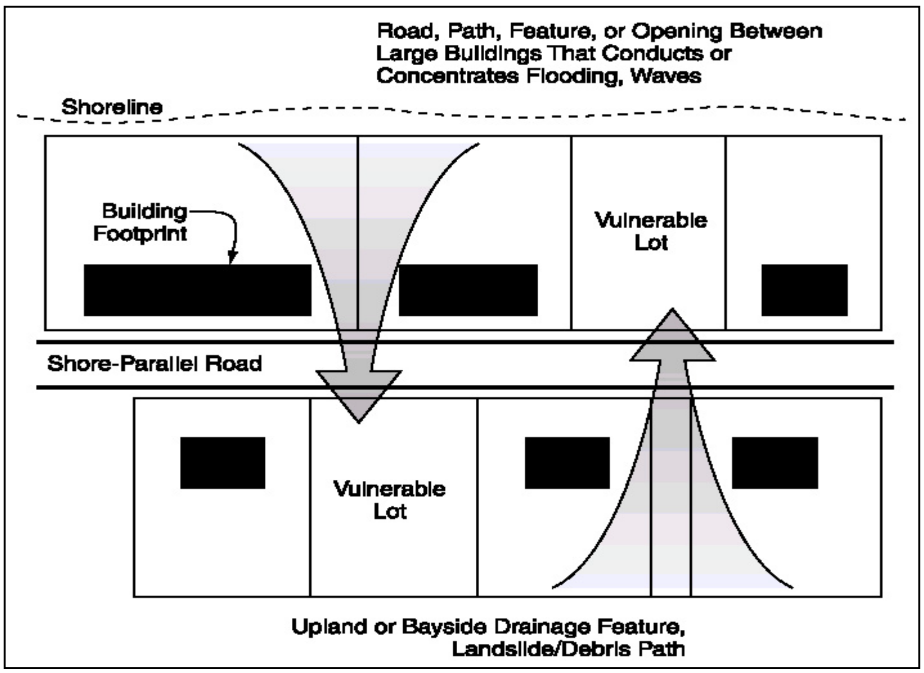
Exposure to Concentrated Floodwaters

Lots should not be created in line with natural or manmade features that concentrate floodwaters. These features can include:

- Areas of historic shoreline breaching.
- Roads or paths across dunes.
- Drainage features or canals.
- Areas of historic landslides or debris flows.

In the layout shown in Figure 8-12, the lot landward of an opening between dunes, or landward of obstructions, may be more vulnerable to flooding and wave effects. The front-row lot waterward of an interior drainage feature may be vulnerable to concentrated flooding from the upland or bay side.

Figure 8-12.
Lot layout that exposes lots to concentrated floodwaters.



One alternative is to **leave these vulnerable areas as open space** and/or to modify them to reduce associated hazards to adjacent lots.

Care should also be exercised when lots are created between or landward of gaps between large buildings or objects capable of channeling floodwaters and waves.

Concentration of Small Lots Near Shoreline

Lot configurations should not be created where small lots are concentrated along an eroding or otherwise hazardous shoreline.

The following approaches are preferable:

- Create **deeper lots** along the shoreline.
- Locate building sites **farther landward** on the lots.
- **Cluster development** away from the shoreline.

Figure 8-13 illustrates this progression, from a "conventional" lot layout, to a "modified" lot layout, to a "cluster development" layout with lot line changes.

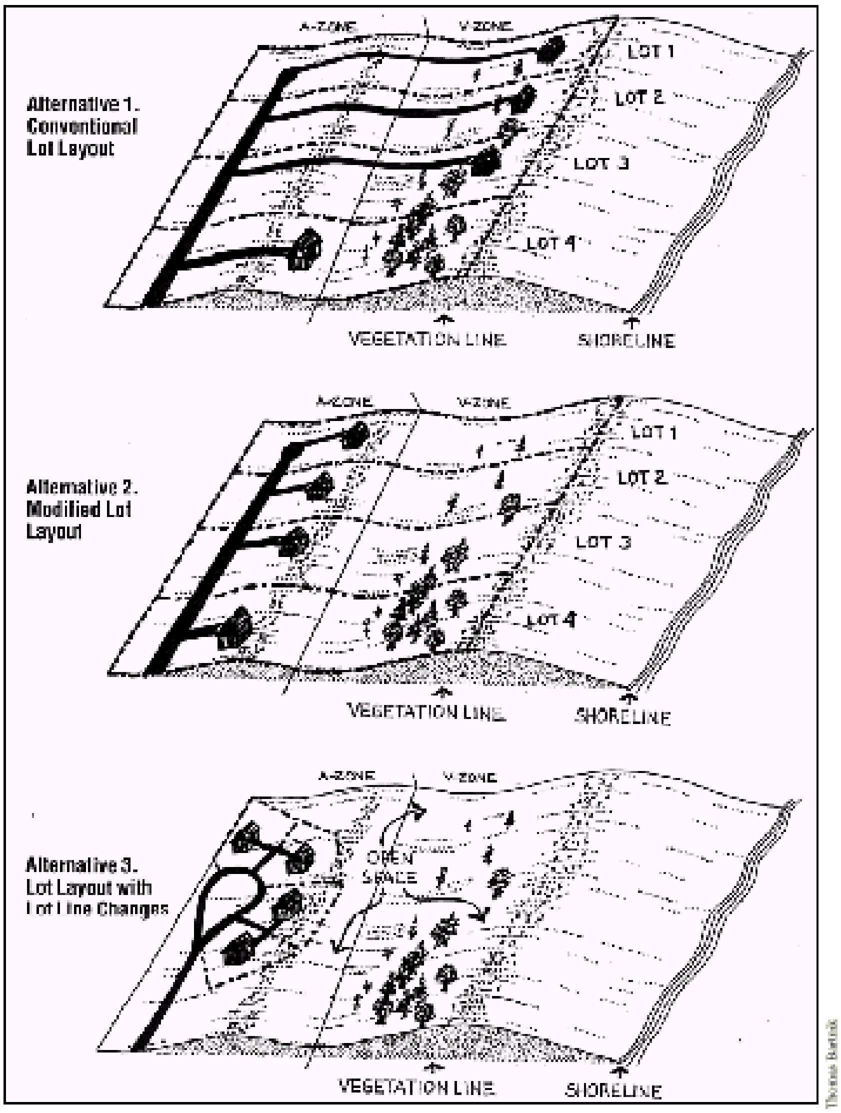


Figure 8-13.
Coast lot development scenarios

Another related approach is to occupy a small fraction of the total buildable parcel and to **accommodate erosion by moving threatened buildings** to other available sites on the parcel.

EXAMPLES

A small Pacific Ocean community in Humbolt County, California, has successfully used this approach. Figure 8-14 shows a community of 76 recreational cabins on a 29-acre parcel, jointly owned by shareholders of a corporation.

As buildings are threatened by erosion, they are relocated (at the building owner's expense) to other sites on the parcel, in accordance with a cabin relocation policy adopted by the corporation.

Figure 8-14.
As buildings are threatened by bluff erosion, they are moved to other sites on the parcel.

village of Shishmaref, Alaska, for example, voted in November 1998 to relocate their community of 600 after recent storm erosion threatened several houses and after previous shore protection efforts failed.

Layout Near Inlets

Layout of lots and infrastructure along shorelines near tidal inlets, bay entrances, and river mouths is especially problematic. The following figures, shown earlier, illustrate instances where the recent subdivision and development of oceanfront parcels near ocean-bay connections have led to buildings being threatened by inlet-caused erosion: Figures 3-2, 3-3, 4-6, and 7-14.

Infrastructure development and lot layout in similar cases should be preceded by a **detailed study of historical shoreline changes**, including development of (at least) a conceptual model of shoreline changes. Projections of potential future shoreline positions should be made, and development should be sited well landward of any areas of persistent or cyclic shoreline erosion.

SELF-CHECK REVIEW: RAW LAND DEVELOPMENT

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. List three siting practices for raw land development that should be avoided, and identify an alternative for each.

   (1) AVOID:

   ALTERNATIVE:

   (2) AVOID:

   ALTERNATIVE:

   (3) AVOID:

   ALTERNATIVE:

2. For each of the following siting practices, check DO or DON'T.

	DO	**DON'T**
a. Assume that engineering and architectural practices can mitigate all hazards.		
b. Incorporate setbacks from identified high-hazard areas.		
c. Consider and integrate topographic and natural features into the design and layout.		
d. Plan development on beaches or dunes.		
e. Plan development on ridge lines.		

ANSWER KEY

1. List three siting practices for raw land development that should be avoided, and identify an alternative for each.

   Answers will vary but should include practices such as the following. (Alternatives are in parentheses.)

   - **Shore-parallel roads with small lots between road and shore. (Road setback; longer lots)**
   - **Shore-parallel utility lines. (Shore-perpendicular access roads and utilities)**
   - **Flag or key lots. (Road setback and longer lots)**
   - **Lots on narrow sand spits. (Build elsewhere.)**
   - **Layout in line with features that concentrate floodwaters. (Leave vulnerable areas as open space.)**
   - **Concentration of small lots near shoreline. (Create deeper lots; site buildings farther landward; cluster development away from the shoreline.)**

2. For each of the following siting practices, check DO or DON'T.

	DO	**DON'T**
a. Assume that engineering and architectural practices can mitigate all hazards.		**X**
b. Incorporate setbacks from identified high-hazard areas.	**X**	
c. Consider and integrate topographic and natural features into the design and layout.	**X**	
d. Plan development on beaches or dunes.		**X**
e. Plan development on ridge lines.		**X**

INFILL DEVELOPMENT: SITING A BUILDING ON AN EXISTING LOT

Many of the same principles discussed for raw land development also apply to the construction or reconstruction of buildings on existing lots. Building siting on a particular lot should take into consideration:

- Site dimensions.
- Site features (e.g., topographic, drainage, soils, vegetation, sensitive resources).
- Coastal hazards.
- Regulatory factors.

KEY ISSUES

However, several other factors must be considered at the lot level that are not a primary concern at the subdivision level:

- **Buildable area limits** imposed by lot line setbacks, hazard setbacks, and sensitive resource protection requirements.
- Impacts of coastal hazards on **lot stability**.
- Location and extent of **supporting infrastructure**, utility lines, septic tanks and drain fields, etc.
- **Impervious area requirements** for the lot.
- **Prior development** of the lot.
- Need for **future** building repairs, relocation, or protection.
- **Regulatory restrictions** or requirements for on-site flood or erosion control.

GENERAL GUIDELINES

Although the local regulations, lot dimensions, and lot characteristics generally define the maximum allowable building footprint on a lot, the designer should not assume construction of a building occupying the entire buildable area is a prudent siting decision. The designer should consider all the factors that can affect an owner's ability to use and maintain the building and site in the future.

Guidelines for siting buildings on existing lots are given on the next page.

DEVELOPMENT OR REDEVELOPMENT OF EXISTING LOTS IN COASTAL AREAS: GUIDELINES FOR SITING BUILDINGS

DO's

1. **DO …** Determine whether the lot is suitable for its intended use. If not, alter the use to better suit the site or look at alternative sites.
2. **DO …** Study the lot thoroughly for all possible resource and hazard concerns. Seek out all available information on hazards affecting the area and prior coastal hazard impacts on the lot.
3. **DO …** Account for all types of erosion (e.g., long-term erosion, storm-induced erosion, erosion from inlets) and governing erosion-control policies when selecting a lot and siting a building.
4. **DO …** Avoid lots that require extensive grading to achieve a stable building footprint area.
5. **DO …** Ensure that the proposed siting is consistent with local, regional, and State planning and zoning requirements.
6. **DO …** Identify and avoid, or set back from, all sensitive resources.
7. **DO …** Consider existing public access to shoreline and resource areas.

DON'Ts

1. **DON'T …** Assume engineering and architectural practices can mitigate poor building siting.
2. **DON'T …** Assume that siting a new building in a previous building footprint or in line with adjacent buildings will protect the building against coastal hazards.
3. **DON'T …** Rely on existing (or planned) erosion or flood-control structures to guarantee long-term stability of the lot.
4. **DON'T …** Overlook the constraints placed on site development and future landward relocation of the building (if necessary) by:
   - Site topography.
   - Infrastructure and ancillary structures (e.g., utility lines, septic tank drain fields, swimming pools).
   - Trees and sensitive resources.
   - Adjacent development.
5. **DON'T …** Overlook the constraints that building footprint size and location place on future work to repair, relocate, or protect the building. Allow for future construction equipment access and room to operate on the lot.
6. **DON'T …** Overlook the effects on surface and groundwater hydrology from development of the lot.

