

# Appendix G

## Examples of State and Community Coastal Erosion Studies and Hazard Zone Maps

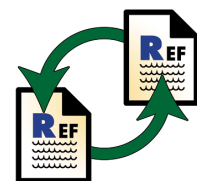
### G.1 Introduction

This appendix provides the designer with two things:

1. *A description of 31 coastal erosion reports, databases, and references* covering all or portions of the U.S. coastline. These documents illustrate the types of studies and knowledge currently available to the designer. Many more reports, databases, and references exist. Those listed are intended to provide a starting point, from which the designer can proceed.
2. *A description of 27 coastal hazard zone delineations* previously completed by local and state agencies. As in the case of erosion studies, these delineations illustrate the types of hazard zone studies and maps that have been produced for areas susceptible to one or more of the following coastal hazards: coastal storms, wave effects, high winds, tsunamis, erosion, bluff failures, landslides, sea level rise, and wildfires. Many more hazard zone studies and maps exist. Those listed are intended to provide a starting point, from which the designer can proceed.

### G.2 Examples of Coastal Erosion Databases and Studies

A few selected methodological reports and sources of shoreline change data are described below. Note that this list is merely a sample of the types of publications, data, and study approaches that exist; the list is not intended to be complete or exhaustive. Reports and data listed below are keyed to the map in Figure G-1.

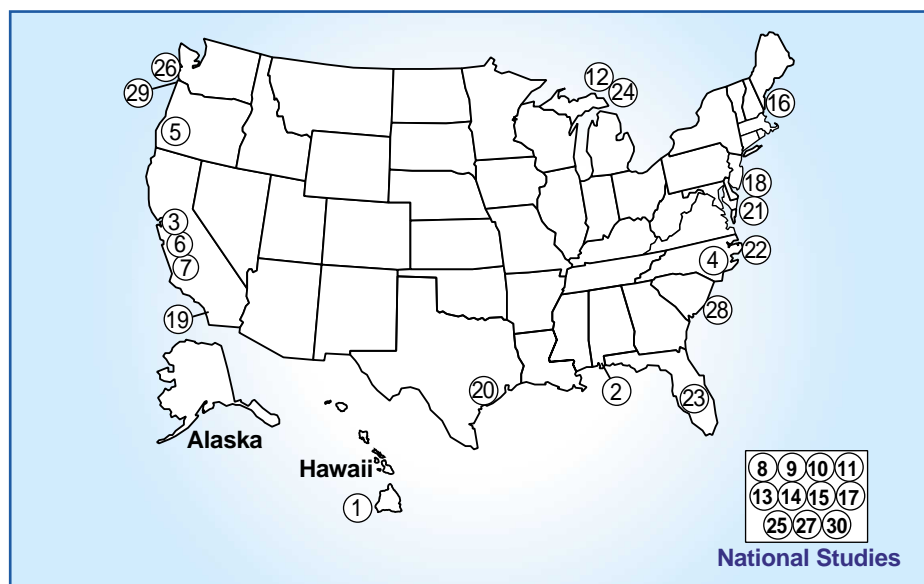


#### CROSS-REFERENCE

See Section 7.5.2.4 for information about additional FEMA-sponsored erosion studies in 27 coastal counties and 18 states.

**Figure G-1**

Key to examples of coastal erosion databases and studies.



1. *A Method for Using Aerial Photos in Delineating Historic Patterns of Beach Accretion and Retreat* (Hwang 1980). This report for the Hawaii Coastal Management Program summarizes shoreline mapping techniques and provides results for a pilot study at Kailua Beach.
2. *Alabama Coastal Hazards Assessment* (NOAA 1997). Along with a wide variety of coastal hazards data, this CD-ROM contains maps, current and historical shorelines, and short-term and long-term erosion rate information for Mobile and Baldwin Counties. This is the first of a series of coastal hazard CD-ROMs planned by NOAA's Coastal Services Center.
3. *Assessment and Atlas of Shoreline Erosion along the California Coast* (California Department of Navigation and Ocean Development 1977). This report presents the first comprehensive mapping of California's shoreline areas subject to damage from erosion. The Atlas presents 129 maps (scale 1" = 2,000') and over 300 photographs covering the entire Pacific shoreline.
4. *Average Annual Long Term Erosion Rate Update, Methods Report* (Benton and McCullough 1988). This report summarizes the methods and results of erosion rate studies by the State of North Carolina for its coastal management program.
5. *Beach-Shoreline Data Base, Pacific Northwest Region, USA* (Peterson et al. 1994). This report describes a database that includes information on beach physiography, beach survey data, and beach sediment characteristics for coastal Washington, Oregon, and northern California.

6. *California's Coastal Hazards* (Griggs 1994). This is one of many pertinent chapters in the *Journal of Coastal Research Special Issue on Coastal Hazards* (Finkl 1994b); the chapter provides an overview of beach erosion, cliff retreat, and coastal flood hazards along the Pacific shoreline of California.
7. *Coast of California Storm and Tidal Waves Study*. A series of reports were produced in the mid-1980s by the USACE, Los Angeles District, as part of a comprehensive study of storms and storm effects along the California shoreline. Report topics included shoreline movement data, geomorphology, geotechnical data, coastal photography and beach profile index, coastal processes data, coastal processes annotated bibliography, meteorological data, socioeconomic data, and annual reports.
8. *Coastal Engineering Manual* (USACE, in preparation). This manual is currently under development as a replacement for the *Shore Protection Manual* (USACE 1984); when complete, it will be an up-to-date compilation of knowledge related to coastal hydrodynamics, coastal sediment processes, coastal geology, coastal project planning, and coastal structures.
9. *Coastal Geology* (USACE 1995a). This report provides an introduction to coastal geology, coastal processes and coastal erosion.
10. *Coastal Inlet Hydraulics and Sedimentation* (USACE 1995b). This report provides an introduction to inlet geomorphology and geology, inlet hydraulics and stability, inlet sediment budgets, and inlet shoaling.
11. *Coastal Littoral Transport* (USACE 1992). This report provides an introduction to waves, littoral processes, nearshore currents, and sediment transport.
12. *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* (Keillor 1998). This manual from the University of Wisconsin Sea Grant Institute provides a thorough treatment of erosion hazards along the Great Lakes shorelines, including guidance for estimating storm surge, wave runup, slope stability and erosion setbacks.
13. *Erosion of the U.S. Shorelines* (Dolan et al. 1983). This is one of many pertinent chapters in the *CRC Handbook of Coastal Processes and Erosion* (Komar 1983); the chapter describes erosion rate information compiled in a nationwide database for the U.S. Geological Survey.
14. *Historical Shoreline Change: Error Analysis and Mapping Accuracy* (Crowell et al. 1991). This paper summarizes the influence of a number of



## NOTE

Information on, and selected sections of, the forthcoming *Coastal Engineering Manual* are available on the USACE website at <http://bigfoot.wes.army.mil/cem001.html>.

parameters (e.g., length of data record, types and accuracy of data sources) on the errors associated with mapped shoreline positions and computed erosion rates.

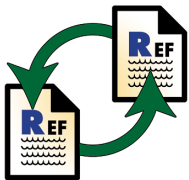
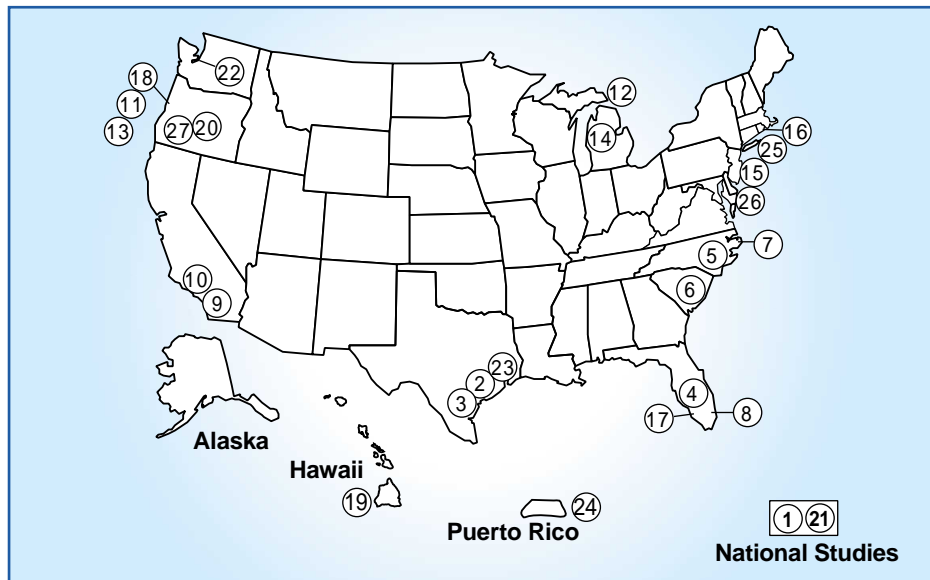
15. *Managing Coastal Erosion* (National Research Council 1990). This report summarizes the conclusions of a national committee on matters related to the causes of erosion, predicting future shoreline changes, and erosion management.
16. *Massachusetts Historic Shoreline Change Analysis Maps* (MCZMP 1985). This series of maps (scale 1:10,000) shows several historical shorelines for the ocean-facing shorelines and includes shoreline change rates calculated at 50-m intervals along the shoreline.
17. *National Shoreline Study* (USACE 1973). Although somewhat dated, this five-volume report provides information on shoreline history, coastal erosion, and erosion control for each U.S. coastal and Great Lakes county.
18. *New Jersey Historical Shoreline Change Maps, New Jersey Beach Profile Data, and New Jersey Historical Inlet Bathymetry* (NJDEP, various dates). A series of maps and data that provide historical shoreline locations between the 1850s and 1990s (available as paper maps or digital files), semiannual beach and nearshore profiles (from 1986 to the present), and historical bathymetry at tidal inlets.
19. *Shoreline Erosion Assessment and Atlas of the San Diego Region* (Flick 1994). This two-volume report summarizes local coastal processes and conditions, along with shoreline management recommendations for various shoreline reaches between Imperial Beach and Dana Point. It updates a portion of the 1977 study, *Assessment and Atlas of Shoreline Erosion along the California Coast*.
20. *Shoreline Movement along Developed Beaches of the Texas Gulf Coast: A Users' Guide to Analyzing and Predicting Shoreline Changes* (Morton 1993). This report summarizes erosion rate methods and results for the Gulf coast.
21. *Shoreline Movements: Report 3* (Knowles and Byrnes, undated). This report and accompanying historical shoreline maps were the product of a U.S. Army Corps of Engineers/NOAA cooperative study of shoreline changes covering the Atlantic shoreline from Delaware to Virginia.
22. *Shoreline Movements: Reports 1 and 2* (Everts et al. 1983, Anders et al. 1990). These reports and accompanying historical shoreline maps were the product of a U.S. Army Corps of Engineers/NOAA cooperative study of shoreline changes covering the Atlantic shoreline from Virginia to South Carolina.

23. *Statistical Characteristics of Florida Shoreline Changes* (Cheng 1998). This report summarizes erosion rate computations and related studies for 25 coastal counties in Florida.
24. *United States Great Lakes Shoreline Recession Rate Data: Final Report and Great Lakes Shoreline Recession Rate Data Base* (Stewart 1994a, 1994b). This report and database provide the most comprehensive collection and assessment of erosion rate data for the Great Lakes shoreline.
25. *Wave Information Studies (WIS) reports* (USACE various dates). The USACE WIS program has produced a series of reports containing detailed hindcast (predicted past) wave data for the Atlantic, Gulf, Pacific and Great Lakes coasts. See Appendix F for a description of WIS and other sources of wave and water level data.
26. *At Ocean's Edge: Coastal Change in Southwest Washington* (Washington Department of Ecology 1998). This video was produced as part of the Southwest Washington Coastal Erosion Study. It summarizes shoreline management issues associated with coastal erosion in southwest Washington, and the scientific efforts underway to document and understand those shoreline changes.
27. *Our Changing Coastlines* (Shepard and Wanless 1971). This book is an excellent reference. It provides an introduction to coastal geology and coastal processes, and detailed information on the history and evolution of U.S. Atlantic and Pacific shorelines.
28. *South Carolina Coastal Erosion Annotated Bibliography* (Sautter and Sangster 1996). A good compilation of reports and studies dealing with coastal erosion and shoreline processes in South Carolina.
29. *Southwest Washington Coastal Erosion Workshop Report* (Gelfenbaum et al. 1997). Proceedings of a May 1996 erosion workshop held at Ocean Shores, WA. The report summarizes the state of knowledge concerning coastal erosion, influence of river entrances on sediment budgets and shoreline movements, community responses to erosion, and related issues.
30. *Coastal Erosion Mapping and Management* (Crowell and Leatherman 1999). This report presents a series of papers summarizing recent erosion mapping studies in 14 states. The studies were undertaken as part of the Coastal Erosion Hazards Study, which was mandated by the NFIP Reform Act of 1994.
31. *Atlas of Shoreline Changes in Louisiana from 1853 to 1989* (Williams et al. 1992). This report summarizes shoreline erosion and accretion data for coastal Louisiana.

### G.3 Examples of State and Community Coastal Hazard Zone Delineations

A few selected hazard zone delineation methods and maps are listed below. Note that this list is merely a sample of the types of hazard identification and delineation approaches that exist; the list is not intended to be complete or exhaustive. Items listed below are keyed to the map in Figure G-2.

**Figure G-2**  
Examples of state and community coastal hazard zone delineations.



#### CROSS-REFERENCE

See Section 5.3.2 for selected hazard disclosure requirements.

#### 1 USACE Coastal High Hazard Zone

The Galveston District of the U.S. Army Corps of Engineers (1975) identified a breaking wave height of 3 feet as critical in terms of causing significant structural damage. This determination became the basis for identifying V zones on National Flood Insurance Program (NFIP) coastal FIRMs.