PRACTICES TO AVOID AND RECOMMENDED ALTERNATIVES

Just as there are certain subdivision development practices to avoid in hazardous coastal areas, there are individual lot siting and development practices to avoid.

Shore Proximity

One of the most common siting errors is placing a building as far seaward or waterward as allowed by local and State regulations. Although such siting is permitted by law, it can lead to a variety of avoidable problems, including:

- Increased building vulnerability.
- Damage to the building.
- Encroachment onto a beach.

On an eroding shoreline, this type of siting often results in the building owner being faced with one of three options:

- Loss of the building.
- Relocation of the building.
- Protection of the building through an erosion-control measure (if permitted).

Alternatives. Alternatives to this practice include the following:

- Site the building farther landward than required by minimum setbacks. This also allows (in come cases) for the natural episodic cycle of dune building and storm erosion to occur without jeopardizing the building itself.

- Design the building so it can be easily relocated.

Bluff Proximity

Siting a building too close to a coastal bluff edge can result in building damage or loss (see Fig. 8-15). (Figures 3-3 and 7-6, presented earlier, also illustrate this problem.)

Figure 8-15. Residential buildings outside the floodplain threatened by long-term erosion along the Lake Michigan shoreline. Ozaukee County, WI (1996).

To avoid these hazards, construction setbacks (see Fig. 8-16) should be used:

- **Stable slope setback** (where the bluff toe has been stabilized against extreme lake levels and storm events)—based on bluff height and local soils and geology.
- **Recession setback** (where the bluff is not stabilized).
- **Minimum facility setback** (whether stabilized or not)—based on building construction, use, and maintenance considerations.

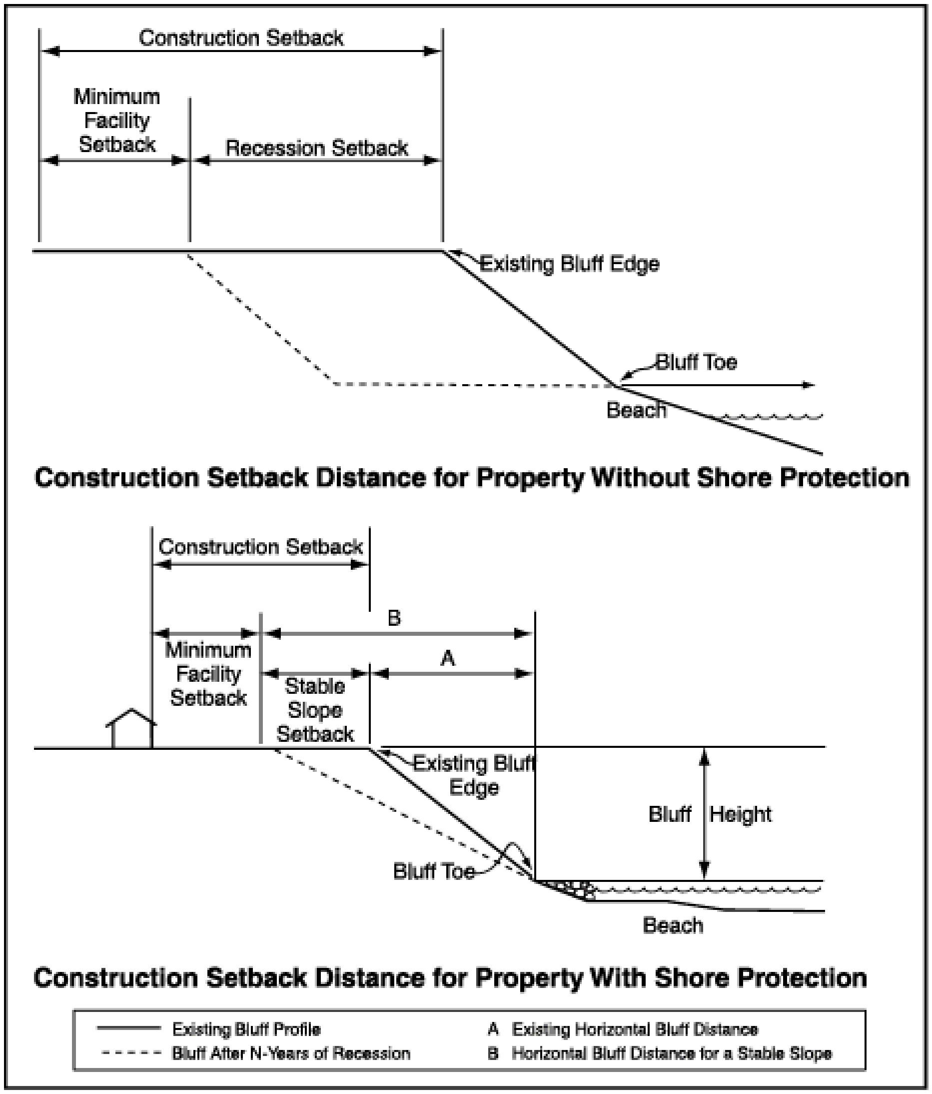


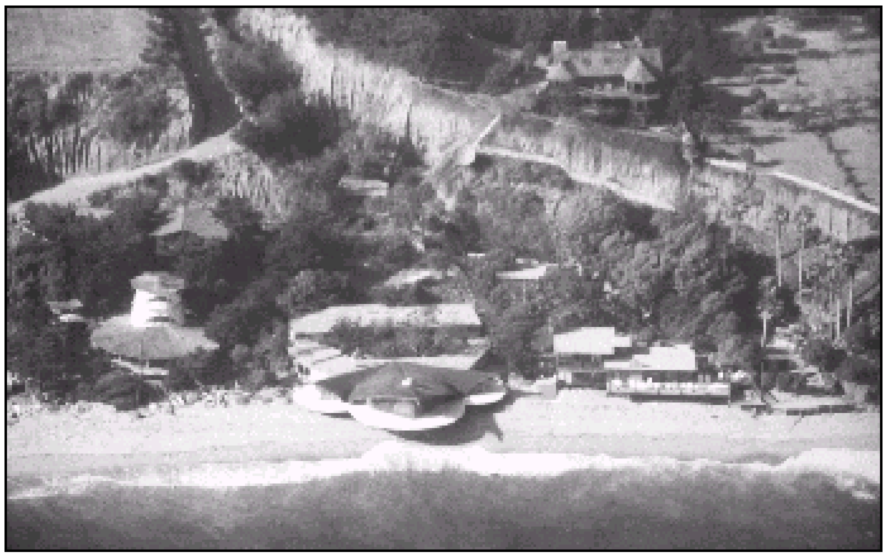
Figure 8-16. Recommended coastal bluff setbacks

Exposure to Multiple Hazards

Some sites present multiple hazards, which designers and owners may not realize. For example, Figure 8-17 shows southern California homes that have been constructed along the Pacific shoreline at the mouth of a coastal stream. The homes may be subject to:

- Storm waves and erosion.
- Stream flooding and debris flows.
- Earthquakes.

Figure 8-17. Coastal building site subject to multiple hazards. Malibu, CA (1994).



Proximity to Erosion-Control Structures

Siting a building too close to an erosion-control structure, or failing to allow sufficient room for such a structure to built, is another siting practice to avoid. Figure 8-18 shows an example of buildings that were constructed near the shoreline, only to be damaged by storm effects and erosion.

Figure 8-18. Damage to buildings sited close to an eroding shoreline. Garden City Beach, SC, Hurricane Hugo (1989). Storm waves often overtop revetments and damage buildings.

Alternatives. Subsequent construction of a rock revetment will provide some protection to the buildings, but not as much as if there were a greater distance between the revetment and buildings. Storm waves can easily overtop the revetment and damage the buildings.

An alternative to this situation is simply to plan ahead by siting the building farther landward and providing enough room between the building and the erosion-control structure to dissipate the effects of wave and flood overtopping.

Bulkheads. A related siting problem (also observed along bay or lake shorelines, canals, manmade islands, and marina/townhouse developments) is the construction of buildings immediately adjacent to bulkheads (see Fig. 8-19). The bulkheads are rarely designed to withstand a severe coastal flood and are easily overtopped by floodwaters and waves.

During severe storms, landward buildings receive little or no protection from the bulkheads. In fact, if such a bulkhead fails, the building foundation will be undermined and the building may sustain additional damage or be a total loss.

Figure 8-19. Damage at Bonita Beach, FL, from 1982 subtropical storm. Had this building not been supported by an adequate pile foundation, it would have collapsed.

Proximity to Large Trees

Although preservation of vegetation and landscaping are an important part of the siting process, designers should avoid siting and design practices that can lead to building damage. The potential consequences of siting a building immediately adjacent to existing large trees (capable of falling and damaging structures) should be evaluated carefully.

Additionally, designs that "notch" buildings and rooflines for placement of large trees should be avoided (see Fig. 8-20). This siting practice may lead to avoidable damage to the roof and envelope during a high-wind event.

Figure 8-20.
Avoid notching for trees. Siting and designing buildings to accommodate large trees is important for a variety of reasons. However, notching the building and roofline to allow placement around a tree can lead to roof and envelope damage during a high-wind event.

Uncontrolled Access

Pedestrian access between a coastal building and the shoreline is often overlooked when siting decisions and plans are made. Experience shows, however, that uncontrolled access can damage coastal vegetation and landforms, providing weak points upon which storm forces can act.

Dune blowouts and breaches during storms often result, and buildings landward of the weak points can be subject to increased flood, wave, erosion, or overwash effects.

Several options exist for controlling pedestrian and vehicular access to shorelines. The *Coastal Construction Manual* identifies various publications that provide guidance for the planning, layout, and construction of access structures and facilities.

SELF-CHECK REVIEW: INFILL DEVELOPMENT

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. List three siting practices for infill development that should be avoided, and identify an alternative for each.

   (1) AVOID:

   ALTERNATIVE:

   (2) AVOID:

   ALTERNATIVE:

   (3) AVOID:

   ALTERNATIVE:

2. For each of the following siting practices, check DO or DON'T.

	DO	**DON'T**
a. Avoid lots that require extensive grading to achieve a stable building footprint.		
b. Substitute engineering and architectural practices for prudent siting decisions.		
c. Allow for future construction equipment access and room to operate on a lot.		
d. Consider the constraints that building footprint size places on future repair work.		
e. Rely on existing erosion- or flood-control structures to guarantee long-term stability of the lot.		

ANSWER KEY

1. List three siting practices for infill development that should be avoided, and identify an alternative for each.

   Answers will vary but should include practices such as the following. (Alternatives are in parentheses.)

   - **Siting as close to the shoreline as permitted by regulations. (Exceed minimum setbacks; design for easy relocation of the building.)**
   - **Siting too close to a coastal bluff edge. (Incorporate construction setbacks for slope instability, recession, and facility issues, as needed.)**
   - **Siting without regard for multiple hazards. (Consider all hazards in siting the building.)**
   - **Proximity to erosion-control structures. (Site farther landward with enough room between the structure and the building for hazard forces to dissipate.)**
   - **Siting too close to—or notching for—large trees. (Maintain distance from large trees.)**
   - **Uncontrolled access. (Restrict pedestrian access to protect dunes and vegetation; plan vehicle access to avoid creating weak points that storm forces can exploit.)**

2. For each of the following siting practices, check DO or DON'T.

	DO	**DON'T**
a. Avoid lots that require extensive grading to achieve a stable building footprint.	**X**	
b. Substitute engineering and architectural practices for prudent siting decisions.		**X**
c. Allow for future construction equipment access and room to operate on a lot.	**X**	
d. Consider the constraints that building footprint size places on future repair work.	**X**	
e. Rely on existing erosion- or flood-control structures to guarantee long-term stability of the lot.		**X**

BEACH NOURISHMENT AND DUNE RESTORATION

Beach nourishment was discussed in Unit VII as a means of mitigating potential adverse effects of shore protection structures. Beach nourishment and dune restoration can also be carried out alone, as a way of replacing beach/dune sediments already lost to erosion or of providing nourishment in anticipation of future erosion.

BEACH NOURISHMENT

Beach nourishment projects typically involve dredging or excavating hundreds of thousands to millions of cubic yards of sediment and placing it along the shoreline. Beach nourishment projects are preferred over erosion-control structures by many States and communities, largely because the projects add sediment to the littoral system and provide recreational beach space.

Longevity

NOTE

Beach nourishment and dune restoration projects are temporary. Although they can mitigate some storm and erosion impacts, they should not be used as a substitute for sound siting, design, and construction practices.

The longevity of a beach nourishment project will depend on several factors:

- Project length.
- Project volume.
- Native beach and borrow site sediment characteristics.
- Background erosion rate.
- Incidence and severity of storms following construction.

Thus, most projects are designed to include an initial beach nourishment, followed by periodic maintenance nourishment (usually at intervals of 5 to 10 years). The projects can provide protection against erosion and storms, but future protection is tied to a community’s commitment to future nourishment efforts.

Controversy

Beach nourishment projects are expensive and often controversial. The controversy usually arises over environmental concerns and the use of public monies to fund the projects. Planning and construction of these projects can take years to carry out, and economic considerations usually restrict their use to densely populated shorelines.

Therefore, as a general practice, designers and owners should not rely on future beach nourishment as a way of providing significant and continuous relief that can compensate for poor siting decisions.

Implications for Siting

As a practical matter, beach nourishment is the only viable option available to large, highly developed coastal communities where both upland protection and preservation of the recreational beach are vital. Beach nourishment programs have been established and are ongoing in many of these communities, and infill development and redevelopment will continue landward of nourished beaches.

Owners and designers should realize, however, while the nourishment programs will reduce potential storm and erosion damage to upland development, **they will not eliminate all damage. Sound siting, design, and construction practices MUST be followed.**

DUNE RESTORATION

Dune restoration projects typically involve placement of hundreds to tens of thousands of cubic yards of sediment along an existing or damaged dune. The projects can be carried out in concert with beach nourishment or alone. Smaller projects may fill gaps or blowouts caused by pedestrian traffic or minor storms, while large projects may reconstruct entire dune systems.

Dune Revegetation

Dune restoration projects are often accompanied by dune revegetation efforts, where native dune grasses or ground covers are planted to stabilize the dune against windblown erosion, and to trap addition windblown sediment.

WARNING

Although dune vegetation serves many valuable functions, it is not very resistant to coastal flood and erosion forces.

Success Factors

The success of dune restoration and revegetation projects depends largely on the condition of the beach waterward of the dune. Dune restoration and revegetation projects along an eroding shoreline will be short-lived. Without a protective beach, high tides, high water levels, and minor storms will erode the dune and wash out most of the planted vegetation.

Implications for Siting

In some instances, new buildings are sited so that there is not sufficient space waterward to construct and maintain a viable dune. In many instances, erosion has placed existing development in the same situation. A dune restoration project waterward of these structures will not be effective; those buildings in greatest need of protection will receive the least protection.

Therefore, dune restoration and revegetation should not be used as a substitute for proper siting, design, and construction practices.

UNIT VIII EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit VIII. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to Unit IX.

1. Which of the following is a siting strategy for minimizing risk?

   a. Place a road near the shoreline with small lots between road and shore.
   b. Design the building to facilitate future relocation.
   c. Site a building behind the gap between two shore-front buildings.
   d. Cluster development as close to the shoreline as possible.

2. It is best to undertake a detailed hazard study:

   a. After purchasing a lot but before building on it.
   b. During development.
   c. Before acquiring a property for development.
   d. As soon as the decision has been made about building placement.

3. Regulatory controls:

   a. Are the best guideline for siting decisions.
   b. Should be disregarded when making siting decisions.
   c. If complied with, guarantee the safety of the site.
   d. Do not necessarily result in prudent siting of coastal buildings.

4. Designers and owners should consider the effects of hazards on future property owners.

   True False

5. Which of the following siting decisions would be preferable?

   a. Exceed the minimum setback requirements on a shore-front property.
   b. Create lots on a narrow sand spit if the shore has not eroded appreciably in the last ten years.
   c. Place houses as close to the beach as possible and build erosion-control structures to protect them.
   d. Site close to a bluff edge as long as the bluff toe has been stabilized.

6. The supporting infrastructure should be considered in siting decisions for infill development.

   True False

7. If erosion-control structures are present or will be used at a coastal property, the best location for the building would be:

   a. Against the structures.
   b. Atop the structures.
   c. Landward and away from the structures.
   d. Anywhere on the lot because the structures provide protection.

8. Beach nourishment involves feeding the natural grasses that grow on and stabilize the dunes.

   True False

9. Beach nourishment and dune restoration:

   a. Are most often used in sparsely populated areas.
   b. Are permanent measures for erosion control.
   c. Make siting practices such as construction setback unnecessary.
   d. Are temporary measures for erosion control.

UNIT VIII EXERCISE — ANSWER KEY

1. Which of the following is a siting strategy for minimizing risk?

   b. Design the building to facilitate future relocation.

2. It is best to undertake a detailed hazard study:

   c. Before acquiring a property for development.

3. Regulatory controls:

   d. Do not necessarily result in prudent siting of coastal buildings.

4. Designers and owners should consider the effects of hazards on future property owners.

   True

5. Which of the following siting decisions would be preferable?

   a. Exceed the minimum setback requirements on a shore-front property.

6. The supporting infrastructure should be considered in siting decisions for infill development.

   True

7. If erosion-control structures are present or will be used at a coastal property, the best location for the building would be:

   c. Landward and away from the structures.

8. Beach nourishment involves feeding the natural grasses that grow on and stabilize the dunes.

   False

9. Beach nourishment and dune restoration:

   d. Are temporary measures for erosion control.

UNIT IX: FINANICAL AND INSURANCE IMPLICATIONS

FINANCIAL AND INSURANCE IMPLICATIONS

INTRODUCTION

It is easy for property owners to become complacent about the threat of a natural disaster affecting their buildings. After all, hurricanes and earthquakes are infrequent events—a particular geographic area may escape a major hazard event for 20 or more years. Conversely, residents of a recently affected area may believe that a recurrence is unlikely to happen soon. Complacent attitudes are based on inaccurate assumptions and/or a lack of understanding of natural hazards and their associated risks.

The population and property values along the U.S. coast, meanwhile, are rapidly increasing. Better warning systems have allowed us to reduce the number of fatalities and injuries associated with natural disasters. However, greater numbers and higher values of coastal structures make dramatic increases in property losses likely.

NOTE

NOAA predicts that by 2010, more than 73 million people will be living in hurricane-prone areas.

Before undertaking a coastal construction project, property owners and design professionals should be aware of the financial and insurance implications of siting, design, and construction decisions. Site selection, building location, and design requirements will all influence the costs of construction and insurance.

Previous units of this course provided detailed information about hazards and risks associated with building in coastal areas. In this unit, we will look at general financial implications of siting, design, and construction of residential buildings in high-hazard areas and the benefit/cost of mitigation measures. Information will also be provided about flood, wind, and earthquake insurance that may help offset potential financial losses to residential buildings.

UNIT OBJECTIVES

After completing this unit, you should be able to:

9.1 Give examples of the costs and benefits associated with hazard mitigation measures in siting, design, and construction.
9.2 Describe the role of hazard insurance in mitigating potential losses in residential coastal construction.
9.3 Identify factors that affect the availability and cost of hazard insurance.

BENEFIT/COST IMPLICATIONS OF SITING, DESIGN, AND CONSTRUCTION

THE RISK

In 1986, the All-Industry Research Advisory Council (an advisory organization for the insurance industry) estimated that two $7 billion hurricanes could occur in the same year. However—

- In 1989, Hurricane Hugo struck South Carolina, causing approximately $9 billion in damage.
- In 1992, Hurricane Andrew caused $15.5 billion in damage to insured properties.

Neither hurricane hit densely populated areas. If they had, losses would have been far greater.

Following Hurricane Andrew, studies were conducted to determine whether the damage suffered was attributable to the intensity of the storm or to the location and type of development in South Florida. The Institute for Business and Home Safety (IBHS) found the following:

"A 40-year period of relatively benign weather left southern Florida with a false sense of security regarding its ability to withstand hurricanes. This led to a complacency about hurricane risk, leading to 'helter-skelter' development, lackluster code enforcement, building code amendments, shortcuts in building practices, and violations that seriously undermined the integrity of the [building] code and the quality of the building stock. Conservative estimates from claim studies reveal that approximately 25 percent of Andrew-caused insurance losses (about $4 billion) were attributable to construction that failed to meet the code due to poor enforcement, as well as shoddy workmanship. At the same time, concentrations of population and of property exposed to hurricane winds in southern Florida grew many-fold."

—IBHS and Insurance Research Council. *Coastal Exposure and Community Protection: Hurricane Andrew's Legacy* (Boston, MA: 1995)

NOTE

From 1986 to 1992, hurricanes and tropical storms accounted for the major share of all property insurance losses. The proportion of all property damage (e.g., wind, flood, other) caused by various events during this period were:

- Hurricane/tropical storm: 53%
- Tornado/other wind: 35%
- Fire/explosion: 5%
- Earthquake: 3%
- Riot/civil disorder: 2%
- Other: 2%

MANAGING THE RISK

As we have seen in earlier units, studies of past natural disasters have demonstrated that sound siting, design, engineering, construction, and maintenance practices are important factors in the ability of a building to survive a hazard event with little or no damage.

This course—along with the related classroom course *Residential Coastal Construction*—is designed to help property owners manage some of the risk associated with constructing a residential building in a coastal hazard area.

The classroom course (which draws heavily on Volume 2 of the *Coastal Construction Manual*) will provide detailed information about how to site, design, construct, and maintain a building in ways that will help manage risks.

BENEFITS VS. COSTS

Risk management is not simple. It is a continuous process of weighing benefits against costs to arrive at the optimal balance. Here are some examples:

- Constructing to a model building code and complying with regulatory siting requirements will provide a building with a certain level of protection against damage from natural hazards. However, compliance with minimum code and regulatory requirements does not guarantee that a building will be free from danger.
- At the same time exceeding code and regulation minimums provides an added measure of safety, it also adds to the cost of construction. That cost must be weighed against the benefit gained.
- The often minimal initial cost of additional mitigation measures offers **long-term benefits** that will provide a positive life-cycle cost—reducing insurance premiums and better protecting the building and its contents and occupants during a natural hazard event.

Table 9.1 lists examples of flood and wind mitigation measures that can be taken to help a structure better withstand a natural disaster.

Table 9.1. Examples of Flood and Wind Mitigation Measures

Mitigation Measure	Benefits/Advantages	Costs/Disadvantages
Elevation of lowest floor: Add 1 to 2 feet to the required elevation of the lowest floor or lowest horizontal structural member of the building.	Reduces the potential for the structure to be damaged by waves and/or floodwaters.	May conflict with community building height restrictions; may require additional seismic design considerations; longer pilings may cost more.
Embedment depth: Increase embedment depth of pile foundations.	Adds protection against scour and erosion.	Longer pilings may cost more.
Flashing/weather-stripping: Improve flashing and weather-stripping around windows and floors.	Reduces water and wind infiltration into building.	Increases the number of important tasks for contractor to monitor.
Areas below BFE: Install fewer breakaway walls or install more openings in continuous foundation walls.	Decreases potential for damage to understory of structure; reduces amount of debris during storm event.	Reduces the ability to use understory of structure for storage.
Open coastal A zone foundation: Elevate a building in a coastal A zone on an open foundation or use only breakaway walls for enclosures below the lowest floor.	Reduces the potential for the structure to be damaged by waves, erosion, and floodwaters.	Reduces the ability to use understory of structure for storage.
Shutters: Add shutters for glazing protection.	Reduces the potential for damage from windborne debris impact during a storm event and reduces potential for wind-driven rain water infiltration.	Shutters require installation or activation before a storm event.
Shingles: Use asphalt roof shingles with high bond strength.	Reduces shingle blowoff during high winds.	High-bond-strength shingles are slightly more expensive.
Siding: Install wood siding instead of vinyl siding.	Wood siding reduces blowoff on walls during high winds.	Wood siding may cost more than other materials and requires additional maintenance
Connectors: Use metal connectors or fasteners with a thicker galvanized coating or connectors made of stainless steel	Reduces the potential for corrosion of connectors.	Thicker coating and stainless steel are more costly
Roof covering: Install additional roof sheathing fasteners, install additional underlayments, or improve roof covering details as required.	Reduces roof covering and interior wind and water damage from a severe event.	There is minimal increased cost when these tasks are done during a reroofing project

BENEFIT/COST MODELS

The need for and benefit of some measures may be difficult to predict.