#### 2 Texas Hurricane Hazard Zones

Figure G-3 is a schematic for hurricane hazard zones proposed by the Texas Coastal and Marine Council (1976). The hazard zones should not be confused with the flood insurance zones on FIRMs that bear the same letter designations:

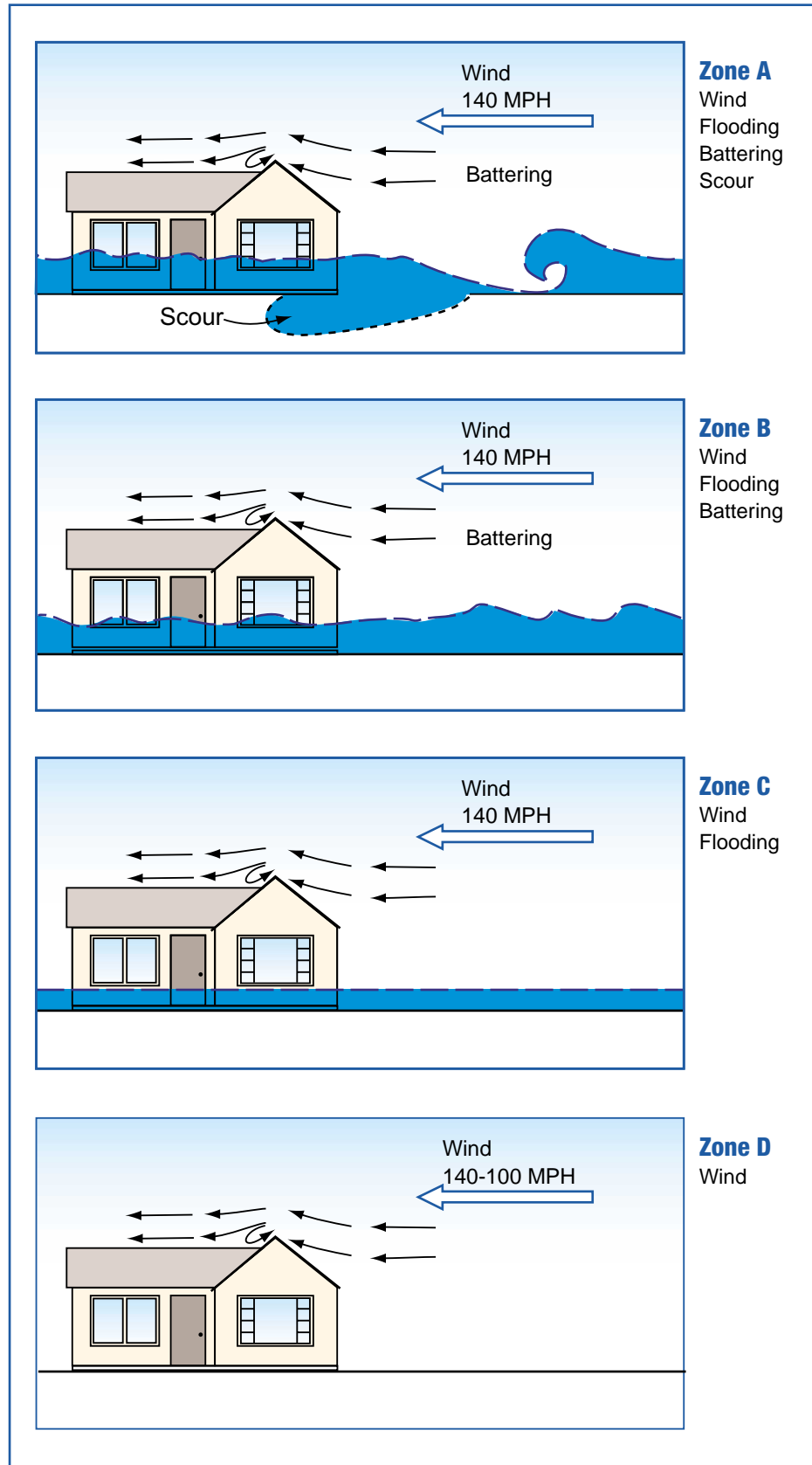
- **Zone A**, closest to the shoreline, subject to scour (due to currents and wave action), battering, flooding, and wind. Note that the report states Zone A can be defined in a number of ways:
  - narrow, low segments of barrier island **subject to breaching**
  - a zone at least **300 feet wide**, extending landward from the dune crest

- a zone along **unprotected bay shorelines, extending at least 200 feet inland** from the highest elevation near the shoreline
- areas with a sand substrate subject to hurricane **flooding greater than 3 feet in depth**, and with expected **flow velocities greater than 3 ft/sec** for 1 hour or more
- **Zone B**, inland of Zone A, subject to battering, flooding, and wind
- **Zone C**, inland of Zone B, subject to flooding and wind
- **Zone D**, most inland zone, subject to wind only

Specific construction standards were proposed in the report for each hazard zone. Although the zones and construction standards were never adopted as part of a building code, they provide a conceptual framework for understanding the variation of hurricane hazards relative to the shoreline.

**Figure G-3**

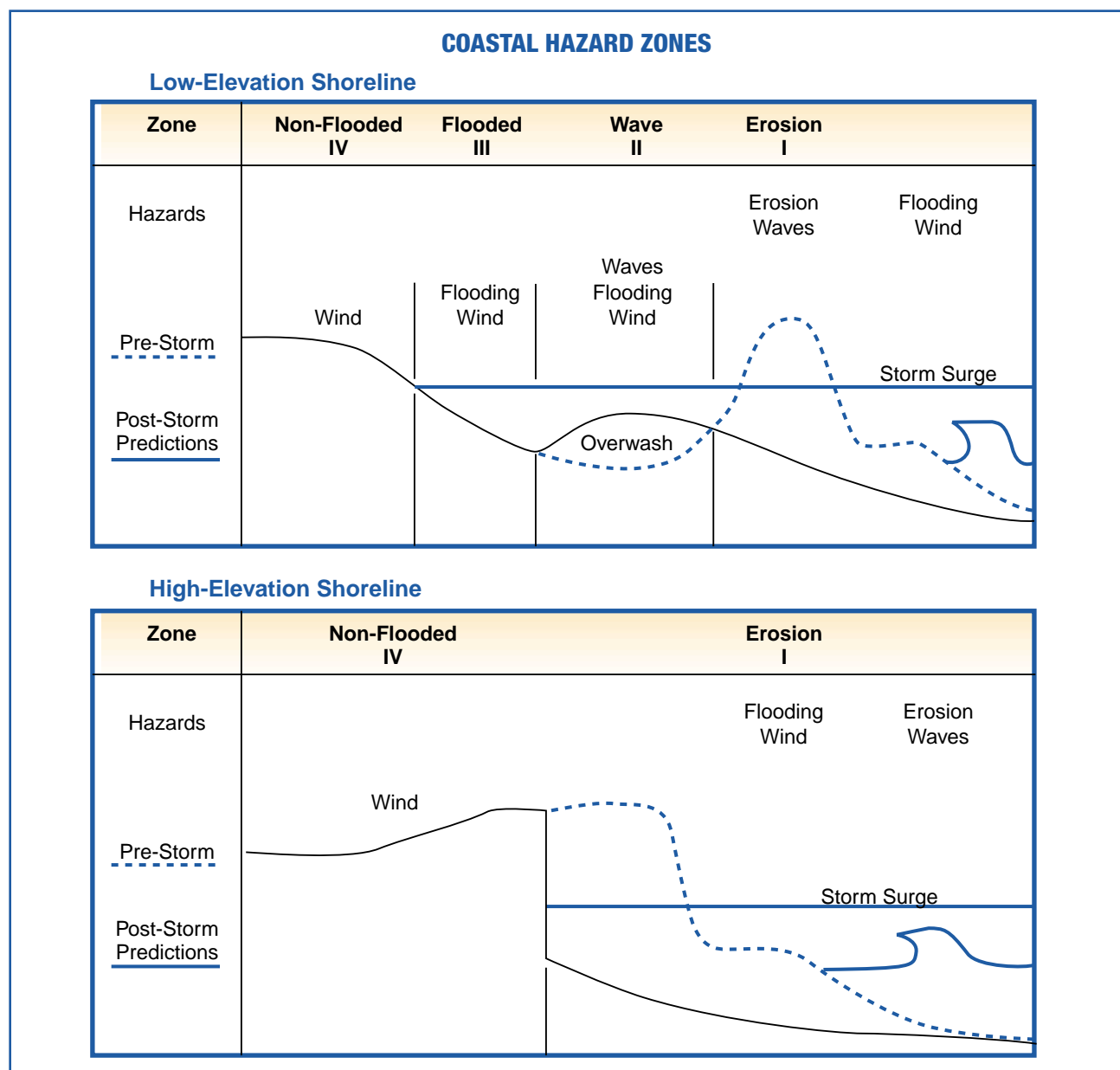
Schematic representation of hazard zones A through D in Texas coastal areas (from Texas Coastal and Marine Council 1976).



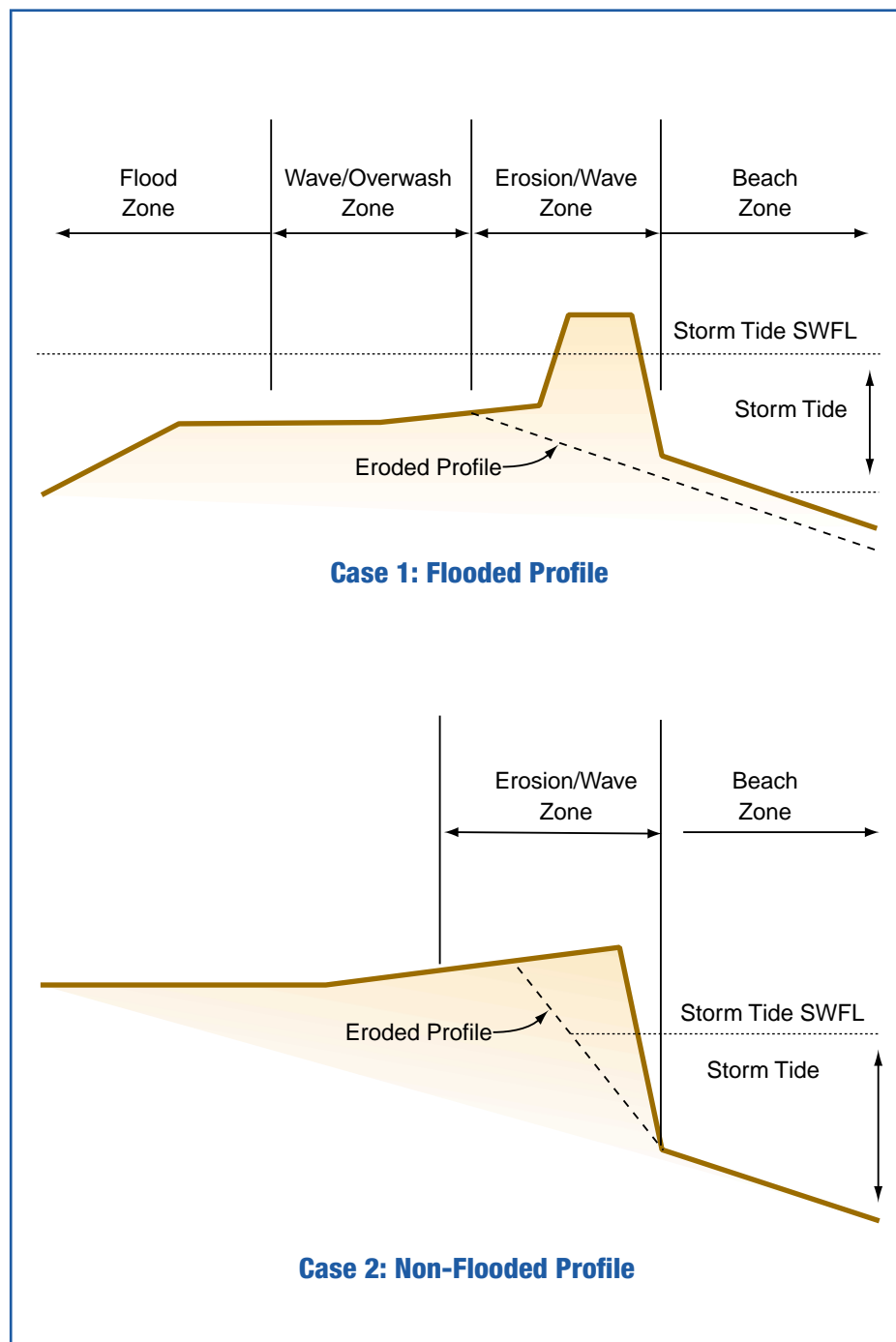
### 3 Coastal Hazard Zones, Low Elevation and High Elevation Shorelines in Texas

Based on field observations after Hurricane Frederic and several other storms, Rogers (1990) suggested modifications to the Texas Coastal and Marine Council coastal hazard zones. The modified zones were developed for low-elevation and high-elevation shorelines, and are shown in Figure G-4. A similar delineation (see Figure G-5) was used in a recent mapping of coastal flood hazard zones along the Atlantic Ocean and Delaware Bay shorelines of Delaware (Dewberry & Davis 1997).

**Figure G-4** Coastal hazard zones for low-elevation and high-elevation shorelines in Texas (from Rogers 1990).



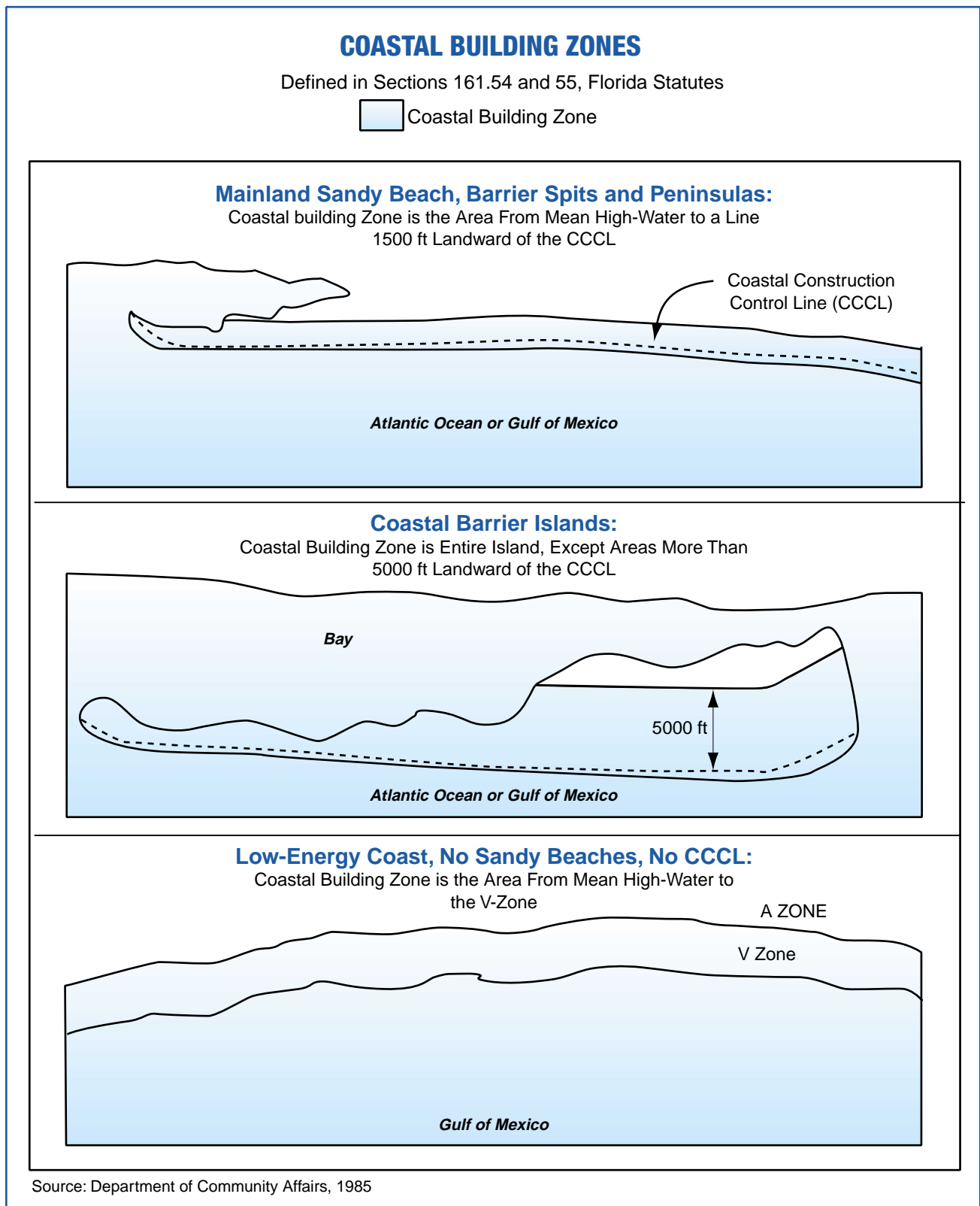
**Figure G-5**  
Delaware coastal hazard  
zones (from Dewberry &  
Davis 1997).