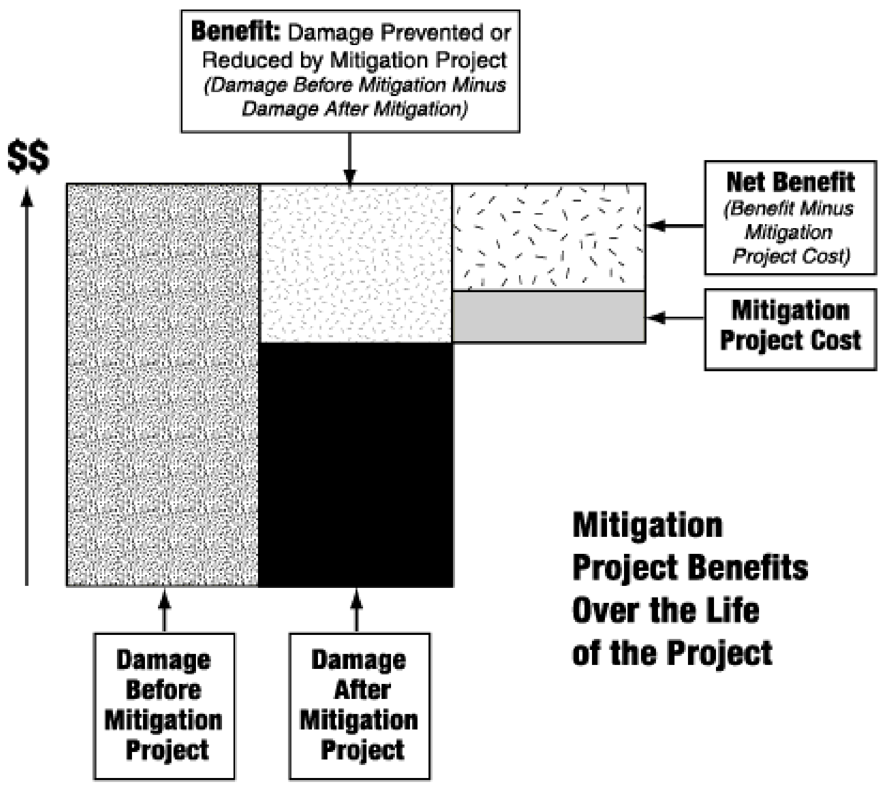
For example, elevating a building above the DFE could add to the cost of the building. This additional cost must be weighed against the probability of a flood or storm surge exceeding the DFE.

Benefit/cost models are useful tools that provide a reasonable method for determining whether a project is or is not cost-effective.

Basic Model

The chart shown in Figure 9-1 illustrates the comparative relationship between damage, project costs, and benefits associated with a hazard mitigation project. These comparisons are made on a present-value basis over the life of the project. A project-specific benefit/cost analysis will assist in the development of such comparisons.

Figure 9-1.
Basic benefit/cost model



WARNING

In general, benefit/cost models do not take into account human suffering (e.g., the emotional stress induced by the loss of irreplaceable items and the trauma of rebuilding after a devastating event).

FEMA's Benefit/Cost Models

NOTE

FEMA benefit/cost models include computer software that can be used to perform calculations.

FEMA has developed benefit/cost models for flood, wind, and seismic hazard mitigation measures. These models can be used to determine the value of measures intended to mitigate against different natural hazards.

The FEMA models measure benefit as the **amount of future damage avoided** as a result of the mitigation measure undertaken. (Note that, although costs can be determined from detailed engineering studies, **benefits are estimated** because the timing and severity of future hazard events can only be probabilistically estimated.)

Types of Data Used. The benefit/cost analysis method is basically the same for each type of hazard mitigation project. The FEMA models use the following types of data to determine the benefit/cost ratio of a given mitigation measure:

- Building type.
- Building location.
- Number of stories or elevation.
- Construction date.
- Building replacement value.
- Value of contents.
- Displacement costs incurred because of damage to the residence.
- Rental/business income.
- Useful life of the mitigation project.
- Mitigation project cost.
- Annual maintenance costs.
- Relocation costs for the mitigation project.
- Hazard data, including the expected number of events at various intensities.

Hazard Data. The only differences among models are in the types of hazard data used in the calculations:

- **Wind:** Wind speed/storm class is used to estimate damage for wind mitigation projects.

- **Flood:** Depth of flooding is used to estimate damage for flood mitigation projects.

- **Earthquake:** Severity of ground shaking is used to estimate damage for earthquake mitigation projects.

WIND MITIGATION

Table 9.2 presents the default estimates for damage to a building from high winds used in FEMA's Hurricane Wind Mitigation Benefit/Cost Model. The table indicates the percentage of the building that would be damaged by various storm classes (according to the Saffir-Simpson scale) for different building (engineering) types. Definitions for the building types are given below.

Table 9.2. Default Wind Damage as a Percent of Building Value

	Building Type			
Storm Class (Wind Speed in mph)*	Non-Engineered Wood	Non-Engineered Masonry	Lightly Engineered	Fully Engineered
0 (60–73)	0	0	0	0
1 (74–95)	7.5	5	5	2.5
2 (96–110)	20	15	15	5
3 (111–130)	50	40	40	20
4 (131-155)	90	80	80	40
5 (>155)	100	100	100	60

*Wind speed is 1-minute sustained wind speed over land at 33 ft above the ground at a specific building site.

- **Non-engineered wood —** These buildings do not receive specific engineering attention. They include single- and multi-family residences, some one- or two-story apartment units, and some small commercial buildings.
- **Non-engineered masonry —** These buildings do not receive specific engineering attention. They include single- and multi-family residences, some one- or two-story apartment units, and some small commercial buildings.
- **Lightly engineered —** These buildings may combine masonry, light steel framing, open-web steel joists, wood framing, and wood rafters. Some parts of these buildings receive engineering attention, while others do not. These buildings include motels, and commercial and light industrial buildings.
- **Fully engineered —** These buildings are usually designed for a specific site and therefore receive individualized design attention. They include high-rise office buildings, hotel buildings, hospitals, and most public buildings.

The default wind-damage information may need to be modified to account for:

- Variations in building height.
- Differences in construction practices, age of the building, or general location in the country.
- Variation in wind exposure and topographic effects.
- Windborne debris.

FEMA's Hurricane Wind Mitigation Benefit/Cost Model can help determine the benefit of implementing a mitigation measure to protect a building from wind damage, as shown in the following example.

EXAMPLE

The addition of storm shutters to a $250,000 house 2 miles from the North Carolina coast can reduce potential damage to a building from over $33,000 to $15,000 over a period of 30 years, adjusted to present value.

After subtracting the project cost (approximately $15,000 for storm shutters), the present-value net benefit to the homeowner is over $17,000, for a benefit/cost ratio greater than 2.

FLOOD MITIGATION

Tables 9.3 and 9.4 present FEMA's Federal Insurance Administration (FIA) damage estimates for various flood depths for site-built buildings in V zones and A zones.

Note the following about these two sets of data:

- Flood depths in Table 9.3 are given in relation to the bottom of the lowest horizontal structural member, whereas flood depths in Table 9.4 are given in relation to the top of the lowest floor.

- All construction types are included in the building categories listed, so one-story houses may include any of several types (e.g., wood-frame or masonry).

- Differences in foundation types, construction practices, and the age of the buildings are not considered.

- Because the information comes from actual claims data, the damage percentage from large flood depths is less reliable, because there is less flood history at these depths.

- The loss data are for flood losses caused by any type of flood hazard—including high-velocity flow, debris flow, and ice flows—and for floods of any duration.

Table 9.3. FIA Depth-Structure Damage Data for V-Zone Buildings (Damage in Percent of Building Replacement Value—1987 FIA Data)

	Building Condition	
Flood Depth[a]	**No Obstruction[b]**	**With Obstruction**
-2	10.0	20.0
-1	12.0	21.5
0	15.0	24.0
1	23.0	29.0
2	35.0	37.0
3	50.0	54.0
4	58.0	60.5
5	63.0	64.5
6	66.5	68.0
7	69.5	70.0
8	72.0	72.0
9	74.0	74.0
10	76.0	76.0
11	78.0	78.0
12	80.0	80.0
13	81.5	81.5
14	83.0	83.0
15	84.0	84.0
16	85.0	85.0
17	86.0	86.0
18	87.0	87.0

[a] Relative to bottom of lowest horizontal structural member.
[b] Obstruction = machinery, equipment, or enclosure below the elevated floor.

Table 9.4. FIA Depth-Structure Damage Data for A-Zone Buildings
(Damage in percent of building replacement value)

	Building Type				
Flood Depth*	One-Story w/o Basement	Two-Story w/o Basement	Split Level w/o Basement	One- or Two-Story w/ Basement	Split Level w/ Basement
-2	0	0	0	4	3
-1	0	0	0	8	5
0	9	5	3	11	6
1	14	9	9	15	16
2	22	13	13	20	19
3	27	18	25	23	22
4	29	20	27	28	27
5	30	22	28	33	32
6	40	24	33	38	35
7	43	26	34	44	36
8	44	29	41	49	44
9	45	33	43	51	48
10	46	38	45	53	50
11	47	38	46	55	52
12	48	38	47	57	54
13	49	38	47	59	56
14	50	38	47	60	58
15	50	38	47	60	58
16	50	38	47	60	58
17	50	38	47	60	58
18	50	38	47	60	58

*Relative to top of lowest floor.

Note: The depth-damage data presented in this table are used in FEMA's Riverine and Coastal A-Zone Flood Mitigation Benefit/Cost Model.

V-Zone vs. A-Zone Buildings

Using the data from Tables 9.3 and 9.4, Figure 9-2 compares the depth-damage relationships for two types of buildings:

- V-zone building with no obstruction below the lowest floor.
- Two-story A-zone building without a basement.

NOTE

The flood depths shown in Figure 9-2 for both V-zone and A-zone buildings are given in relation to the bottom of the lowest horizontal structural member. (The conversion of A-zone depths shown in Table 9.4—which are in relation to the top of the lowest floor—is based on the assumption that the distance between the top of the lowest floor and the bottom of the lowest horizontal structural member is equal to 2 feet.)

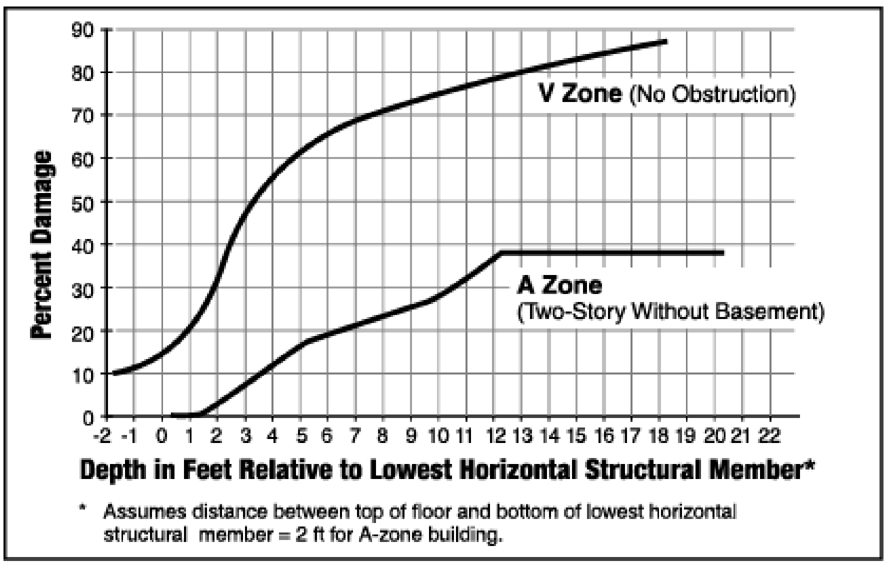


Figure 9-2. Comparison of FIA V-zone and A-zone depth-structure damage functions. No contents damage included.

According to FEMA's Flood Mitigation Benefit/Cost Model, elevating a new two-story house in South Carolina's coastal A zone 3 feet above the BFE on longer piles would provide a benefit/cost ratio greater than 2, and result in significantly lower flood insurance premiums under the NFIP.

SELF-CHECK REVIEW: BENEFIT/COST IMPLICATIONS OF SITING, DESIGN, AND CONSTRUCTION

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Give an example of a mitigation measure that could help protect a structure against coastal hazards, and describe the kinds of cost/benefit factors that could influence the decision whether to use that measure.

2. Give an example of a flood mitigation measure and a wind mitigation measure. List a cost and a benefit associated with each.

   - Flood mitigation measure ____

     Cost: Benefit:

   - Wind mitigation measure ____

     Cost: Benefit:

3. For a V-zone building with no obstructions, what level of damage (percent of building value) would be caused by a 2-foot flood depth? (Use Table 9.3.)

   ____

   For a two-story house without a basement in a coastal A zone, how great a flood depth would it take to cause the same level of damage? (Use Table 9.4.)

   ____

ANSWER KEY

NOTE: Your answers may be slightly different, but they should include the same main points.

1. Give an example of a mitigation measure that could help protect a structure against coastal hazards, and describe the kinds of cost/benefit factors that could influence the decision whether to use that measure.

   Answers will vary. See Table 9.1 for examples.

2. Give an example of a flood mitigation measure and a wind mitigation measure. List a cost and a benefit associated with each.

   (Any examples drawn from Table 9.1, or comparable examples.)

3. For a V-zone building with no obstructions, what level of damage (percent of building value) would be caused by a 2-foot flood depth? (Use Table 9.3.)

   35%

   For a two-story house without a basement in a coastal A zone, how great a flood depth would it take to cause the same level of damage? (Use Table 9.4.)

   10 feet

HAZARD INSURANCE

Insurance should never be viewed as an alternative to damage prevention. However, despite best efforts to manage risk, there is always the potential for structures in coastal areas to be damaged during a natural hazard event. Hazard insurance to offset potential losses, therefore, is an important consideration for homeowners in coastal areas.

INSURANCE CONSIDERATIONS

The availability and cost of hazard insurance will vary with the location of the building and the quality of the design and construction techniques used. Insurance companies base hazard insurance rates on the potential for a building to be damaged by various hazards and the ability of the building to withstand those hazards.

Hazard insurance rates are affected by the following factors:

- Type of building.
- Location of the building.
- Date of construction.
- Existence and effectiveness of a fire department and fire hydrants (or other dependable, year-round sources of water).
- Effectiveness of the building code and building department in place at the time of construction.

Implications for Homeowners

While designers and builders may not be able to control the rates and availability of insurance, they should understand the implications of siting and construction decisions on insurance costs, and they should make homeowners aware of the risk and potential expense associated with owning a house in a high-hazard area.

Insurance considerations can and do affect the placement and height of coastal buildings and the materials used in their construction. Input from an insurance industry representative during the design process—rather than after the completion of the building—can positively influence important decisions in addition to potentially saving homeowners money on insurance premiums.

Coverage

Typical homeowner's insurance coverage is summarized in Table 9.5.

Table 9.5. Typical Coverage Under Standard Policies

Hazard	Coverage
Fire Lightning Hail Explosion Riot Smoke Vandalism Theft Volcanic eruption Falling objects Weight of snow Freezing	Typically covered
Wind	Usually—but not always—covered
Liability	Typically covered
Earthquake	Endorsements may often be added
Flood	Separate policy normally required

NOTE

A single-family home is covered by a homeowner's policy, and a multi-family building is covered by a dwelling policy—two different types of insurance.

- A **homeowner's policy** is a multi-peril package policy that automatically includes fire and allied lines, theft, and liability coverage.
- With a **dwelling policy**, peril coverages are purchased separately.

This unit focuses on homeowner's insurance. Standard homeowner's insurance policies do not normally cover damage from flood or earth movement (e.g., earthquakes and mudslides).

FLOOD INSURANCE

Flood insurance is offered through the NFIP in communities (e.g., incorporated cities, towns, villages; unincorporated areas of counties, tribes, and parishes) that participate in the program. As discussed in Unit V, the purchase of flood insurance is required as a condition of receiving federally backed, regulated, or insured financial assistance for the acquisition of buildings in the SFHA. This includes almost all mortgages secured by property in an SFHA.

This insurance is not available in communities that do not participate in the NFIP. Most coastal communities do participate in the program, because they recognize the flood hazard and the need for flood insurance.

NFIP RATING FACTORS

The following factors are used in determining flood insurance rates for buildings (not including building contents):

- Building occupancy.
- Building type.
- Flood insurance zone.
- Date of construction.
- Elevation of lowest floor or bottom of the lowest horizontal structural member of the lowest floor.
- Enclosures below the lowest floor.
- Location of utilities and service equipment.

Building Occupancy

The NFIP bases its rates on four types of building occupancy:

- Single-family.
- Two- to four-family.
- Other residential.
- Nonresidential.

Only slight differences exist among the rates for the three types of residential buildings.

NOTE

Condominium policies are also available. Designers may wish to consult knowledgeable insurance agents and the *Flood Insurance Manual* for policy details and exclusions that will affect building design and use. Additional information is available in *Answers to Questions About the National Flood Insurance Program*, FIA-2 (FEMA 1990).

Building Type

The NFIP bases its rates on the following building-type factors:

- **Number of floors**—Whether there is one floor or more than one floor.
- **Basement—**Whether there is a basement (i.e., any area having its floor below ground level on all sides).
- **Elevation, and enclosures below the BFE**—Whether the building is elevated (with or without an enclosure below the lowest elevated floor).
- **Manufactured housing**—Whether the building is a manufactured home on a permanent foundation.

NFIP insurance is generally more expensive for buildings with basements and for buildings with enclosures below the BFE.

Flood Insurance Zone

The zones are grouped as follows for rating purposes:

- **V zones (V, VE, and V1–V30)—**The zones closest to the water, subject to "coastal high hazard flooding" (i.e., flooding with wave heights greater than 3 feet). Insurance is most expensive in V zones because of the severity of the hazard. However, the zones are often not very wide, and most coastal buildings are located in A or X zones.
- **A zones (A, AE, AR, AO, and A1–A30)—**In coastal flood hazard areas where the wave heights are less than 3 feet.
- **B, C, and X zones—**The zones outside the 100-year floodplain or SFHA. Insurance is least expensive in these zones and generally not required by mortgage lenders.

FIRMs show areas designated as being within the Coastal Barrier Resources System or "otherwise protected areas." Flood insurance is available for buildings in these zones only if the buildings were walled and roofed before the CBRA designation date shown in the FIRM legend, and only if the community participates in the NFIP.

NOTE

Zones V1–V30, A1–A30, B, and C were used on FIRMs until 1986. FIRMs published since then show VE, AE, and X zones.

Construction in B, C, and X zones is not subject to NFIP floodplain regulations. This summary does not discuss the flood insurance rating of buildings in these zones.

Date of Construction

Pre-FIRM Buildings. In each community participating in the NFIP, buildings constructed on or before the date of the first FIRM for that community (or December 31, 1974—whichever is later) have flood insurance rates that are "grandfathered" or "subsidized." These buildings are charged a flat rate based on:

- Building occupancy.
- Building type.
- Flood insurance zone.

NOTE

The local building official or floodplain administrator—not the insurance agent—determines whether a building is substantially improved or substantially damaged.

For additional information about substantial damage, refer to *Answers to Questions About Substantially Damaged Buildings*, FEMA 213 (1991).

If a pre-FIRM building is substantially improved (i.e., the value of the improvement exceeds 50 percent of the market value of the building before the improvement was made), it is rated as a post-FIRM building.

If a pre-FIRM is substantially damaged (i.e., the true cost of repairing the building to its pre-damaged condition exceeds 50 percent of the value of the building before it was damaged), it too is rated as a post-FIRM building—regardless of the amount of repairs actually undertaken.

Post-FIRM Buildings. The rates for buildings constructed after the date of the first FIRM are based on:

- Building occupancy.
- Building type.
- Flood insurance zone.
- Elevation of the top of the lowest floor (in an A zone) or bottom of the lowest horizontal structural member of the lowest floor (in a V zone).
- Enclosed areas below the lowest floor in an elevated building.

An additional insurance rate table is applied to buildings constructed in V zones on or after October 1, 1981. The table differentiates between buildings with an **obstruction below the elevated lowest floor** and those without such an obstruction.

Elevation of Lowest Floor

The rating for post-FIRM buildings is based on:

- In A zones—elevation of the lowest floor in relation to the BFE.
- In V zones—elevation of the bottom of the lowest horizontal member in relation to the BFE.

The flood insurance rates decrease for buildings elevated above the BFE. The premiums increase significantly for a building rated at 1 foot or more below the BFE.

Openings in Crawlspace Walls. In A zones, a building on a crawlspace must have openings in the crawlspace walls that will allow for the unimpeded flow of floodwaters more than 1 foot deep. If the crawlspace walls do not have enough properly sized openings, the crawlspace will be considered an enclosed floor and the building may be rated as having its lowest floor at the elevation of the grade inside the crawlspace.

Service Equipment. Similarly, if furnaces and other equipment serving the building are below the BFE, the insurance agent must submit more information on the structure to the NFIP underwriting department before the policy's premium can be determined.

WARNING

There are some significant differences between what is permitted under floodplain management regulations and what is covered by NFIP flood insurance. **Building designs should be guided by floodplain management requirements, not by flood insurance policy provisions.**

Enclosures Below the Lowest Floor

In V zones, buildings built on or after October 31, 1981, are rated in one of three ways:

COST CONSIDERATION

There may be significant financial penalties associated with the improper design, construction, conversion, or use of areas below the lowest floor.

- **Free of obstruction**—A building is rated as "free of obstruction" if there is no enclosure below the lowest floor other than insect screening or open wood latticework. ("Open" means at least 50 percent of the lattice construction is open.)

- **With obstruction**—A building is subject to a more expensive "with obstruction" rate if service equipment or utilities are located below the lowest floor or if breakaway walls enclose an area of less than 300 ft^2 below the lowest floor.

- **Other**—If the area below the lowest floor has more than 300 ft^2 enclosed by breakaway walls, has nonbreakaway walls, or is finished, then the floor of the enclosed area is the building's lowest floor. The insurance agent must submit more information on the structure to the NFIP before the policy's premium can be determined.

SFIP The Standard Flood Insurance Policy (SFIP) provides coverage for walled and roofed structures, including certain building components and contents in areas below the elevated floors of elevated buildings. This coverage can even include some items *prohibited* by FEMA/local floodplain management regulations where the NFIP deems the items essential to the habitability of the building.

WARNING

Do not confuse insurability with proper design and construction. Significant financial penalties (e.g., increased flood insurance premiums and increased uninsured losses) may result from improper design or use of enclosed areas below the BFE.

Items Covered Below the BFE

Given the above caveats, buildings insured under the SFIP will have coverage (up to specified policy limits) for items below the BFE as listed in Table 9.6.

Table 9.6. SFIP Coverage

Items Covered	Items Not Covered
• Required utility connections • Footings, foundation, posts, pilings, piers, or other foundation walls and anchorage system as required for the support of the building • Stairways and staircases attached to the building that are not separated from the building by an elevated walkway • Elevators, dumbwaiters, and relevant equipment (except for such relevant equipment installed below the BFE on or after October 1, 1987) • Building and personal property items (e.g., air conditioners, fuel tanks, furnaces, hot water heaters, washers, and dryers) that are necessary for habitability of the building, connected to a power source, and installed in their functioning location—as long as the building and personal property coverage has been purchased • Debris removal, where such debris was generated during a flood	• Breakaway walls and enclosures that do not provide support to the building • Non-structural slabs beneath an elevated building • Walks, decks, driveways, and patios located outside the perimeter of the exterior walls of the building • Underground structures and equipment, including wells, septic tanks, and septic systems • Equipment, machinery, appliances, and fixtures not deemed necessary for the habitability of the building • Fences, retaining walls, seawalls, and revetments • Indoor and outdoor swimming pools • Structures over water, including piers, docks, and boat houses • Personal property • Loss of land and landscaping

INSURABILITY UNDER NFIP

To be insurable under the NFIP, a "building" must be walled and roofed with two or more rigid exterior walls and must be more than 50 percent above grade. Examples of structures that are **NOT** insurable because they do not meet this definition are:

- Gazebos and pavilions.
- Docks.
- Campers and tents.
- Underground storage tanks.
- Swimming pools.
- Fences.
- Retaining walls, seawalls, and bulkheads.
- Septic tanks.

Buildings constructed entirely over water or seaward of mean high tide after October 1, 1982, are not eligible for flood insurance coverage. Certain parts of boathouses located partially over water (e.g., the ceiling and roof over the area where boats are floated) are not eligible for coverage.

PREMIUMS

The premium paid is based on the rating factors previously discussed, plus the following:

- An expense constant.
- A Federal policy fee.
- The cost of Increased Cost of Compliance (ICC) Coverage.
- The amount of deductible chosen by the insured.