#### 4 Florida Coastal Construction Requirements

There are three principal components to the State program regulating coastal construction in Florida (see Figure G-6):

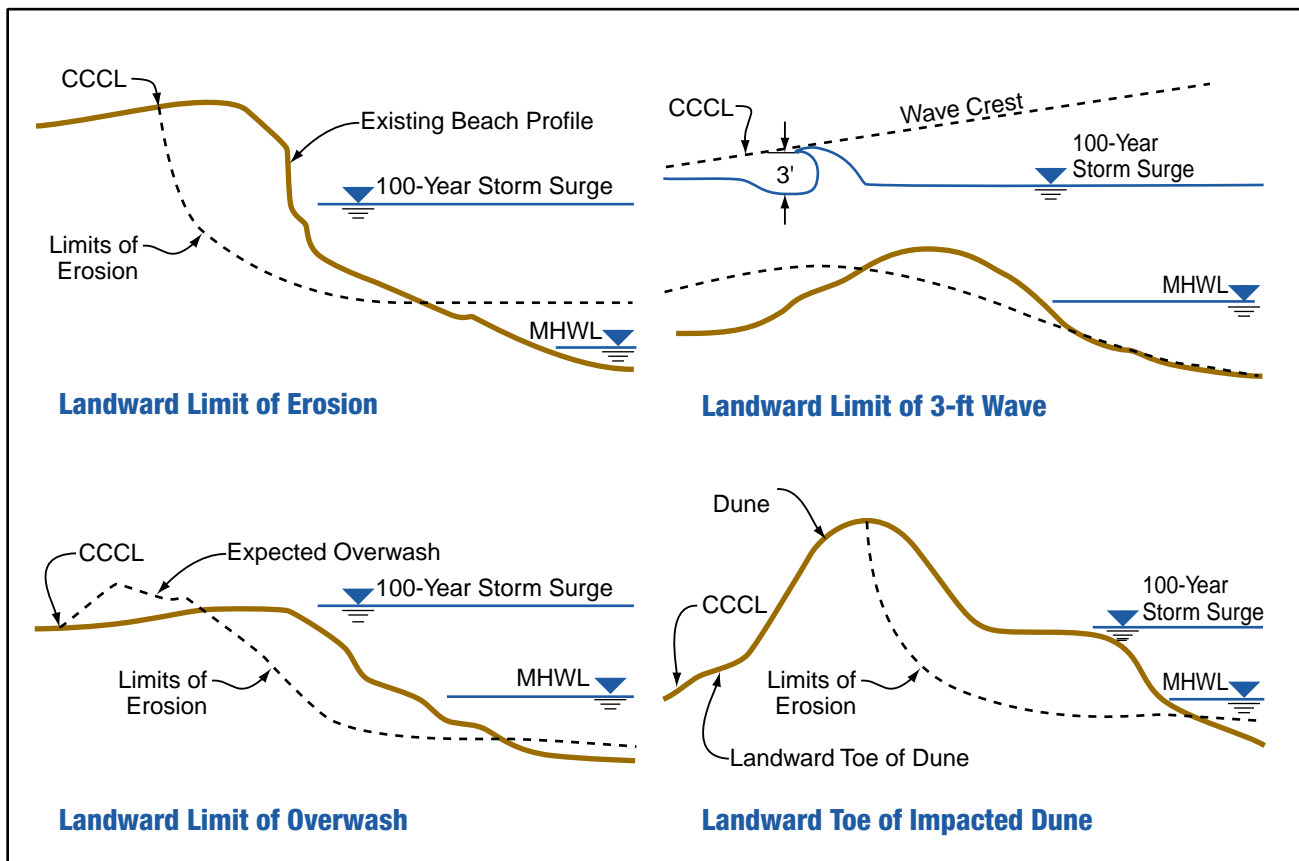
- Coastal Construction Control Line (CCCL)
- 30-Year Erosion Projection
- Coastal Building Zone

**Figure G-6** Coastal construction building zones in Florida.

In general, the CCCL is a line which defines that portion of the beach-dune system that is subject to severe fluctuations based on a 100-year storm event (see Chapter 161, Florida Statutes, and Chapter 62B, Florida Administrative Code). The State of Florida regulates – but does not prohibit – construction, excavation, and alterations seaward of the CCCL. Four criteria are used to establish the location of the CCCL (see Figure G-7):

1. The landward limit of dune erosion during a 100-year storm event
2. The landward toe of a dune eroded by a 100-year storm event
3. The landward limit of overwash during a 100-year storm event
4. The landward limit of the 3-foot wave during a 100-year storm event

**Figure G-7** Criteria used to establish Florida's Coastal Construction Control Line (CCCL) (from Olsen 1987).



It should be noted that the State of Florida has established 100-year storm tide elevations and dune erosion predictions for sandy beach areas. The state's 100-year stillwater elevations are not the same as, and are frequently several feet higher than, FEMA's 100-year stillwater levels determined during FISs (due to different storm tide modeling procedures). Thus, state wave crest and runup elevations are frequently higher than FEMA's BFEs, and state dune

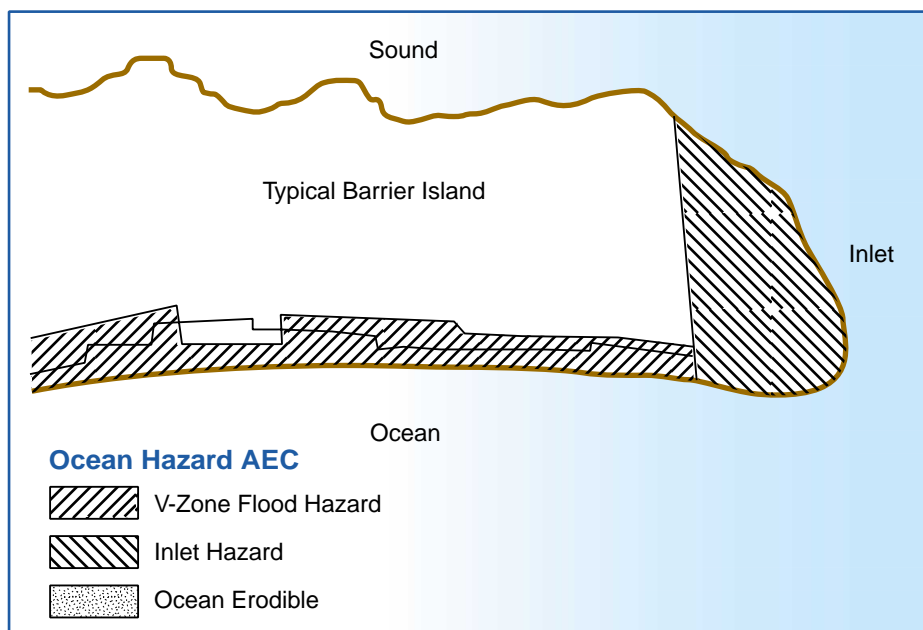
erosion predictions often exceed those calculated during FEMA's studies (in a few instances, FEMA flood elevations or zone designations are more restrictive than those of the state). Construction seaward of the Florida CCCL must satisfy whichever requirements are more restrictive—CCCL or FEMA.

The State of Florida also establishes a 30-year erosion projection on a parcel when an application is received for construction seaward of the CCCL (note that state law prevents the 30-year projection from being established farther landward than the CCCL). The projection is based on long-term erosion rates calculated by the state. No multi-family structures are permitted by the state seaward of the 30-year erosion projection; however, a single-family structure may extend seaward of the 30-year erosion projection in certain instances.

The State of Florida has also established a Coastal Building Zone, within which new construction must meet certain requirements. In areas where a CCCL has been established, the Coastal Building Zones extends landward from the CCCL a distance of 1,500 feet (or a distance of 5,000 feet on coastal barrier islands). In areas where a CCCL has not been established, the Coastal Building Zone extends from the seasonal high water line to the most landward V zone established by FEMA.

## 5 North Carolina Coastal Construction Requirements

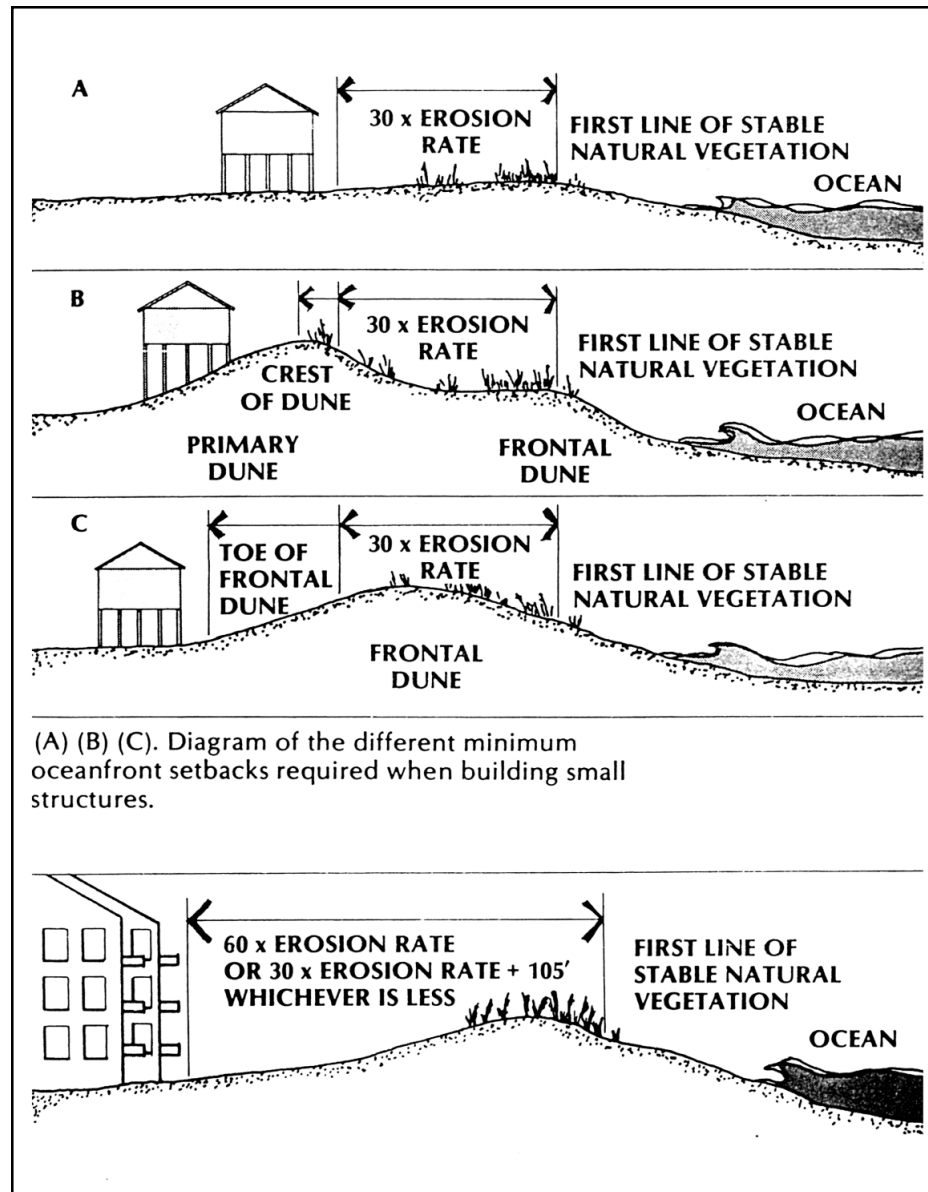
North Carolina's Coastal Area Management Act (CAMA) has resulted in the identification of Ocean Hazard Areas of Environmental Concern (AEC) and the adoption of development standards for those areas. Ocean Hazard AECs are divided into three categories: Ocean Erodible Areas, High Hazard Flood Areas, and Inlet Hazard Areas (see Figure G-8).



**Figure G-8**  
North Carolina Ocean  
Hazard Areas of  
Environmental Concern.

Ocean Erodible Areas are defined as beaches and lands adjacent to the ocean that have a substantial possibility of long-term erosion and shoreline change (North Carolina Coastal Management Program 1985). The ocean erodible area extends from the mean low water line landward to a point 60 times the long-term average annual erosion rate, plus an additional distance where significant erosion can be expected during major storms. Widths of ocean erodible areas generally vary from 150 feet to over 700 feet. Siting and construction standards are enforced within the ocean erodible area (see Figure G-9).

**Figure G-9**  
Minimum setbacks in North  
Carolina Ocean Erodible  
Areas.



High hazard flood areas are identified as V zones on FIRMs. If FIRMs are not available for a coastal community, the State establishes a high hazard flood area based upon the best available data. High hazard flood areas overlap with, but are usually wider than, ocean erodible areas.

Inlet Hazard Areas are areas especially vulnerable to erosion, flooding, and inlet-induced shoreline changes. Inlet hazard areas are mapped by the state based on analyses of inlet migration rates, topography of adjacent lands, previous inlet locations, and the effects of jetties and other manmade influences.

## **6 South Carolina Coastal Siting Requirements**

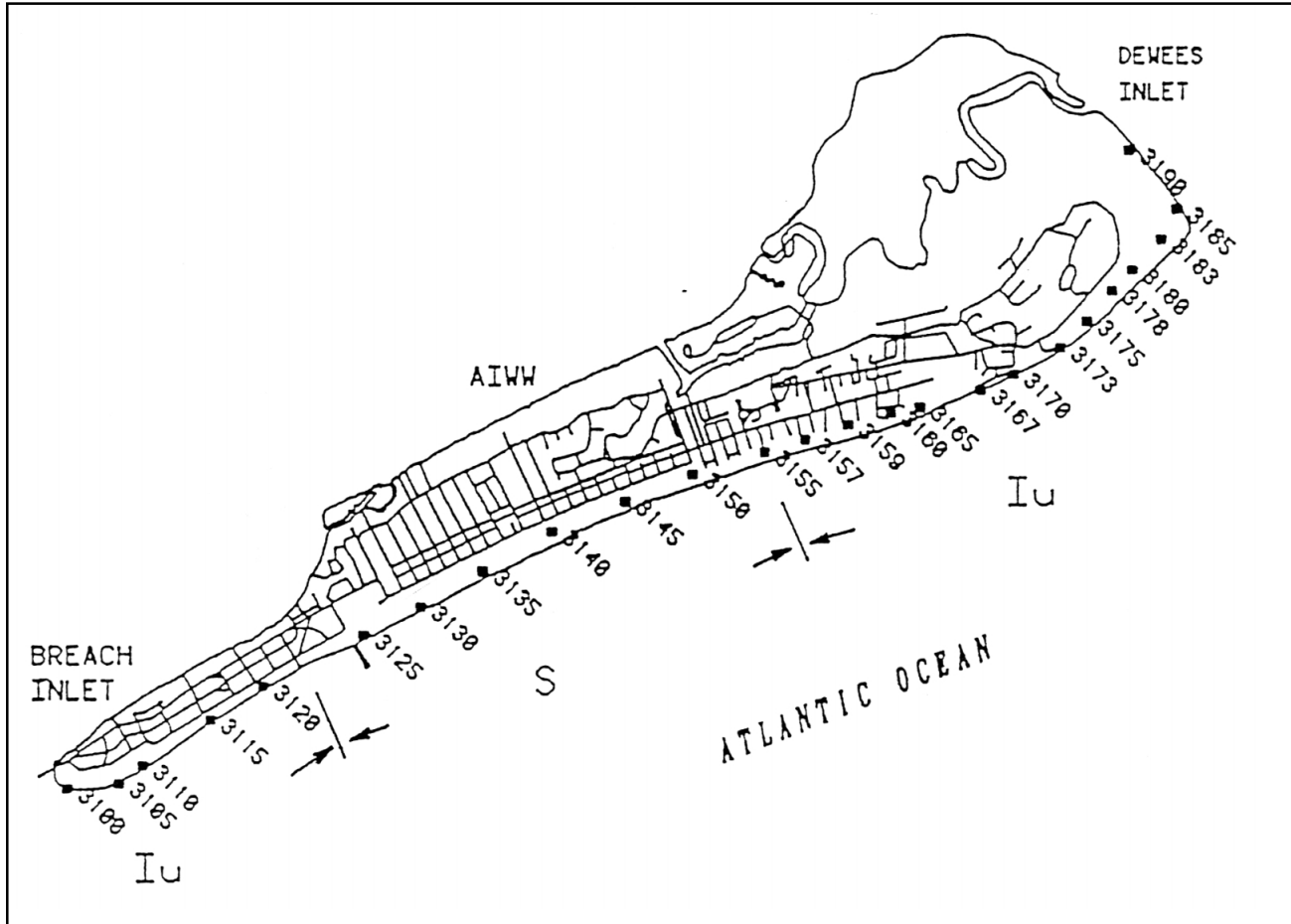
The South Carolina Beachfront Management Act was passed in 1988 and amended in 1990. The act led to the establishment of construction setback lines along the oceanfront shoreline. The location of a setback line in a given area is determined by local coastal processes and long-term erosion rates. The State prohibits the construction of large habitable structures seaward of the setback line, but allows the construction of smaller structures (< 5,000 ft<sup>2</sup>) under certain circumstances.