Community Rating System

If a community elects to exceed the minimum NFIP requirements, it may apply for a classification under the NFIP Community Rating System (CRS). Based on its floodplain management program, the community could receive a CRS classification that provides up to a 45 percent premium discount for property owners within the community. Approximately 900 communities participate in the CRS, representing over 65 percent of all flood insurance policies.

Impact of Zone and Elevation on Premiums

Tables 9.7 and 9.8 illustrate differences in premiums because of zone and elevation in relation to the BFE.

Table 9.7 lists sample NFIP premiums for a post-FIRM, one-story, single-family residence without a basement in an A zone with different elevations of the lowest floor. For buildings in A zones, premiums rise when proper flood openings are not provided in enclosed areas or when service equipment or utilities are located below the BFE.

Table 9.8 makes the same kinds of comparisons for a V-zone building, with and without obstruction. For buildings in V zones, premiums rise somewhat for structures with breakaway obstructions, and premiums rise dramatically for structures with obstructions (e.g., service equipment, utilities, or non-breakaway walls) below the lowest floor.

Table 9.7. Sample NFIP Flood Insurance Premiums for Buildings in A Zones (Coverage: $200,000 Building / $100,000 Contents)

Flood Zone	Elevation of Lowest Floor Above/Below the BFE (ft)	Annual Premium[a]	Savings
AE	-1	$3,093	$-2,376
AE	0	$717	0
AE	+1	$531	$186
AE	+2	$440	$277
AE	+3	$420	$297

Table 9.8. Sample NFIP Flood Insurance Premiums for Buildings in V Zones — With and Without Obstructions Below the Lowest Floor[b] (Coverage: $200,000 Building / $100,000 Contents)

Flood Zone	Elevation of the Lowest Floor Above or Below the BFE (ft)	Annual Premium[a] w/ No Obstruction	Savings	Annual Premium[a] w/ <300ft^2 Obstruction	Savings
VE	-2	$4,850	-$2,150	$5,430	-$2,010
VE	-1	$3,610	-$910	$4,250	-$830
VE	0	$2,700	0	$3,420	0
VE	+1	$2,010	$690	$2,810	$610
VE	+2	$1,430	$1,270	$2,290	$1,130
VE	+3	$1,110	$1,590	$2,050	$1,370
VE	+4	$990	$1,710	$1,950	$1,470

[a]Rates as of May 1998.
[b]For buildings with >300 ft^2 obstruction, premium to be determined by NFIP underwriting department from information provided by insurance agent.

SELF-CHECK REVIEW: FLOOD INSURANCE

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Insurance considerations can affect the height of coastal buildings.

   True False

2. When is the best time to involve an insurance industry representative?

   a. As soon as the building is completed.
   b. During construction.
   c. During design.
   d. When the building is walled and roofed.

3. Flood insurance is typically part of standard homeowner's insurance policies.

   True False

4. In most areas, earthquake insurance is not available.

   True False

5. Gazebos, swimming pools, and seawalls are insurable under NFIP.

   True False

6. What impact are the following likely to have on insurance premiums? (Mark one column for each.)

	Increase	Decrease	No Impact
a. Participate in the Community Rating System			
b. Locate the lowest floor of elevated building in a V-zone below the BFE			
c. Build in an X zone rather than an A zone.			
d. Eliminate breakaway walls in a V-zone design.			
e. Build in a V zone rather than an A zone.			
f. Eliminate openings in the enclosed area below the BFE in an A zone.			
g. Locate the furnace in the space below an elevated building in a V zone.			
h. Add freeboard.			

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Insurance considerations can affect the height of coastal buildings.

   True

2. When is the best time to involve an insurance industry representative?

   c. During design.

3. Flood insurance is typically part of standard homeowner's insurance policies.

   False

4. In most areas, earthquake insurance is not available.

   False

5. Gazebos, swimming pools, and seawalls are insurable under NFIP.

   False

6. What impact are the following likely to have on insurance premiums? (Mark one column for each.)

	Increase	Decrease	No Impact
a. Participate in the Community Rating System		x	
b. Locate the lowest floor of elevated building in a V-zone below the BFE	x		
c. Build in an X zone rather than an A zone.		x	
d. Eliminate breakaway walls in a V-zone design.		x	
e. Build in a V zone rather than an A zone.	x		
f. Eliminate openings in the enclosed area below the BFE in an A zone.	x		
g. Locate the furnace in the space below an elevated building in a V zone.	x		
h. Add freeboard.		x	

WIND INSURANCE

Sources of Wind Insurance

Homeowner's Policy. Wind insurance coverage is generally part of a homeowner's insurance policy.

Insurance Pools. Underwriting associations (or "pools") provide last-resort insurance to homeowners in coastal areas who cannot obtain coverage from private companies. States that have beach and windstorm insurance plans include Alabama, Florida, Louisiana, Mississippi, New York, North Carolina, South Carolina, and Texas.

Wind-MAP. New Jersey operates the Windstorm Market Assistance Program (Wind-MAP) to help residents in coastal communities find homeowner's insurance on the voluntary market. When Wind-MAP does not identify an insurance carrier for a homeowner, the New Jersey FAIR Plan may provide a policy for windstorm, hail, fire, and other events; it does not cover liability.

Rating Factors

Wind is only one part of the rating system for multi-peril insurance policies such as a homeowner's insurance policy.

The following factors are considered in rating a homeowner's (HO) insurance policy:

- Form (e.g., HO2, HO3, which determines the type of coverage).
- Territory.
- Fire protection class.
- Building code effectiveness.
- Construction type.
- Protective devices.

Premiums can also vary because of other factors (e.g., amount of coverage and deductible) not related to building construction. Some companies adjust their higher optional deductible credit according to construction type, giving more credit to more fire-resistant concrete and masonry buildings.

NOTE

Most companies rely on the Homeowner's Multistate General Rules and State-specific exceptions manual of the Insurance Services Office (ISO) as the benchmark for developing their own manuals. (ISO stresses that its rules are advisory and that it is up to each company to decide what to use and charge.)

The ISO publishes a homeowner's manual in every State except Hawaii, North Carolina, and Washington (where State-mandated insurance bureaus operate), and in Texas (where the ISO Homeowner's Program has been under development).

Territory. Wind coverage credit varies by "territory." An entire State may be one territory. Some States—such as Florida—are broken down into county and sub-county territories. In Florida, the Intracoastal Waterway is frequently used as the boundary line.

Fire Protection Class. ISO publishes a public protection classification for each municipality or fire district based on an analysis of the local fire department, water system, and fire alarm system. This classification does not affect wind coverage, but it is an important part of the rate setting.

Building Code Effectiveness Grading Schedule. ISO also publishes a Building Code Effectiveness Grading Schedule (BCEGS) that rates communities on factors such as the adopted building codes and enforcement of these codes. The schedule focuses on natural hazard mitigation and is used only in the determination of wind, hail, and earthquake coverage. Credit is based on the building code adopted and the relative degree of commitment the community has to code enforcement. In Florida, the BCEGS grading can provide a credit of as much as 11 percent.

NOTE

BCEGS is a **voluntary** program, and not all insurance companies have adjusted their premiums to reflect the community's BCEGS class.

BCEGS—while not fully implemented—is expected to have all States graded by the end of the year 2000. The schedule applies only to buildings constructed during the year of ISO's grading or later.

Construction Type. To simplify insurance underwriting procedures, buildings are identified as being in one of four categories:

Frame	Exterior walls of wood or other combustible construction, including stucco and aluminum siding.
Masonry Veneer	Exterior walls of combustible material, veneered with brick or stone.
Masonry	Exterior walls of masonry materials, floor and roof of combustible materials. (Because it is hard to differentiate masonry veneer from masonry, they are often given the same rating.)
Superior	"Non-combustible," "masonry non-combustible," or "fire resistive." Not many single-family homes qualify as "superior," which qualifies for a 15 percent credit off the masonry rates. A home of this type may also qualify for a wind credit because some insurers believe that buildings with walls, floors, and roofs made of concrete products offer good resistance to windstorms and Category 1 hurricanes. Therefore, a fire-resistive home may get a wind-resistive credit.

ISO's dwelling insurance program allows companies to collect data from the owner, the local building department, or their own inspectors to determine whether a house can be classified as "wind-resistive" or "semi-wind-resistive" for premium credit purposes.

Protective Devices. Protective devices are not considered basic factors, but items that may deserve some credits. This approach is more common for fire and theft coverages which, for example, credit sprinklers and fire and/or burglar alarms tied to the local fire or police stations.

ISO's rules do not address wind protective devices, except in Florida.

FLORIDA

In Florida, a premium credit is given if "…exterior wall and roof openings [other than roof ridge and soffit vents] are fully protected with storm shutters of any style and material that are designed and properly installed…" to:

(1) Meet the latest ASCE 7 engineering standard adopted by Dade County and

(2) Withstand impact from windborne debris in accordance with standards set by

   (a) The municipality or
   (b) If there are no local standards, by Dade County.

The rules also provide specifications for alternatives to storm shutters, such as windstorm protective glazing material.

EARTHQUAKE INSURANCE

Earthquake insurance is an addition to a regular homeowner's insurance policy. Earthquake insurance carries a very high deductible—usually 10 or 15 percent of the value of the house.

In most States, ISO has developed advisory earthquake loss costs based on a seismic model used to estimate potential damage to individual properties in the event of an earthquake. The model is based on:

- Seismic data.
- Soil types.
- Damage information from previous earthquakes.
- Structural analysis of various types of buildings.

Based on this model, postal ZIP codes have been assigned to rating bands and loss costs developed for each band. The number of bands varies within each State and, at times, within a county.

In California, the California Earthquake Authority (CEA), a State-chartered insurance company, writes most earthquake policies for homeowners. These policies cover the dwelling and its contents and are subject to a 15 percent deductible. CEA rates are also based on a seismic model used to estimate potential damage to individual properties in the event of an earthquake.

SELF-CHECK REVIEW: WIND AND EARTHQUAKE INSURANCE

Instructions: Answer the following questions. Then turn the page to check your answers. If you answered any items incorrectly, you should review the related material before continuing.

1. Wind insurance coverage is generally part of a homeowner's insurance policy.

   True False

2. The Building Code Effectiveness Grading Schedule is a voluntary rating program that focuses on natural hazard mitigation.

   True False

3. Earthquake insurance is generally part of a homeowner's standard insurance policy.

   True False

4. Give three examples of factors that affect wind insurance rates.

The Answer Key for the preceding Self-Check Review is located on the next page.

ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Wind insurance coverage is generally part of a homeowner's insurance policy.

   True

2. The Building Code Effectiveness Grading Schedule is a voluntary rating program that focuses on natural hazard mitigation.

   True

3. Earthquake insurance is generally part of a homeowner's standard insurance policy.

   False

4. Give three examples of factors that affect wind insurance rates.

   Any of the following:
   - **Form of coverage**
   - **Territory**
   - **Fire protection class**
   - **Building code effectiveness**
   - **Construction type**
   - **Protective devices**

UNIT IX EXERCISE

Instructions: Use this Unit Exercise to test how well you learned the material presented in Unit IX. When you complete the exercise, check your answers against those in the Answer Key that follows. If you answered any questions incorrectly, be sure to review the corresponding section of the unit before proceeding to the Final Test.

1. Name a benefit and a cost of using connectors that have thicker galvanized coating or that are made of stainless steel.

   Benefit: ____

   Cost: ____

2. Name another mitigation measure and a potential benefit and cost of using that measure.

   Mitigation measure: ____

   Benefit: ____

   Cost: ____

3. The initial costs of additional mitigation measures are often offset by long-term benefits.

   True False

4. Match the types of insurance on the left with the descriptions on the right.

____ Flood insurance		a.	Typically covered under homeowner's policy
____ Wind insurance		b.	Usually covered under homeowner's policy
____ Earthquake insurance		c.	Usually requires a separate endorsement
____ Coverage for lightning, hail, and freezing		d.	Separate insurance available in communities that participate in NFIP

5. Factors used to determine NFIP insurance rates include building occupancy and building type. Name two other factors.

   (1) ____

   (2) ____

6. What can change the insurance rate for pre-FIRM buildings?

7. List two examples of items below the BFE that typically are not covered under a Standard Flood Insurance Policy.

   (1) ____

   (2) ____

8. Explain how zone and elevation affect flood insurance premiums.

9. Two factors used to determine wind insurance rates include territory and fire protection class. Name two other factors.

   (1) ____

   (2) ____

The Answer Key for the preceding Unit Exercise is located on the next page.

UNIT IX EXERCISE — ANSWER KEY

NOTE: Some of your answers may be slightly different, but they should include the same main points.