The State's ocean shoreline is divided into "standard erosion zones," which are generally unaffected by fluctuations at unstabilized inlets (i.e., not stabilized by jetties or groins), and "unstabilized inlet erosion zones," which are subject to fluctuations caused by unstabilized tidal inlets. The boundary between standard erosion zones and unstabilized inlet erosion zones is typically based on historical shoreline maps and present day bathymetry – standard erosion zones are typically drawn where historical shorelines are approximately parallel and where nearshore contours are approximately parallel to the shoreline (see Figure G-10).

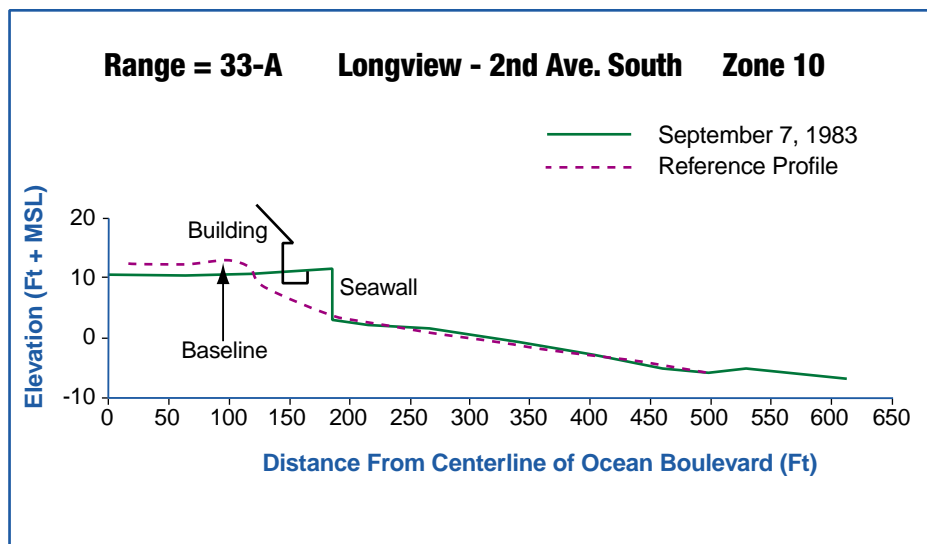
A "baseline" and "40-year setback line" are established along each oceanfront and inlet shoreline. In standard erosion zones, the baseline is set along the dune crest where a dune exists; where the shoreline is armored by seawalls or revetments, the baseline is set where a dune crest would exist in the absence of the erosion control structure (see Figure G-11). In unstabilized inlet erosion zones, the baseline is established along the most landward shoreline (i.e., line of stable vegetation) in the past 40 years, unless detailed studies show the shoreline is unlikely to return to its most landward location. The setback line is established landward of the baseline a distance equal to 40 times the long-term average annual erosion rate (with a minimum setback of 20 feet).

**Figure G-10**

Example of delineation between standard erosion zone and unstabilized inlet erosion zone, Isle of Palms, South Carolina (Iu = unstabilized inlet erosion zone, S = standard erosion).

**Figure G-11**

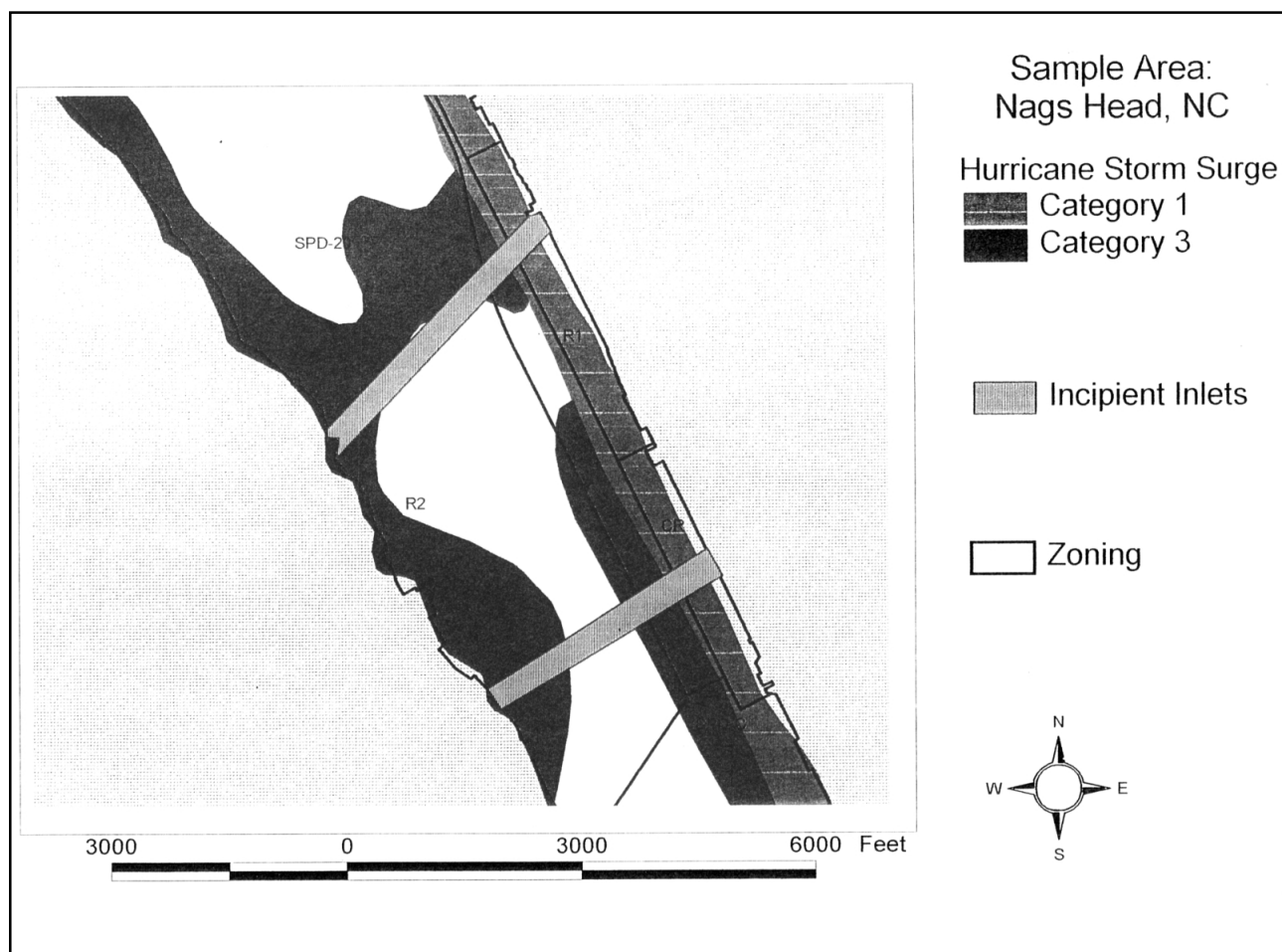
Example of South Carolina baseline location where seawall encroaches onto active beach—dashed line indicates natural beach/dune profile superimposed on actual profile (Kana et al. 1984).



## 7 Incipient Inlet Hazards, Town of Nags Head, North Carolina

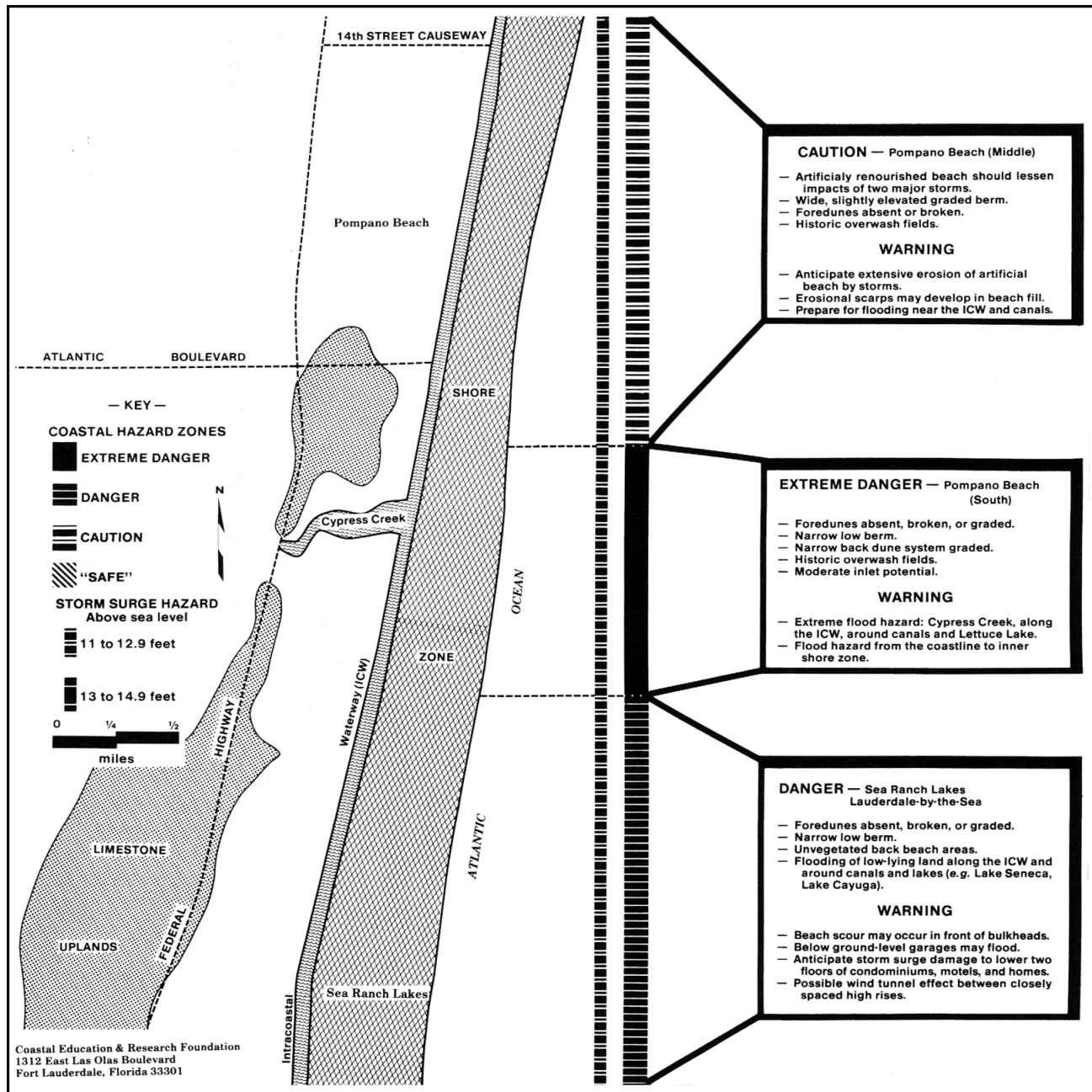
The Town of Nags Head, North Carolina, has been recognized as one of the leaders in managing coastal hazards. A recent report for the Town (Nags Head Department of Planning and Development 1998) describes and maps natural hazards affecting the town, including areas vulnerable to the formation of tidal inlets (see Figure G-12).

**Figure G-12** Map of Nags Head, North Carolina, showing incipient inlets and areas subject to hurricane flooding (from Nags Head Department of Planning and Development 1998).



## 8 Broward County, Florida, Coastal Hazards Mapping

Finkl (1994a) shows how information compiled or developed by Broward County can be integrated into an overall coastal hazard assessment. The assessment includes consideration of coastal landforms, hurricane hazards, hydrologic factors, shoreline erosion, and emergency planning. Figure G-13 shows an example of a coastal hazard map prepared using hurricane storm surge, landform and erosion data.

**Figure G-13** Sample coastal hazard map, Broward County, Florida (from Finkl 1994a).

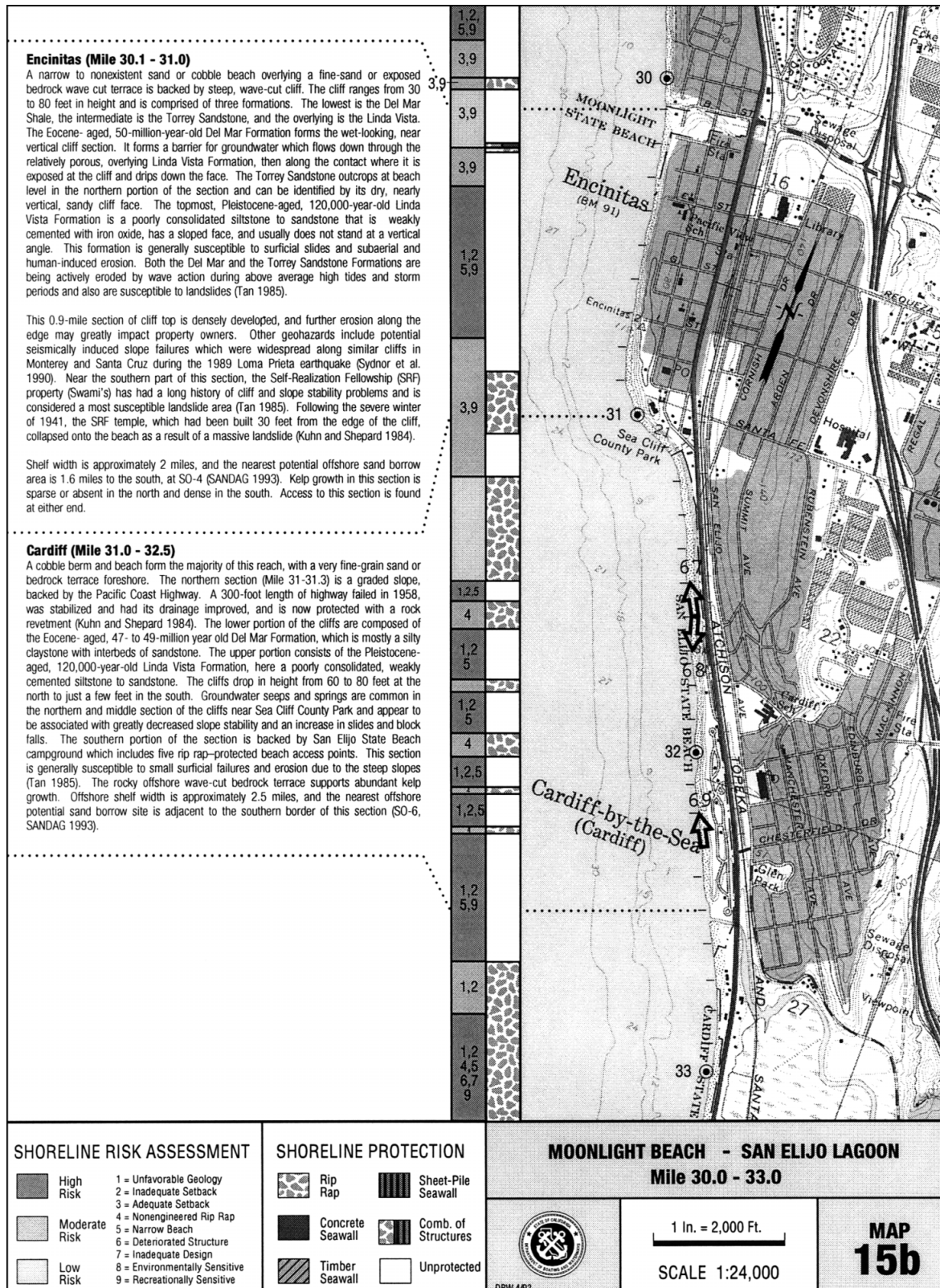
## 9 San Diego Region, California, Shoreline Erosion Atlas