1. Name a benefit and a cost of using connectors that have thicker galvanized coating or that are made of stainless steel.

   Benefit: **Reduces potential for corrosion**

   Cost: **Thicker coating and stainless steel are more costly.**

2. Name another mitigation measure and a potential benefit and cost of using that measure.

   (Answers will vary; see Table 9.1.)

3. The initial costs of additional mitigation measures are often offset by long-term benefits.

   True

4. Match the types of insurance on the left with the descriptions on the right.

__**d**__	Flood insurance	a.	Typically covered under homeowner's policy
__**b**__	Wind insurance	b.	Usually covered under homeowner's policy
__**c**__	Earthquake insurance	c.	Usually requires a separate endorsement
__**a**__	Coverage for lightning, hail, and freezing	d.	Separate insurance available in communities that participate in NFIP

5. Factors used to determine NFIP insurance rates include building occupancy and building type. Name two other factors.

   Any of the following:
   - **Flood insurance zone**
   - **Date of construction**
   - **Elevation of the lowest floor or bottom of the lowest horizontal structural member of the lowest floor**
   - **Enclosures below the lowest floor**
   - **Location of utilities and service equipment**

6. What can change the insurance rate for pre-FIRM buildings?

   Substantial improvement or substantial damage

7. List two examples of items below the BFE that typically are not covered under a Standard Flood Insurance Policy.

   (Answers will vary; see Table 9.6.)

8. Explain how zone and elevation affect flood insurance premiums.

   Premiums tend to be higher in V zones than A zones. Premiums for buildings in B, C, and X zones are the least expensive. Elevating a building above the BFE lowers the premium, with greater savings for greater freeboard.

9. Two factors used to determine wind insurance rates include territory and fire protection class. Name two other factors.

   Any of the following:
   - **Building code effectiveness**
   - **Construction type**
   - **Protective devices**

A NOTE ABOUT RELATED COURSES AND THE COASTAL CONSTRUCTION MANUAL

This independent study course has drawn heavily from Volume I of the *Coastal Construction Manual*. The related classroom course, "Residential Coastal Construction," is available as a 5-day resident course presented at the National Training Center of the Emergency Management Institute (EMI) in Emmitsburg, Maryland, as well as a 2-day nonresident course presented at field locations.

The classroom course draws heavily from Volume II of the *Coastal Construction Manual*, which covers the following topics:

- **Determining site-specific loads—**dead, live, snow, flood, tsunami, wind, tornado, and seismic loads and load combinations.

- **Designing the building**—carrying out the design process, including (1) determining loads, (2) applying loads to the building, (3) determining forces at connections and stresses, (4) developing connections at each link, and (5) selecting building materials. Detailed information is also provided on design of the building envelope, utilities/mechanical equipment, and appurtenant structures.

- **Constructing the building**—key issues related to constructing the foundation, structural frame, and building envelope. Information is also provided about accessory structures and utility/mechanical equipment.

- **Maintaining the building**—effects of the coastal environment, building elements that require frequent maintenance, and maintenance techniques required for natural hazards. Information is also provided on retrofit opportunities and costs.

Volume III of the *Coastal Construction Manual* contains a wide array of supplemental information, including FEMA, NFIP, and CZMA contact information; examples of State and community coastal erosion studies and hazard zone maps; FEMA technical bulletins; and other guidance. Many of the technical bulletins referenced in this independent study course are provided in Volume III.

All three volumes of the *Coastal Construction Manual* are provided to course participants.

APPENDIX A: GLOSSARY

GLOSSARY

A zone — Under the NFIP, area subject to inundation by the 100-year flood where wave action does not occur or where waves are less than 3 feet high; designated Zone A, AE, A1–A30, A0, AH, or AR on Flood Insurance Rate Maps. See **Coastal A zone** and **Non-coastal A zone**.

Base flood — Flood that has a one percent probability of being equaled or exceeded in any given year. Also known as the 100-year flood.

Base Flood Elevation — Elevation of the base flood in relation to a specified datum, such as the NGVD. The base flood elevation is the basis of the insurance and floodplain management requirements of the NFIP.

Basement — Under the NFIP, any area of a building having its floor subgrade on all sides. (Note: What is typically referred to as a "walkout basement," which has a floor that is at or above grade on at least one side, is not considered a basement under the NFIP.)

Bathymetry — Ground elevations below the waterline.

Beach nourishment — Replacement of beach sand removed by ocean waters.

BFE — Base Flood Elevation**.**

BPAT — Building Performance Assessment Team.

Breakaway wall — Under the NFIP, a wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system. Breakaway walls are required by the NFIP regulations for any enclosures constructed below the BFE beneath elevated buildings in V zones. In addition, breakaway walls are recommended in areas where flood waters flow at high velocities or contain ice or other debris.

Bulkhead — Wall or other structure, often of wood, steel, stone, or concrete, designed to retain or prevent sliding or erosion of the land. Occasionally, bulkheads are used to protect against wave action.

CCCL — Coastal Construction Control Line.

Coastal A zone — The portion of the SFHA landward of a V zone or landward of an open coast without mapped V zones (e.g., the shorelines of the Great Lakes, in which the principal sources of flooding are astronomical tides, storm surges, seiches, or tsunamis, not riverine sources). This classification, introduced in the *Coastal Construction Manual*, is not currently recognized by the NFIP.

Coastal geology — The origin, structure, and characteristics of the sediments that make up the coastal region, from the uplands to the nearshore region.

Coastal sediment budget — The identification of sediment sources and sinks, and the quantification of the amounts and rates of sediment transport, erosion, and deposition within a defined region.

Cross-shore sand transport — Wave- and/or tide-generated movement of shallow-water coastal sediments toward or away from the shoreline.

Design flood — The greater of either (1) the base flood or (2) the flood associated with the flood hazard area depicted on a community's flood hazard map, or otherwise legally designated.

Design flood elevation (DFE) — Elevation of the design flood, or the flood protection elevation required by a community, including wave effects, relative to the NGVD or other datum.

Dune toe — Junction of the gentle slope seaward of the dune and the dune face, which is marked by a slope of one on 10 or steeper.

Ebb shoals — Sediment deposits formed by ebb tidal currents just offshore of a tidal inlet (also called ebb tidal delta).

Enclosure — That portion of an elevated building below the DFE that is partially or fully surrounded by solid (including breakaway) walls.

FBBCS — Florida Bureau of Beaches and Coastal Systems.

Fetch — Distance over which wind acts on the water surface to generate waves.

Fill — Material such as soil, gravel, or crushed stone placed in an area to increase ground elevations or change soil properties. See **structural fill**.

FIRM — Flood Insurance Rate Map.

FIS — Flood Insurance Study.

500-year flood — Flood that has a 0.2 percent probability of being equaled or exceeded in any given year.

Flood — Under the NFIP, either (a) a general and temporary condition or partial or complete inundation of normally dry land areas from:

(1) the overflow of inland or tidal waters,
(2) the unusual and rapid accumulation or runoff of surface waters from any source, or
(3) mudslides which are proximately caused by flooding as defined in (2) and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when the earth is carried by a current of water and deposited along the path of the current,

or (b) the collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined in (1).

Flood-damage-resistant material — Any construction material capable of withstanding direct and prolonged contact (i.e., at least 72 hours) with flood waters without suffering significant damage (i.e., damage that requires more than cleanup or low-cost cosmetic repair, such as painting).

Flood elevation — Height of the water surface above an established elevation datum such as the NGVD or mean sea level.

Flood shoals — Sediment deposits formed just inside a tidal inlet by flood tidal currents (also called flood tidal delta).

Freeboard — Under the NFIP, a factor of safety, usually expressed in feet above flood level, that is applied for the purposes of floodplain management. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than those calculated for a selected flood, such as the base flood.

Frontal dune reservoir — Ridge or mound of unconsolidated sandy soil, extending continuously along shore landward of the sand beach and defined by relatively steep slopes abutting markedly flatter and lower regions on each side.

Groins — Short, shore-perpendicular structures designed to trap available littoral sediments.

Hazard identification — The process of defining and describing a hazard (including its physical characteristics, magnitude, severity, frequency, and causative factors) and the locations or areas it affects.

High-velocity wave action — Condition in which wave heights or wave runup depths are greater than or equal to 3 feet.

Hydrodynamic loads — Loads imposed on an object, such as a building, by water flowing against and around it. Among these loads are positive frontal pressure against the structure, drag effect along the sides, and negative pressure on the downstream side.

Hydrostatic loads — Loads imposed on a surface, such as a wall or floor slab, by a standing mass of water. The water pressure increases with the square of the water depth.

Jetty — Wall built out into the water to restrain currents or protect a structure.

Littoral — Of or pertaining to the shore, especially of the sea; coastal.

Littoral drift — Movement of sand by littoral (longshore) currents in a direction parallel to the beach along the shore.

Longshore sand transport — Wave- and/or tide-generated movement of shallow-water coastal sediments parallel to the shoreline.

Lowest floor — The lowest floor of a building includes the floor of a basement. The NFIP regulations define a basement as "…any area of a building having its floor subgrade (below ground level) on all sides."

Lowest horizontal structural member — In an elevated building, the lowest beam, joist, or other horizontal member that supports the building. Grade beams installed to support vertical foundation members where they enter the ground are not considered lowest horizontal structural members.

Masonry — Built-up construction of a combination of building units or materials of clay, shale, concrete, glass, gypsum, stone, or other approved units bonded together with or without mortar or grout or other accepted methods of joining.

Mean sea level — Average height of the sea for all stages of the tide, usually determined from hourly height observations over a 19-year period on an open coast or in adjacent waters having free access to the sea.

Mitigation — Sustained action taken to reduce or eliminate long-term risk to people and property from hazards and their effects.

NEHRP — National Earthquake Hazard Reduction Program.

NFIP — National Flood Insurance Program.

NGVD — National Geodetic Vertical Datum, established in 1929 and used as a basis for measuring flood, ground, and structural elevations. Previously referred to as Sea Level Datum or Mean Sea Level. The BFEs shown on most of the FIRMs issued by FEMA are referenced to NGVD or, more recently, to the North American Vertical Datum.

NOAA — National Oceanic and Atmospheric Administration.

Non-coastal A zone — Portions of the SFHA in which the principal source of flooding is runoff from rainfall, snowmelt, or a combination of both. (The NFIP does not differentiate between coastal and non-coastal A zones.)

100-year flood — See **Base flood**.

Overwash — Transport of sediments carried landward by floodwaters, burying uplands, roads, and at-grade structures.

Pre-FIRM — In communities participating in the NFIP, buildings constructed on or before the date of the first FIRM for that community (or 12/31/74—whichever is later). These buildings have flood insurance rates that are "grandfathered" or "subsidized."

Post-FIRM — For purposes of determining insurance rates under the NFIP, structures for which the start of construction began on or after the effective date of an initial FIRM or after 12/31/74 (whichever is later), including any subsequent improvements to such structures.

Primary frontal dune — Under the NFIP, a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope.

Revetment — Facing of stone, cement, sandbags, or other materials placed on an earthen wall or embankment to protect it from erosion or scour caused by flood waters or wave action.

Risk — Potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences.

Risk assessment — The process of evaluating risk that is associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude, severity, exposure, and consequences.

Risk management — Measures taken to reduce, modify, offset, or share risks associated with development in areas subject to coastal hazards. In the context of coastal residential construction, this is usually accomplished through mitigation or insurance.

Seawall — Solid barricade built at the water's edge to protect the shore and to prevent inland flooding.

SFHA — Special Flood Hazard Area. Under the NFIP, an area having special flood, mudslide, and/or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or FIRM as Zone A, AO, A1–A30, AE, A99, AH, V, V1–V30, VE, M, or E.

Stillwater elevation —The elevation of the water surface resulting solely from storm surge (i.e., the rise in the surface of the ocean caused by the action of wind and the drop in atmospheric pressure associated with hurricanes and other storms).

Storm surge — Rise in the water surface above normal water level on the open coast caused by the action of wind stress and atmospheric pressure on the water surface.

Storm tide — Combined effect of storm surge, existing astronomical tide conditions, and breaking wave setup.

Structural fill — Fill compacted to a specified density to provide structural support or protection to a structure. See **Fill**.

Substantial damage — Damage to a building (regardless of the cause) is considered substantial damage if the cost of restoring the building to its before-damage condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement — An improvement of a building (e.g., reconstruction, rehabilitation, or addition) is considered a substantial improvement if its cost equals or exceeds 50 percent of the market value of the building before the start of construction of the improvement.