The California Department of Boating and Waterways, and the San Diego Association of Governments, completed a shoreline erosion assessment and atlas (Flick 1994). The atlas contains a series of maps (see Figure G-14), each indicating the types and locations of shore protection structures and the degree of risk due to coastal erosion for each shoreline segment. Shoreline risk is categorized as “high,” “moderate,” or “low” according to nine criteria:

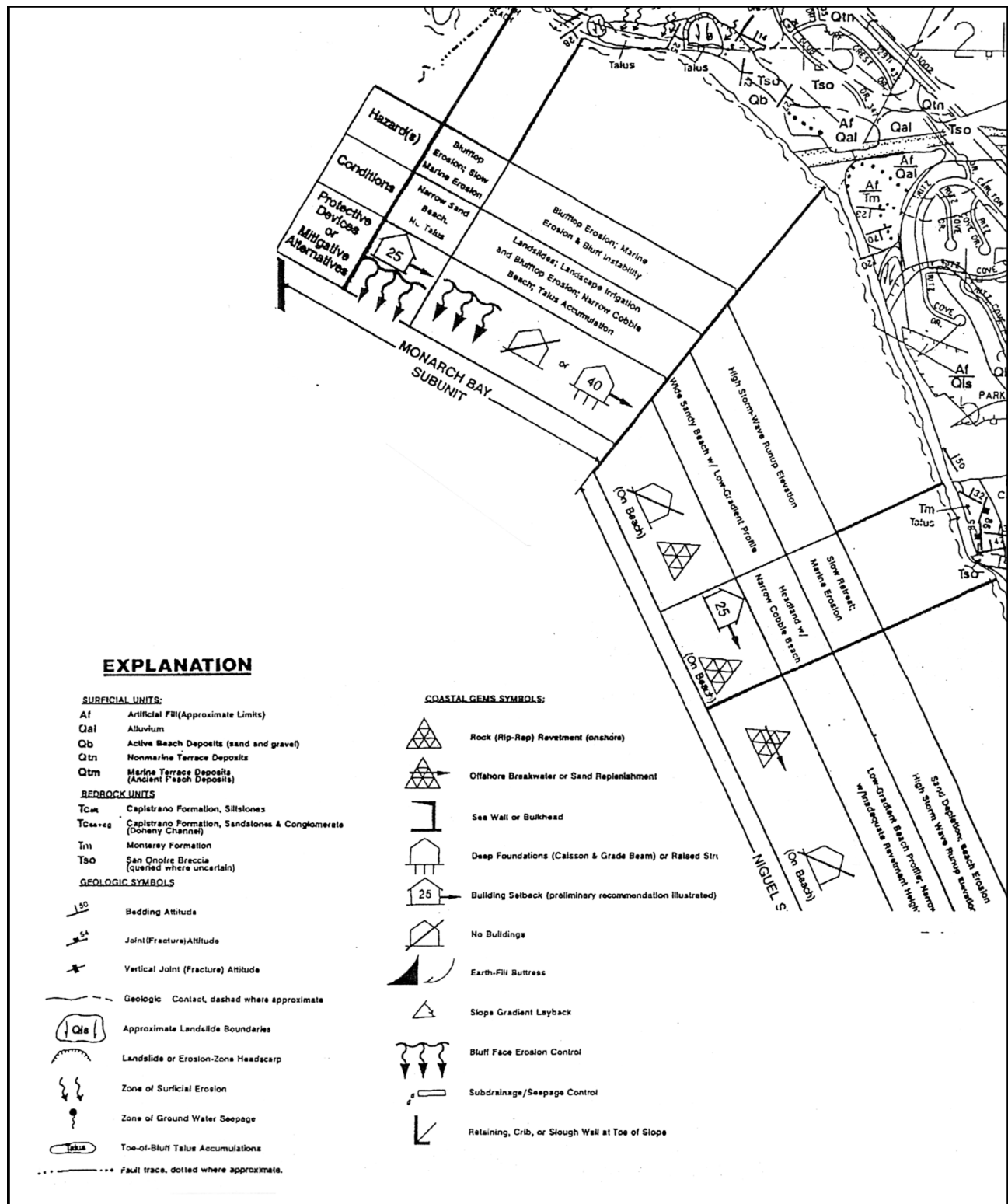
1. geology unfavorable (a combination of one or more unfavorable geologic conditions which diminish the stability of an area)
2. inadequate setback (setback of development from edge of coastal cliff or bluff is inadequate to provide long-term freedom from erosion or flood damage)
3. adequate setback (setback of development from edge of coastal cliff or bluff is adequate to provide long-term freedom from erosion or flood damage)
4. non-engineered rip rap (rock rip rap or concrete rubble dumped in haphazard manner without apparent engineering design specifications or interlocking placement)
5. narrow beach (beach width is too narrow to provide protection from major storm wave overtopping and flooding)
6. deteriorated structure (shore protection structure has outlived its useful life, and may be subsided, broken or unraveled)
7. inadequate design (structure is not adequately designed or built for the area’s potential or actual flooding, wave conditions, or beach width fluctuations and scour)
8. environmentally sensitive (areas such as wetlands or marine preserves which may suffer damage from flooding or wave and sand overtopping)
9. recreationally sensitive (areas such as popular recreational beaches and public facilities which could suffer damage from erosion, flooding or wave overtopping)

## 10 City of Dana Point, California, Coastal Erosion Hazards

A study of coastal erosion hazards and existing geologic conditions was conducted for the City of Dana Point (Zeizer Geotechnical 1990). One product of the study was a series of maps (see Figure G-15) summarizing shoreline hazards, shoreline conditions, and recommendations for protective measures or other shoreline mitigation alternatives (including building setbacks).

**Figure G-14** Shoreline erosion risk assessment map, San Diego, California (from Flick 1994).

**Figure G-15** Coastal erosion hazard and mitigation map, City of Dana Point, California (from Zeizer Geotechnical 1990).

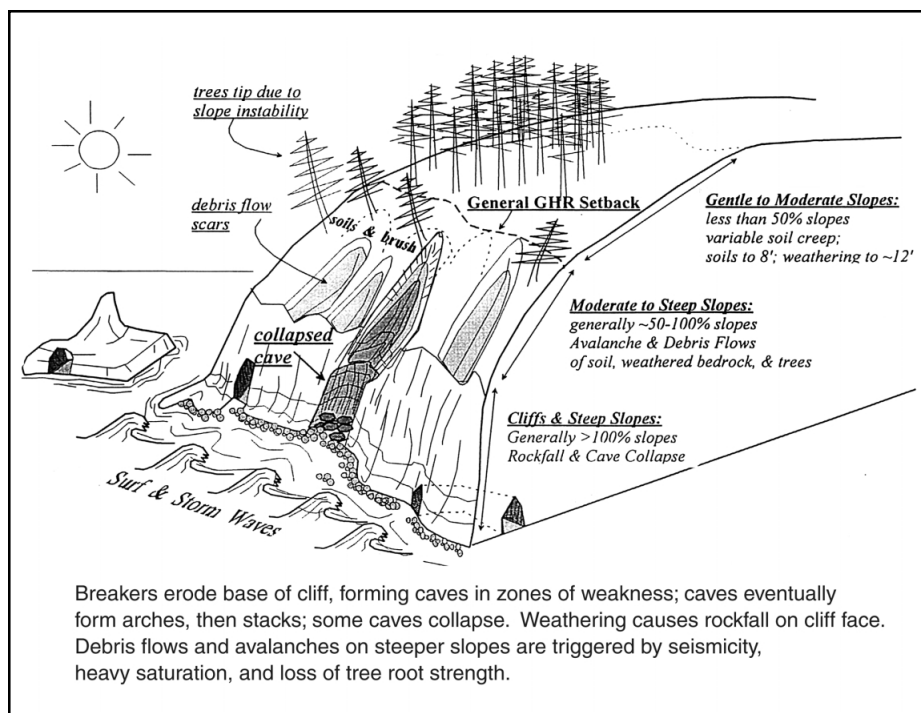


## 11 Geologic Hazards along Coastal Cliffs

Figure G-16 (Horning Geosciences 1998) illustrates the principal geologic hazards acting along a typical sea cliff in coastal Oregon. The figure provides a conceptual basis for understanding sea cliff erosion and slope instabilities. The “General GHR Setback” shown in the figure represents a generalized building setback line location based on several factors: geology and soils, topography, vegetation, and drainage.

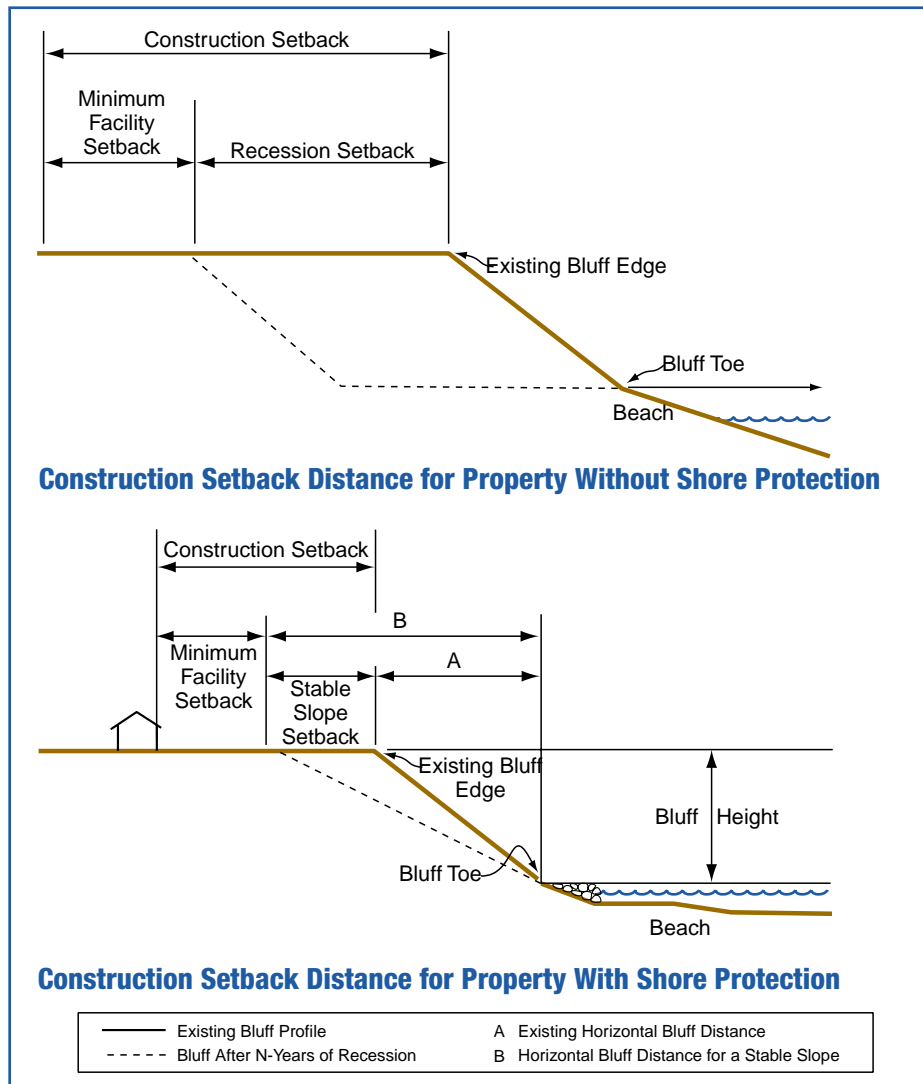
**Figure G-16**

Generalized depiction of geologic hazards along a coastal sea cliff (from Horning Geosciences 1998).



## 12 Great Lakes Coastal Bluff Hazard Areas

Hazards along erodible coastal bluffs on the Great Lakes are generally divided into two categories: (1) hazards associated with long-term recession of the bluff face and (2) hazards associated with unstable slopes. Only stable slopes must be considered where the bluff toe has been stabilized against extreme lake levels and storm events; both hazards must be considered where bluffs have not been adequately stabilized. Recommended construction setbacks in both cases are illustrated in Figure G-17 (Keillor 1998). Note that the recommended setback is the sum of several setbacks: recession setback (where bluff is not stabilized), plus stable slope setback, plus minimum facility setback. The stable slope setback will be a function of bluff height and local soils and geology. The minimum facility setback will be a function of building construction, use, and maintenance considerations.



**Figure G-17**  
Recommended coastal bluff setbacks (from Keillor 1998).

### 13 Oregon Chronic Coastal Natural Hazards Model Overlay Zone

At the time this manual went to print, the Oregon Department of Land Conservation and Development (1998) had developed a Chronic Coastal Natural Hazards Model Overlay Zone, including a draft model ordinance, draft planners guide, and draft practitioners guide. Collectively, these documents describe the need for and recommended establishment of a natural hazards overlay zone in coastal areas. The overlay zone includes areas subject to the following coastal hazards:

- dune erosion hazards (long-term and storm-induced)
- bluff erosion hazards (long-term and storm-induced)
- slide hazards (landslide hazards associated with episodic events)
- inlet hazards (migration and shoreline changes associated with unstabilized tidal inlets)

The draft documents include recommended procedures for identifying and delineating zones of high and moderate relative risk.

#### **14 Michigan High-Risk Erosion Areas and Readily Moveable Structure Requirements**

The State of Michigan defines High Risk Erosion Areas as areas along the Great Lakes shoreline where active erosion has been occurring at an average annual rate of 1 foot or more per year, based on a minimum period of 15 years. Thirty-year and 60-year erosion projections are made, with additional allowance for recession rate variability and severe short-term erosion losses.

Large structures (> 3,500 ft<sup>2</sup> foundation size, or more than five individual living units) must be constructed landward of the 60-year erosion setback. Small “readily movable” structures must be constructed landward of the 30-year erosion setback, with exceptions for certain cases (e.g., setback distance exception for substandard parcels and presence of a shore protection structure meeting specified design criteria; readily movable exception for lack of access to the site for moving equipment).

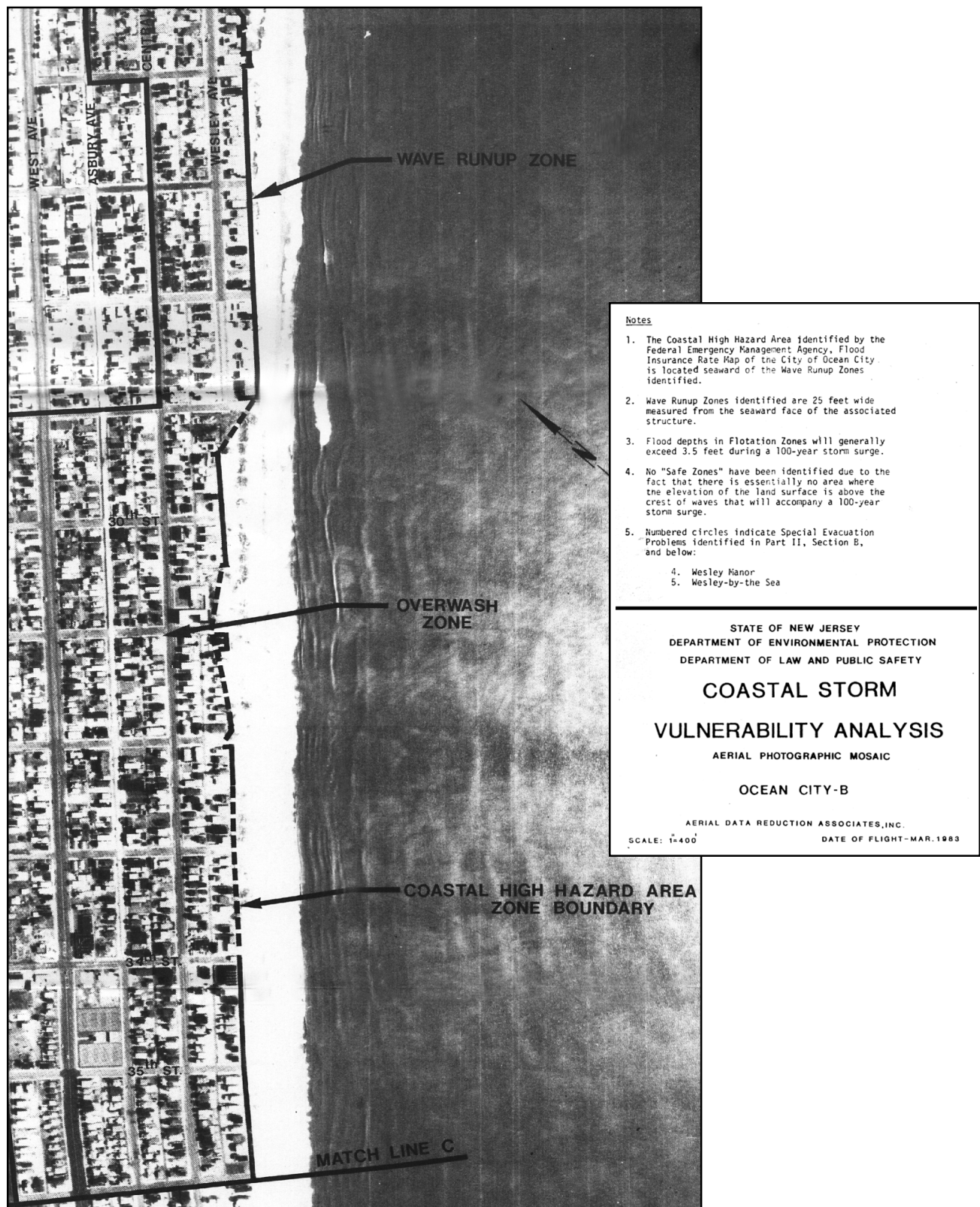
*Readily movable structures* must satisfy the following requirements (Michigan Department of Environmental Quality 1997):

1. The foundation must be constructed of either pilings, crawlspace, or a basement. Slab-on-grade foundations are not considered readily movable.
2. Above-grade walls must be stud wall construction, with no stone, poured concrete, or concrete block walls (note: brick veneer walls are considered readily movable).

#### **15 New Jersey Coastal Storm Vulnerability Analysis**

The State of New Jersey completed a Coastal Storm Vulnerability Analysis (NJDEP 1983), and mapped several coastal hazards (see Figure G-18, a sample portion of a map for Ocean City, New Jersey):

- Coastal High Hazard Areas (V zones taken from FIRMs)
- Wave Runup Zones (a zone landward of erosion control structures, and 25 feet in width)
- Flotation Zones (zones where 100-year flood depths exceed 3.5 feet)
- Overwash Zones (zones subject to overwash of beach sediments during the 100-year storm event)

**Figure G-18** Sample coastal hazard map from New Jersey Coastal Storm Vulnerability Analysis (NJDEP 1983).

## 16 Rhode Island Coastal Buffer and Setback

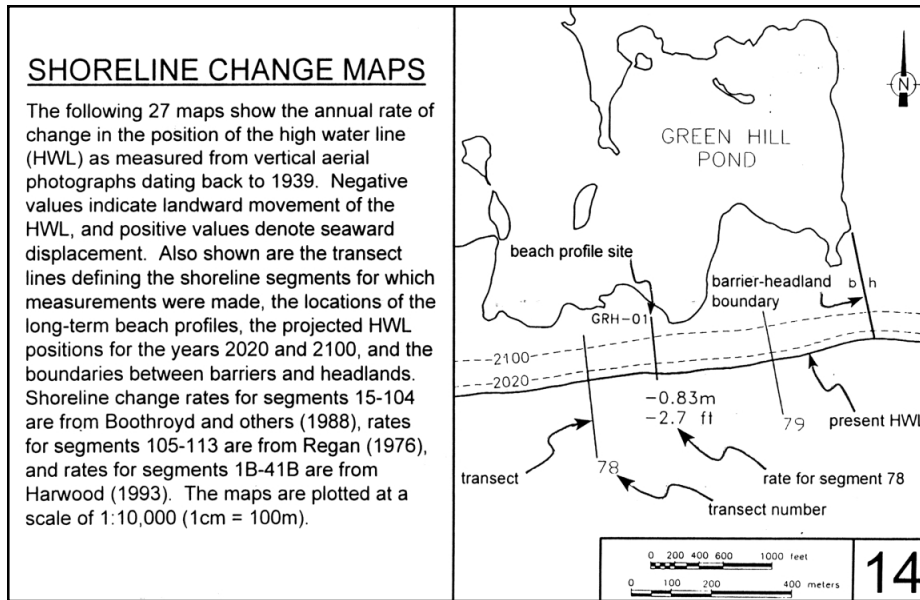
The State of Rhode Island has adopted buffer and coastal construction setback requirements along beach, cliff, and wetland shore areas. The coastal buffer zone is a land area adjacent to a shoreline feature that is (or will) be vegetated with native shoreline species. Coastal buffer zone widths will vary with residential lot size and water use category, ranging from as narrow as 15 feet to as much as 200 feet. The coastal setback extends a minimum of either 50 feet from the inland boundary of a coastal feature, or 25 feet inland of the edge of a coastal buffer zone, whichever is farther landward. In *Critical Erosion Areas* (average annual erosion rate greater than 2 feet per year), setbacks are approximately equivalent to a 30-year setback for a building with four units or less, and approximately equivalent to a 60-year setback for a building with more than more units. Average annual erosion rates are taken from shoreline change maps published by the State (RICRMC 1995) (see Figure G-19).

## 17 Sarasota County, Florida, Gulf Beach Setback Line and Barrier Island Pass Hazard Line

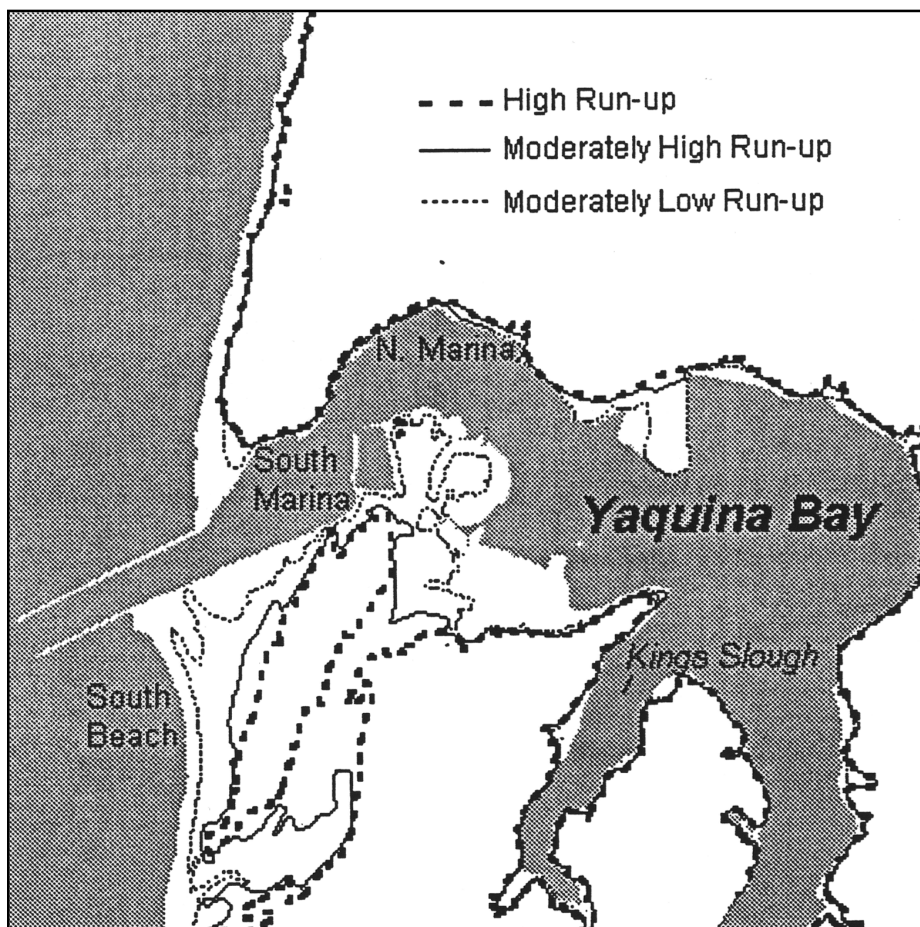
Sarasota County, Florida, chose to adopt local siting requirements more restrictive than those of the state's Coastal Construction Control Line program (see Section 7.9.2.4). In doing so, the county established a *Gulf Beach Setback Line* congruent with the State's CCCL (Sarasota County Ordinance 79-03, as amended). While building siting and construction are subject to state regulation seaward of the CCCL, the Gulf Beach Setback Line is a line of prohibition (although a variance procedure exists for certain situations). The County also adopted a *Barrier Island Pass Hazard Line* around the sides of tidal inlets between the county's barrier islands (the CCCL crosses tidal inlets and does not follow the shorelines of the inlets). The Barrier Island Pass Hazard Line lies 50 feet landward of the seawall stabilizing the shoreline of Big Sarasota Pass, and a variable distance landward of unstabilized inlet shorelines subject to fluctuation.

## 18 Yaquina Bay, Oregon, Tsunami Inundation Map

A map and report describing potential tsunami inundation zones were produced by the Oregon Department of Geology and Mineral Industries. The report (Priest et al. 1997) discusses the procedures used to predict inundation limits for various Cascadia subduction zone tsunami scenarios. The map (see Figure G-20) separates the shoreline into three risk zones: high runup, moderately high runup and moderately low runup (Oregon Department of Geology and Mineral Industries 1998).



**Figure G-19**  
Sample shoreline change map showing average annual shoreline change and projected future shoreline locations (RICRMC 1995).



**Figure G-20**  
Yaquina Bay, Oregon, tsunami inundation map (from Priest et al. 1997).

## **19 Hawaii Coastal Hazard Assessment Project**

This study by the Hawaii Coastal Zone Management Program (HCZMP) (1993) examined seven coastal hazards (see Figure G-21) and determined an Overall Hazard Assessment score (OHA, ranging from 1 [low] to 4 [high]) for different shoreline segments. The study also examined how well land use regulations (Special Management Areas, coastal setbacks) reflect the overall coastal hazards. In general, the study found poor correlation between the actual hazards and the existing land use regulations; coastal setbacks from the shoreline of 20 to 40 feet were judged inadequate.

## **20 Oregon Recommended Wildfire Safety Zone**

The Oregon Department of Forestry (1991) recommends a safety zone around homes in areas subject to wildfire hazards. The safety zone consists of a primary zone, immediately around the building, and a secondary zone surrounding the primary zone. The recommended primary zone width is a function of the slope of the land surrounding the building – as the slope increases, the recommended zone width increases. The minimum recommended primary zone width is 30 feet (see Figure G-22). The minimum recommended secondary zone width is 100 feet.

Within the primary zone, fuels that will produce flame lengths in excess of 1 foot should be removed. Vegetation within the primary zone could include lawns and low shrubs, and trees with lower branches (less than 8 feet above ground) and dead branches removed. Other fuels such as accumulated leaves, needles, and dead vegetation should be removed from the primary zone. Fuels within the secondary zone should be reduced (Oregon Department of Forestry 1991).

## **21 Vulnerability of Shorelines to Sea-Level Rise**

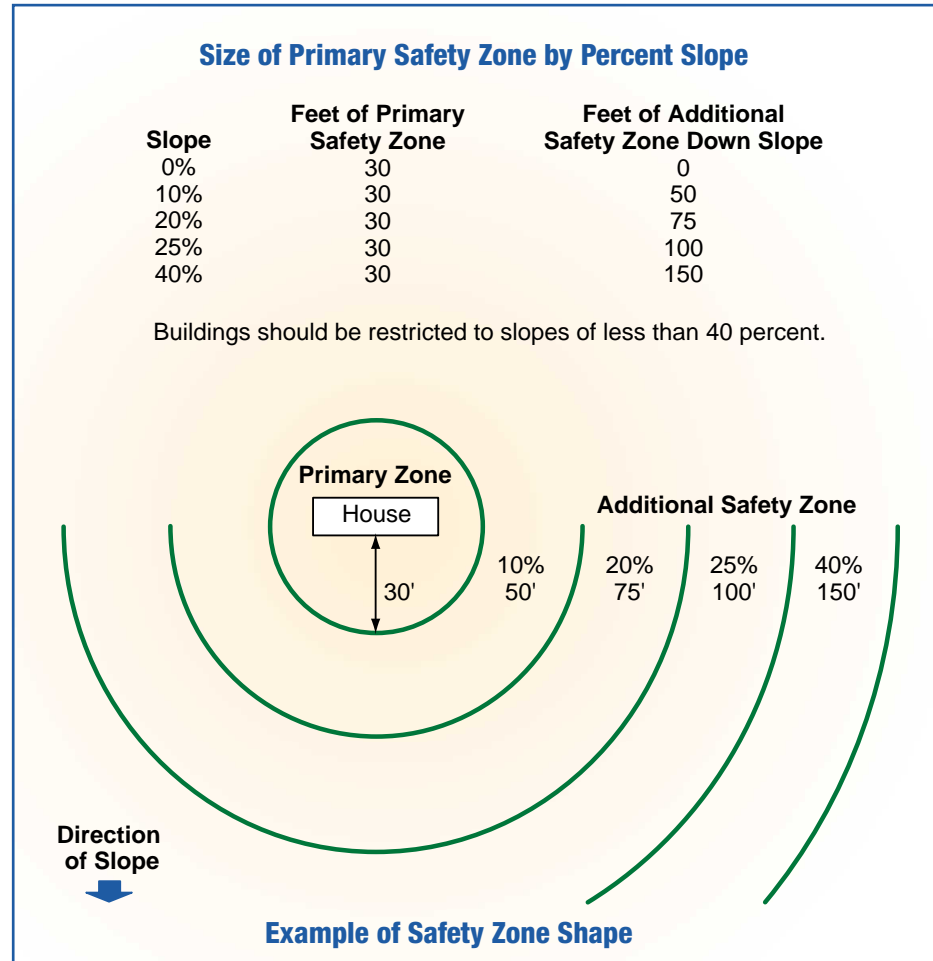
A series of studies examined the vulnerability of U.S. shorelines to sea level rise (Gornitz et al. 1992, 1993, 1994, 1997). The studies examined shoreline vulnerability to inundation (permanent and episodic) and erosion (see Figure G-23) and calculated a Coastal Vulnerability Index for individual shoreline segments. Levels of risk for hazards associated with sea level rise were classified as “high,” “moderate,” or “low” for shoreline segments along the Atlantic, Gulf of Mexico, and Pacific coasts (see Figure G-24).