Tidal inlet — Short, narrow hydraulic connection between the ocean and inland water.

Tsunami — Great sea wave produced by submarine earth movement or volcanic eruption.

Underlayment — One or more layers of felt, sheathing paper, nonbituminous saturated felt, or other approved material over which a steep-sloped roof covering is applied.

Uplift — Hydrostatic pressure caused by water under a building. It can be strong enough to lift a building off its foundation, especially when the building is not properly anchored to its foundation.

V zone — The portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources. Also referred to as the **Coastal High Hazard Area.**

Wave crest elevation — The elevation of the crest of a wave, referenced to the NGVD or other datum.

Wave height — The height, above the wave trough, of the crest of a wind-driven wave (i.e., the vertical distance between the wave crest and wave trough).

Wave runup — The rush of wave water up a slope or structure.

Wave runup depth — Wave runup depth at any point is equal to the maximum wave runup elevation minus the lowest eroded ground elevation at that point.

Wave runup elevation — The elevation reached by wave runup, referenced to the NGVD or other datum.

Wave setup — An increase in the stillwater surface near the shoreline, caused by the presence of breaking waves. Wave setup typically adds 1.5 to 2.5 feet to the 100-year stillwater flood elevation.

X zone — Areas where the flood hazard is less than that in the SFHA. Shaded X zones shown on recent FIRMs (B zones on older FIRMs) designate areas subject to inundation by the flood with a 0.2 percent annual probability of being equaled or exceeded (the 500-year flood). Unshaded X zones (C zones on older FIRMs) designate areas where the annual exceedance probability of flooding is less than 0.2 percent.

APPENDIX B: FINAL EXAMINATION

FINAL EXAMINATION

Instructions: This examination will test how much you have learned during the Introduction to Residential Coastal Construction course. You **must** successfully pass this test to receive credit for the course. Follow the steps below to complete this test.

Individual Enrollments

1. Some machine-scored answer sheets have been preprinted with your name, address, social security number (SSN) and course number. Please make any necessary corrections to this information in the space provided. Because the bar code on this type of answer sheet contains the same data, other students should not use an answer sheet prepared for you. Other machine-scored answer sheets require you to complete your own identification data, and will automatically update or establish your student record according to the information provided on the most recent answer sheet processed.
2. After completing the study units, take the final examination and record your answers on the answer sheet using a #2 pencil or black or blue ink pen only. (Please note: The answer sheet may contain more spaces than the number of questions on your final examination.) **To take the final exam online, visit <u>www.fema.gov/emi/ishome.htm</u>, and follow the links to the specific course. Most courses offer an online testing option.**
3. Fill in your return address on the reverse side of the answer sheet, provide required postage, and mail. If your preprinted answer sheet includes your SSN just above your preprinted name and address, feel free to fold your answer sheet once and mail it in a standard envelope.
4. If you misplace your preprinted answer sheet, a generic answer sheet (FEMA Form 95-5a) may have been bound on or near the last page of the text. Please complete the answer sheet as outlined below.

Students with No Answer Sheet

1. Clearly print your name, address, SSN, and course name and number at the top of a blank sheet of paper.
2. After completing the study units, take the final examination and record your answers. **To take the final exam online, visit <u>www.fema.gov/emi/ishome.htm</u>, and follow the links to the specific course. Most courses offer an online testing option.**

When you have completed your examination and checked your answers, mail the form to:

FEMA Independent Study Program
Independent Study Office
Emergency Management Institute
16825 South Seton Avenue
Emmitsburg, MD 21727

FEMA's Independent Study Office will score your test and notify you of the results.

1. If you are standing between the inland side of the primary frontal dune and the beach, what zone are you in?

   a. AE zone
   b. V zone
   c. X zone
   d. Coastal A zone

2. Areas that are subject to inundation by a flood that has a one percent probability of being equaled or exceeded in any given year are called:

   a. V zones
   b. Special Flood Hazard Zones (SFHAs)
   c. BFEs
   d. Coastal A zones

3. Which of the following should be avoided in coastal areas subject to wave impact?

   a. Freeboard above the BFE
   b. Elevation on pilings
   c. Continuous-perimeter wall foundations
   d. Continuous load path from roof to foundation

4. Current FIRMs do not account for:

   a. Potential loss of protective dunes during the 100-year flood.
   b. Long-term erosion.
   c. Historical trends.
   d. Topographic information.

5. Coastal sediment budget refers to:

   a. The amounts and rates of shoreline accretion vs. shoreline erosion within a defined region.
   b. The process of weighing costs and benefits of mitigation strategies.
   c. The relative pro's and cons of beach nourishment and dune restoration projects.
   d. The amount of financing a community commits to beach preservation.

6. _____________ is used to establish BFEs and differentiate flood hazard zones.

   a. Wave runup
   b. Storm surge
   c. Accretion rate
   d. Wave height

7. Which of the following areas are most vulnerable to hurricanes?

    a. Southern Atlantic and Gulf of Mexico coasts
    b. Great Lakes coasts
    c. Northern Pacific coasts
    d. Alaska coasts

8. To be considered a success, a building must:

    a. Remain undamaged throughout its lifetime.
    b. Resist damage from coastal hazards over a period of decades.
    c. Survive a 100-year hazard event.
    d. Remain structurally sound (whether or not it is accessible and usable).

9. In a coast A zone, which of the following design decisions is likely to result in **reduced** long-term costs?

    a. Building on an open foundation
    b. Building on a perimeter wall foundation
    c. Building on a slab foundation
    d. Building on structural fill

10. Risk assessment must account for all of the following **EXCEPT**:

    a. Short-term and long-term effects of each hazard on the building.
    b. Cumulative effects of multiple hazards on the building.
    c. Combination of effects on the building from different hazards.
    d. The building's ability to remain undamaged over its intended lifetime.

11. Which of the following is an example of risk management through hazard mitigation?

    a. Siting as close to the shoreline as permitted by NFIP regulations.
    b. Eliminating enclosures below an elevated building.
    c. Obtaining hazard insurance.
    d. Placing the lowest floor 2 inches below BFE.

12. To determine the probability that a building will be affected by a specific natural hazard event, the designer must know:

    a. Initial, long-term, and operational costs.
    b. The acceptable level of risk.
    c. Recurrence interval of the event and period of exposure.
    d. Federal, State, and local regulations and codes.

13. After compiling information about candidate properties, the next task is to:

    a. Conduct a hazard analysis and risk assessment.
    b. Determine whether hazards can be mitigated through siting, design, or construction.
    c. Design the building.
    d. Proceed with development or reject the property.

14. FIRMs will give the designer the following information:

    a. Erosion rates and setback information.
    b. Base flood elevation and flood hazard zone.
    c. 100-year stillwater elevation.
    d. Basis for BFE determination (e.g., tide frequency analysis, wave crest, wave runup).

15. The footprint of a coastal residence lies 10 feet in the V zone and 40 feet in the A zone. According to minimum NFIP requirements:

    a. The top of the lowest floor must be at or above BFE, on an open foundation.
    b. The bottom of the lowest horizontal structural member must be at or above BFE, on a solid or open foundation.
    c. The top of the lowest floor must be at or above BFE, on a solid or open foundation.
    d. The bottom of the lowest horizontal structural member must be at or above BFE, on an open foundation.

16. A community that adopts __________ will be compliant with the regulatory requirements of the NFIP and the NEHRP recommendations.

    a. IBC 2000 and IRC 2000
    b. Building codes
    c. Standards
    d. Land use regulations

17. The NFIP regulations require that buildings be constructed with methods and practices that minimize flood damage. This requirement applies to buildings in:

    a. The CBRS.
    b. The SFHA.
    c. V zones only.
    d. A zones only.

18. Which of the following causes the most severe flood damage to coastal buildings?

    a. Vertical hydrostatic forces (flotation)
    b. Breaking waves
    c. Outflow
    d. Floodborne debris

19. Tropical cyclones can cause all of the following **EXCEPT:**

    a. Tsunamis.
    b. Coastal flooding.
    c. High winds.
    d. Significant erosion.

20. In a hurricane, even minor damage to the ___________ can lead to large economic losses.

    a. Space below the BFE
    b. Service equipment and utilities
    c. Structural frame
    d. Building envelope

21. Long-term erosion:

    a. Is a key consideration in flood insurance studies (FIS).
    b. Can be halted by beach nourishment.
    c. Is not a concern for buildings built on bluffs.
    d. Shifts flood hazard zones landward.

22. Wind damage to a building depends on:

    a. The height of the building above ground and the wind event recurrence interval.
    b. The height of wind-generated waves.
    c. The shape of the building and the type, size, and protection of openings.
    d. Location of the building in a V zone, A zone, or coastal A zone.

23. In evaluating existing hazard information, designers should:

    a. Check the date of the FIRM.
    b. Disregard the FIRM because FIS methods have changed.
    c. Assume that FIRM data are reliable if the WHAFIS model was used.
    d. Recalculate all flood depths if short-term erosion has occurred.

24. Siting strategies for reducing risk include all of the following **EXCEPT**:

    a. Combining lots or parcels.
    b. Seeking variances to lot line setbacks along the landward and side property lines.
    c. Constructing protective structures (if permitted).
    d. Maximizing the building footprint to better distribute loads on the structure.

25. Which of the following is a raw land development siting practice to be avoided?

    a. Place a road close to the shoreline, with small lots grouped between it and the shoreline.
    b. Cluster development away from the shoreline.
    c. Leave the lot landward of an opening between dunes as open space.
    d. Create deep, parallel lots that allow generous setback for all buildings.

26. Which of the following is a recommended infill development practice?

    a. Site the building immediately adjacent to an existing erosion-control structure.
    b. Allow uncontrolled pedestrian access to the shoreline across dunes.
    c. Place the building exactly as close to the shoreline as allowed by regulations.
    d. Site the building farther landward than the minimum required setback.

27. Which of the following would cause insurance for a coastal residence to be more costly?

    a. Siting the building in an AE zone rather than a VE zone.
    b. Constructing the lowest floor of an elevated V-zone building above the BFE.
    c. Eliminating openings in the enclosed area below the BFE in an A zone.
    d. Locating service equipment above the BFE.

28. NFIP flood insurance is:

    a. Provided by the Federal Government.
    b. Cost-free for communities that participate in the Community Rating System.
    c. Federally backed insurance obtained through private insurance companies.
    d. Available for all homes within the SFHA.

29. If you obtain a federally regulated mortgage for your beachfront property and use that property to secure the mortgage, you:

    a. Do not need to buy flood insurance because the property is automatically insured.
    b. Are automatically eligible for NFIP insurance.
    c. Cannot obtain flood insurance.
    d. Must obtain flood insurance.

30. When assessing potential flood hazards, the effects of multiple storms should be considered.

    a. True
    b. False

31. Meeting minimum A zone foundation and elevation requirements ensures that a building can resist coastal flood forces.

    a. True
    b. False

32. Siting downdrift of a stabilized tidal inlet does not protect a building from significant erosion.

    a. True
    b. False

33. It is prudent to incorporate freeboard in the design of a coastal building.

    a. True
    b. False

34. Failure to provide a continuous load path from roof to foundation may lead to structural failure.

    a. True
    b. False

35. Designers should ignore the effects of low-frequency, rare events when determining a site's potential vulnerability to hazards.

    a. True
    b. False

36. Designers should minimize the use of breakaway wall enclosures below the BFE in V zones.

    a. True
    b. False

37. If more sediment is transported by coastal processes or human actions into a given area than is transported out, shoreline accretion results.

    a. True
    b. False

38. Stillwater elevations in coastal areas will be controlled by the wave crest elevation or the Base Flood Elevation—whichever is higher.

    a. True
    b. False

39. Because storms are short-lived, the amount of erosion induced by storms tends to be minor.

    a. True
    b. False

40. In a design seismic event, a building that sustains significant damage but protects life and provides safety would be considered a building success.

    a. True
    b. False

41. Building codes do not apply to existing buildings that are being rehabilitated or modified.

    a. True
    b. False

42. Most U.S. coastal States have adopted a model building code and/or specific requirements concerning the construction of buildings in coastal flood and wind hazard areas.

    a. True
    b. False

43. Safety factors are inherent in the design process for wind but not for flood.

    a. True
    b. False

44. Prudent siting and insurance are both mitigation approaches.

    a. True
    b. False

45. In identifying candidate coastal properties for development, past development practices in the area are one of the best indicators of potential success.

    a. True
    b. False