**Figure G-21** Hazard classification used to determine Overall Hazard Assessment, Hawaii (HCZMP 1993).

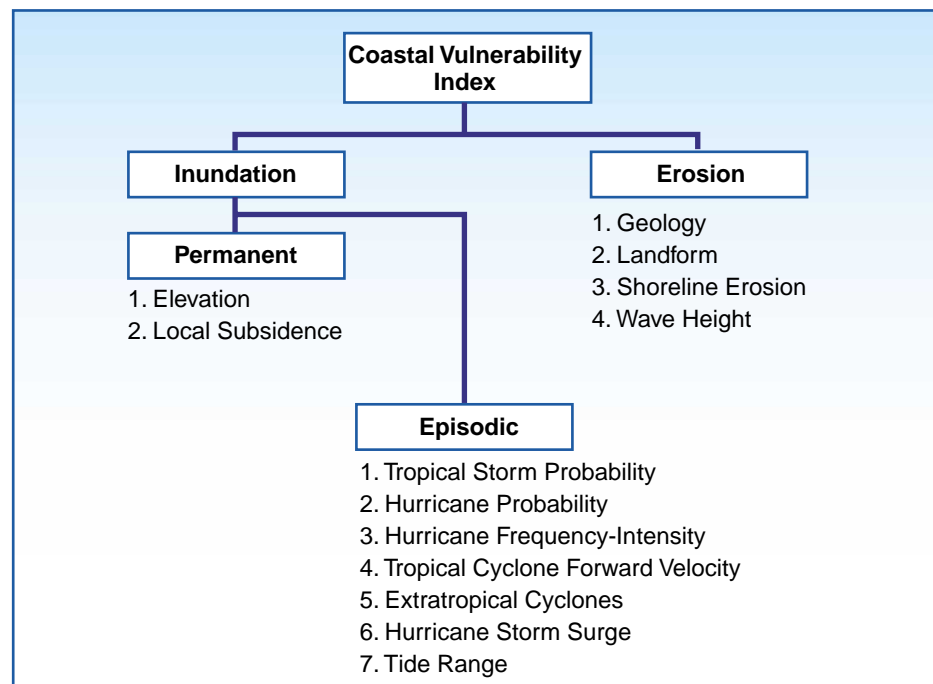
|  | Hazard Severity Ranking  |   |  |  |
|--|--|---|--|--|
|  | Low (1)  | Moderately Low (2)  | Moderately High (3)  | High (4)   |
| <b>1. Tsunami Overwash</b>                 | no history of tsunami activity and no reasonable basis for expected activity   | history of minor tsunami run-up ( $\leq 2\text{m}$ ), or locality is not likely to experience future tsunami hazard because of steep coastal zone slope ( $\geq 45\%$ ) or other mitigating factor                                  | history of major run-up activity ( $>2\text{m}$ ) but historical damage and expected future damage are slight because of steep coastal zone slope ( $\geq 45\%$ )                            | history of major run-up ( $>2\text{m}$ ) and locality has history of significant damage because of moderate to gentle slope ( $<45\%$ )  |
| <b>2. Coastal Stream Flooding</b>          | no history or coastal stream flooding and no reasonable basis for expected flooding because of low seasonal rainfall in watershed (monthly max. $< 125\text{ mm}$ ) or steep coastal slope ( $\geq 45\%$ ) | history of nondamaging flooding where streams or highlands w/ seasonal high rainfall are present (monthly max. $>200\text{mm}$ ) and coastal slope $>30\%$ ; or history of flood damage with full mitigation since last major flood | abundance of streams and high seasonal rainfall in watershed (monthly max. $> 200\text{ mm}$ ); historical flood damage and/or partial mitigation with a coastal slope $> 20\%$ and $< 35\%$ | historically high level of flood damage; coastal slope $< 20\%$ ; seasonal watershed rainfall monthly max. $> 200\text{ mm}$ ; no mitigation efforts or improvements since major flood |
| <b>3. Seasonal High Waves</b>              | no reasonable basis for expected high waves  | seasonal high waves $<1.5 - 2\text{ m}$   | seasonal high waves $1.5 - 3\text{ m}$   | seasonal high waves $>3\text{ m}$  |
| <b>4. Storm Overwash and/or High Winds</b> | no history of overwash or high winds, and no basis for expected activity   | minor historical overwash ( $\leq 2\text{ m}$ ); and/or high winds without significant structural damage ( $\sim 34\text{ kn gust}$ )   | historical overwash $> 2\text{m}$ mitigated by steep slope; and/or high winds causing localized significant structural damage ( $\sim 34\text{ kn sustained}$ )                              | historical overwash $\geq 2\text{ m}$ on moderate to gentle slope; and/or high winds causing widespread significant structural damage ( $\sim 64\text{ kn gust}$ )                     |
| <b>5. Erosion</b>                          | long-term accreting shoreline ( $>10\text{ yr avg.}$ ) with no history of erosion or dynamic cycles, and consistent accretion every year over its lifetime   | long-term stable, or minor erosion/accretion episodes, includes low-slope rocky coasts, erosion episodes fully recovered during accretion phases; industrialized shores   | long-term erosion rate $\leq 0.33\text{ m/yr}$ ; or highly dynamic erosion/accretion cycles causing significant lateral shifts in the waterline  | chronic, long-term erosion $> 0.33\text{ m/yr}$ , or beach lost, or seawall at water line during part of tidal cycle removing the recreational value of the beach                      |
| <b>6. Sea-Level Rise</b>                   | steep coastal slope w/ rise $> 1\text{ mm/yr}$ ; or gentle slope w/ rise $<1\text{mm/yr}$  | gentle or moderate slope, w/ rise $> 1\text{ mm/yr}$ ; or steep slope w/ rise $>2\text{ mm/yr}$   | gentle or moderate slope w/ rise $>2\text{ mm/yr}$ ; or steep slope w/ rise $>3\text{ mm/yr}$  | gentle or moderate slope rise $> 3\text{ mm/yr}$   |
| <b>7. Volcanic and Seismic</b>             | no volcanic activity in historical times; seismic probability zone 0   | no volcanic activity in historic times; seismic probability zone 1, or minor historic seismic damage  | limited volcanic activity in historic times, or seismic probability zones 2 or 3 recommended (historic seismic damage)   | frequent volcanic activity in historic times; seismic probability zones 2 or 3 recommended (frequent historic damage)  |

**Figure G-22**

Wildfire safety zone recommended by Oregon Department of Forestry (from Oregon Department of Forestry 1991).

**Figure G-23**

Variables used to calculate the Coastal Vulnerability Index (from Gornitz et al. 1994).



**Figure G-24** Distribution of low-, moderate-, and high-risk shorelines – Louisiana, Mississippi, Alabama, Florida, Georgia, and South Carolina (from Gornitz et al. 1994).

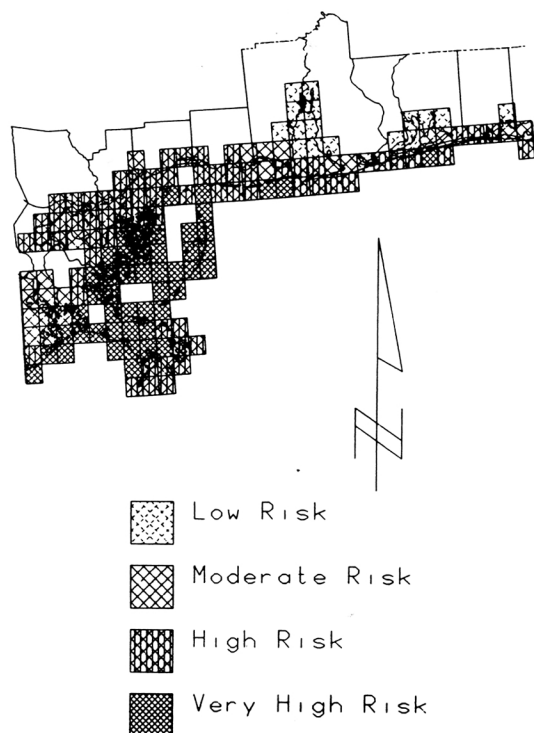


Figure 6c. Distribution of low, moderate, high, and very high risk shorelines (Louisiana, Mississippi, Alabama, and Florida).

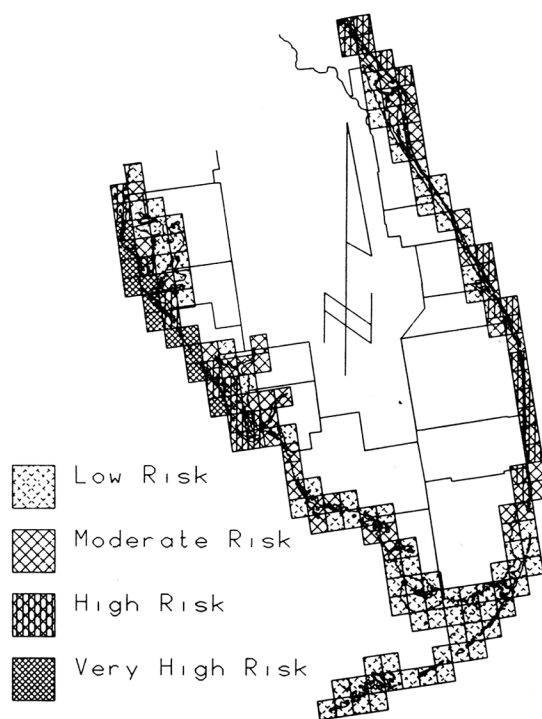


Figure 6e. Distribution of low, moderate, high, and very high risk shorelines (southern coast of Florida).

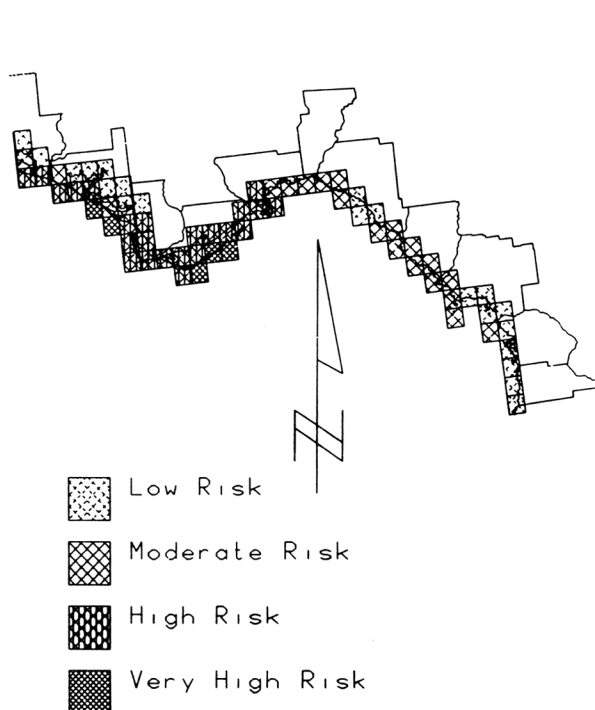


Figure 6d. Distribution of low, moderate, high, and very high risk shorelines (Florida panhandle).

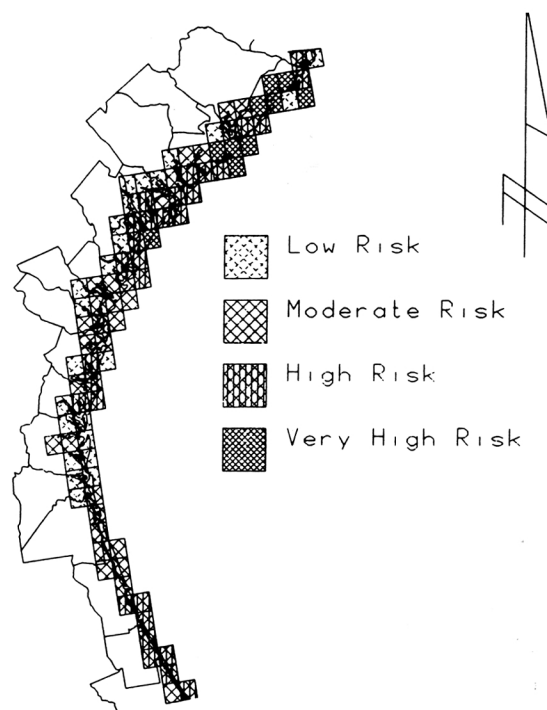


Figure 6f. Distribution of low, moderate, high, and very high risk shorelines (Florida, Georgia, and South Carolina).

## **22 City of Seattle, Washington, Landslide Critical Areas**

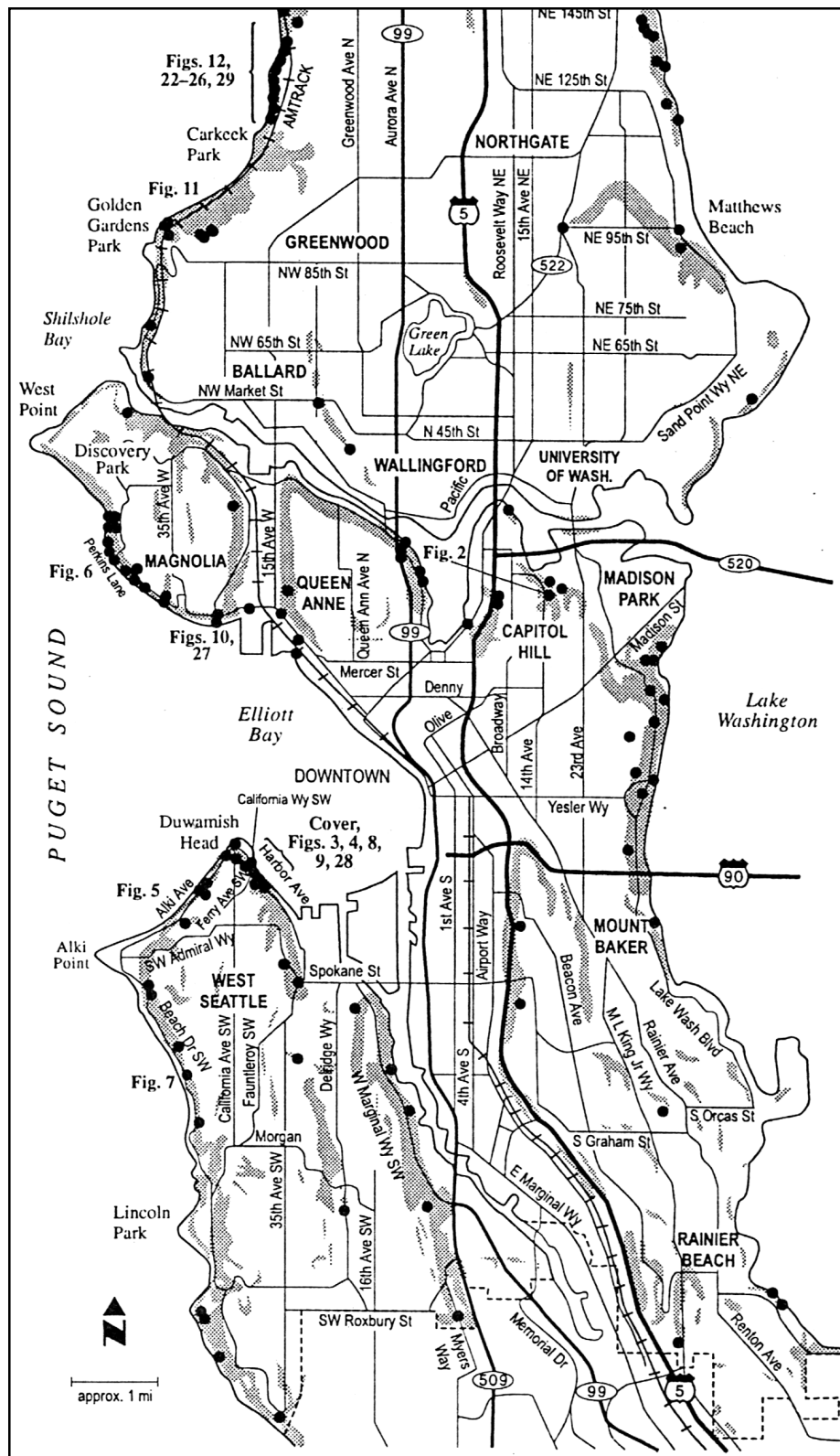
The State of Washington Growth Management Act of 1990 requires communities to identify “critical areas,” including geologically hazardous areas which are not suited to the siting of commercial, residential or industrial development (Gerstel et al. 1997). Areas susceptible to erosion, sliding, earthquakes, and other geological events are included within this broader classification. Landslide critical areas identified by the City of Seattle were excellent predictors of landslide locations resulting from soil saturation and failures, due to a series of winter storms in December 1996 and January 1997 (see Figure G-25).

## **23 Texas Department of Insurance Construction Zones**

In 1998, Texas Department of Insurance guidelines for new construction, repairs, and additions in designated “catastrophe areas” became effective. The “catastrophe areas” within which the guidelines apply include 14 coastal counties and selected portions of Harris County. The areas are subdivided into three zones: “Seaward,” “Inland I,” and “Inland II”. Mandated design wind speeds and construction requirements are highest in the Seaward zone, and lowest in the Inland II zone (Texas Department of Insurance 1998). Figure G-26 is a sample map showing the approximate zone boundaries for Galveston County.

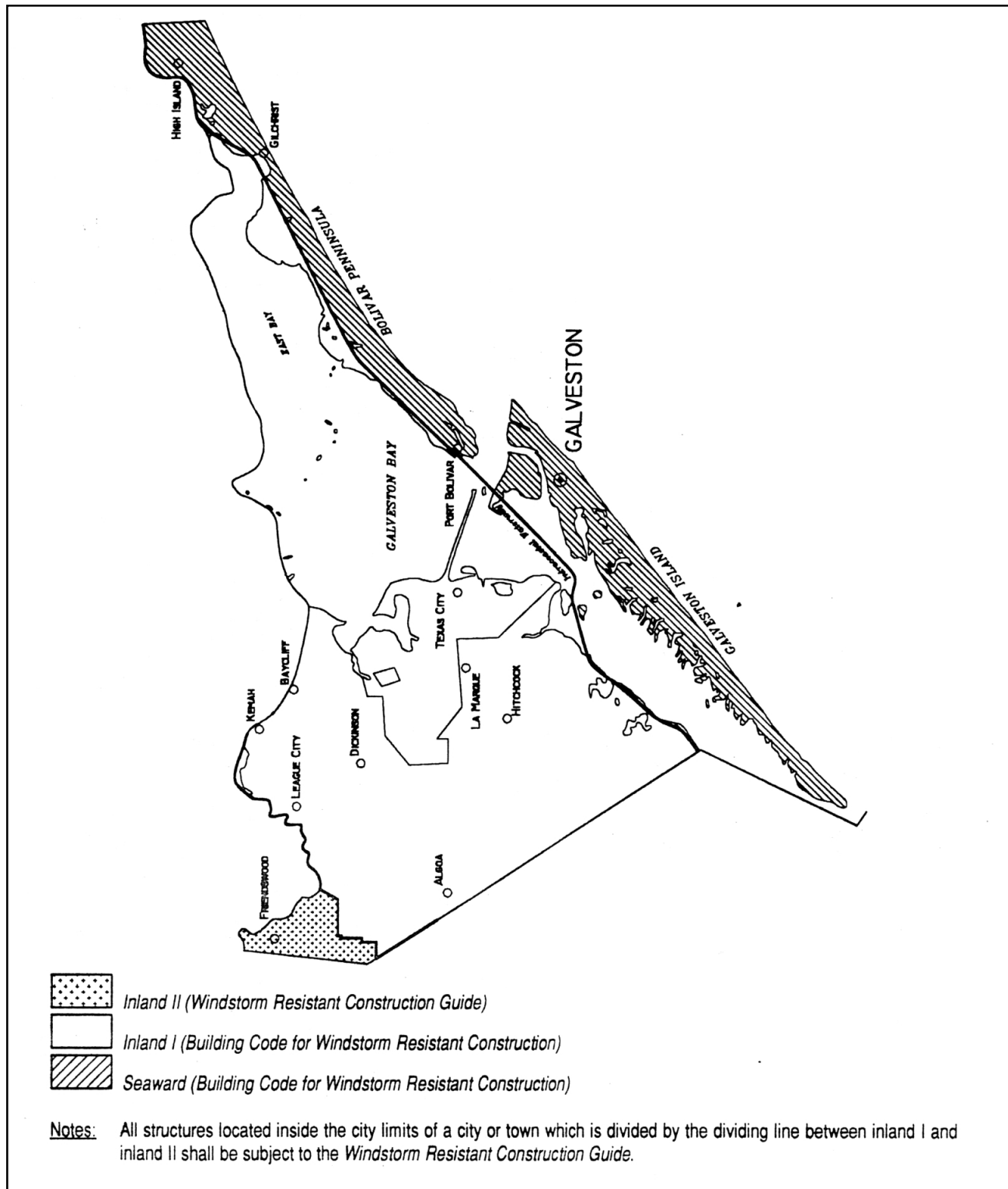
## **24 Analysis of the Tsunami Potential of Northwest Puerto Rico**

This study (Earth Scientific Consultants [undated]), performed for the Earthquake Advisory Board of State Civil Defense of Puerto Rico, provides the first information concerning potential tsunami sources near the northwestern corner of the island. The study report identifies the precise location of tsunami sources and the segments of the coast exposed to major tsunami hazard. Also presented are recommendations for tsunami hazard mitigation. These recommendations include the development of a tsunami hazard zone and the implementation of standards for all development within that zone, including building setbacks; minimum requirements for the elevation, orientation, and structural stability of residential and nonresidential buildings; the prohibition of publicly owned buildings, schools, hospitals, and nursing homes; and stringent requirements regarding utility systems and potentially hazardous materials.



**Figure G-25**  
City of Seattle Landslide  
Critical Areas (hatched  
areas) and locations of some  
of the landslides that  
occurred during the  
December 1996–January  
1997 storms (black dots)  
(Gerstel et al. 1997).

**Figure G-26** Texas Department of Insurance construction zones, Galveston County, Texas (from Texas Department of Insurance 1998).



## **25 Hazard Mitigation Strategy – Charlestown, Rhode Island (1997)**

This draft report—completed by the town in conjunction with the University of Rhode Island, Rhode Island Sea Grant and the Rhode Island Emergency Management Agency—maps populations and properties at risk to flood and wind events, and describes the process by which hazard mitigation goals are identified and implemented.

## **26 New Jersey Erosion Hazard Setbacks**

The New Jersey Administrative Code contains provisions related to erosion hazard area setbacks, bluff setbacks, and overwash zone restrictions. For example, the provisions generally prohibit construction (except for single-family and duplex infill development) within the area likely to be eroded in the next 30 years; all residential development is prohibited on coastal bluffs; and in oceanfront areas with shore protection structures, new residential development must be set back at least 25 feet from the structure.

## **27 Natural Hazards Management on the Oregon Coast**

A Coastal Natural Hazards Policy Working Group convened 19 times over a 2-year period to identify natural hazards problems and possible solutions. The results of the effort are published in a report by Oregon Sea Grant (1994). Twenty-three issues (including hazard assessment, hazard disclosure, shore protection, land use planning, fiscal responsibility, and earthquake/tsunami preparedness and response) are discussed in the report, along with 79 recommendations.

## **G.4 References**

Anders, F.J.; D.W. Reed; E.P. Meisburger. 1990. *Shoreline Movements: Report 2, Tybee Island, Georgia, to Cape Fear, North Carolina*. Technical Report CERC 83-1, Report 2. U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Benton, S.B.; M. McCullough. 1988. *Average Annual Long Term Erosion Rate Update, Methods Report*. North Carolina Department of Natural Resources and Community Development.

California Department of Navigation and Ocean Development. 1977. *Assessment and Atlas of Shoreline Erosion along the California Coast*. California Resources Agency.

Cheng, J. 1998. *Statistical Characteristics of Florida Shoreline Changes*. UFL/COEL 98-009. University of Florida, Coastal and Oceanographic Engineering Department.

Crowell, M.; S. P. Leatherman; M. K. Buckley. 1991. "Historical Shoreline Change: Error Analysis and Mapping Accuracy." *Journal of Coastal Research*. Vol. 7, No. 3. pp. 839-852.

Crowell, M.; S. P. Leatherman. 1999. "Coastal Erosion Mapping and Management." *Journal of Coastal Research*, Special Issue #28.

Dewberry & Davis, Inc. 1997. *Coastal Vulnerability and Construction Standards Study*. Submitted to the Delaware Department of Natural Resources and Environmental Control.

Dolan, R.; B. Hayden; S. May. 1983. "Erosion of the U.S. Shorelines." *CRC Handbook of Coastal Processes and Erosion*, P. Komar, ed. pp. 285-299.

Earth Scientific Consultants. Undated. *Analysis of the Tsunami Potential of Northwestern Puerto Rico*. Prepared for the Earthquake Advisory Board of State Civil Defense of Puerto Rico.

Everts, C. H.; J. P. Battley; P. N. Gibson. 1983. *Shoreline Movements: Report 1, Cape Henry, Virginia to Cape Hatteras, North Carolina, 1949-1980*. Technical Report CERC 83-1, Report 1. U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Finkl, C. W., Jr., 1994a. "Disaster Mitigation in the South Atlantic Coastal Zone (SACZ): A Prodrone for Mapping Hazards and Coastal Land Systems Using the Example of Urban Subtropical Southeastern Florida." *Coastal Hazards – Perception, Susceptibility and Mitigation*, C. W. Finkl, ed. pp. 339-366.

Finkl, C. W., Jr., ed. 1994b. *Journal of Coastal Research Special Issue on Coastal Hazards*.

Flick, R. E., ed. 1994. *Shoreline Erosion Assessment and Atlas of the San Diego Region*. 2 Volumes. California Department of Boating and Waterways.

Florida Department of Community Affairs. 1985. *Coastal Building Zones*.

Gelfenbaum, G., G. Kaminsky; C. Sherwood; C.D. Peterson. 1997. *Southwest Washington Coastal Erosion Workshop Report*. USGS Open File Report 97-471.

Gerstel, W. J.; M. J. Brunengo; W. S. Lingley; R. L. Logan; H. Shipman; T. J. Walsh. 1997. "Puget Sound Bluffs: the Where, Why, and When of Landslides Following the Holiday 1996/97 Storms." *Washington Geology*. Vol. 25, No. 1. pp 17-31.

Gornitz, V. M.; T. W. White. 1992. *A Coastal Hazards Data Base for the U.S. East Coast*. Oak Ridge National Laboratories.

Gornitz, V. M.; T. W. White. 1993. *A Coastal Hazards Data Base for the U.S. Gulf Coast*. Oak Ridge National Laboratories.

Gornitz, V. M.; R. C. Daniels; T. W. White; K. R. Birdwell. 1994. "The Development of a Coastal Risk Assessment Database: Vulnerability to Sea-Level Rise in the U.S. Southeast." *Journal of Coastal Research Special Issue on Coastal Hazards*, C. Finkl, Jr., ed. pp. 327-338.

Gornitz, V. M.; T. W. Beaty; R. C. Daniels. 1997. *A Coastal Hazards Data Base for the U.S. West Coast*. Oak Ridge National Laboratories.

Griggs, G. 1994. "California's Coastal Hazards." *Journal of Coastal Research Special Issue on Coastal Hazards*, C. Finkl, Jr., ed. pp. 2-15.

Hawaii Coastal Zone Management Program (HCZMP). 1993. *Draft Coastal Hazard Assessment Project*.

Horning Geosciences. 1998. Illustration showing principal geologic hazards acting along typical sea cliff in Oregon.

Hwang, D. 1980. *A Method for Using Aerial Photos in Delineating Historic Patterns of Beach Accretion and Retreat*. Technical Supplement 20. Hawaii Coastal Management Program.

Kana, T. W.; S. J. Siah; M. L. Williams; W. J. Sexton. 1984. *Analysis of Historical Erosion Rates and Prediction of Future Shoreline Positions, Myrtle Beach, South Carolina*. Summary Report. Prepared by Research Planning Institute.

Keillor, J. P. 1998. *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*. WISCU-H-98-003. University of Wisconsin Sea Grant Institute.

Knowles, S.; M. R. Byrnes. Undated. *Shoreline Movements: Report 3, Cape Henlopen, Delaware, to Cape Henry, Virginia*. Technical Report CERC 83-1, Report 3. U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Komar, P., ed. 1983. *CRC Handbook of Coastal Processes and Erosion*.

Massachusetts Coastal Zone Management Program. 1985. *Massachusetts Historic Shoreline Change Analysis Maps*.

Michigan Department of Environmental Quality. 1997. *Summary of Shorelands Act and Administrative Rule Amendments*. EQP 2738 (12/97).

Morton, R.A. 1993. *Shoreline Movement along Developed Beaches of the Texas Gulf Coast: A Users' Guide to Analyzing and Predicting Shoreline Changes*. Bureau of Economic Geology Open File Report 93-1. University of Texas at Austin.

Nags Head Department of Planning and Development. 1998. *A Plan to Make Nag's Head, North Carolina, Less Vulnerable to the Impacts of Natural Hazards*.

National Oceanic and Atmospheric Administration. 1997. *Alabama Coastal Hazards Assessment CD-ROM*. Coastal Services Center. Charleston, SC.

National Research Council. 1990. *Managing Coastal Erosion*. National Academy Press.

New Jersey Department of Environmental Protection (NJDEP). 1983. *Coastal Storm Vulnerability Analysis, Ocean City*.

New Jersey Department of Environmental Protection (NJDEP). Various Dates. *New Jersey Historical Shoreline Change Maps, Historical Inlet Bathymetry and Beach Profile Data*.

North Carolina Coastal Management Program. 1985. *A Handbook for Development in Coastal Hazard Areas*.

Olsen, E. J. 1987. *Reestablishment of the Coastal Construction Control Line*. Florida Sea Grant Extension Program SGEF-7.

Oregon Department of Forestry. 1991. *Recommended Fire Siting Standards for Dwellings and Structures and Fire Safety Design Standards for Road*. Land Use Planning Note No. 1.

Oregon Department of Geology and Mineral Industries. 1998. "Tsunami Hazard Map of the Yaquina Bay Area, Lincoln County, Oregon." *Interpretive Map Series IMS-2*.

Oregon Department of Land Conservation and Development. 1998. "Draft Chronic Coastal Natural Hazards Model Overlay Zone." *Model Ordinance, Planners Guide and Practitioners Guide*.

Oregon Sea Grant. 1994. *Improving Natural Hazards Management on the Oregon Coast: Recommendations of the Coastal Natural Hazards Policy Working Group*. ORESU-T-94-002.

Peterson, C. D.; M. E. Darienzo; D. Hamilton; D. J. Pettit; R. Yeager; P.L. Jackson; C.L. Rosenfeld; T.A. Terich. 1994. *Beach-Shoreline Data Base, Pacific Northwest Region, USA*. State of Oregon Department of Geology and Mineral Industries Open File Report 0-94-2.

Priest, G. R.; E. Myers; A. M. Baptista; P. Fleuck; K. Wang; R. A Kamphaus; C. D. Peterson. 1997. *Cascadia Subduction Zone Tsunamis: Hazard Mapping at Yaquina Bay, Oregon*. Department of Geology and Mineral Industries Open File Report O-97-34.

Rhode Island Coastal Resources Management Council (RICRMC). 1995. *Shoreline Change Maps*.

Rogers, S.M., Jr. 1990. "Designing for Storm and Wave Damage in Coastal Buildings." *Proceedings of the 22<sup>nd</sup> International Conference on Coastal Engineering*. American Society of Civil Engineers. New York. pp. 2908-2921.

Sautter, L. R.; D. Sangster. 1996. *South Carolina Coastal Erosion Annotated Bibliography*. South Carolina Sea Grant Consortium.

Shepard, F.P.; H.R. Wanless. 1971. *Our Changing Coastlines*. McGraw Hill.

Stewart, C. J. 1994a. *United States Great Lakes Shoreline Recession Rate Data: Final Report*. Prepared for the U.S. Army Corps of Engineers, Detroit District.

Stewart, C. J. 1994b. *Great Lakes Shoreline Recession Rate Data Base*. Prepared for the U.S. Army Corps of Engineers, Detroit District.

Texas Coastal and Marine Council. 1976. *Model Minimum Hurricane Resistant Building Standards for the Texas Gulf Coast*.

Texas Department of Insurance. 1998. *Building Code for Windstorm Resistant Construction*.

Town of Charlestown, University of Rhode Island Coastal Resources Center, Rhode Island Sea Grant, Rhode Island Emergency Management Agency. 1997. *Hazard Mitigation Strategy – Charlestown, Rhode Island*. Draft. August

U.S. Army Corps of Engineers. 1973. *National Shoreline Study*.

U.S. Army Corps of Engineers. 1975. *Guidelines for Identifying Coastal High Hazard Zones*.

U.S. Army Corps of Engineers. 1984. *Shore Protection Manual*.

U.S. Army Corps of Engineers. 1992. *Coastal Littoral Transport*. Engineering Manual EM-1110-2-1502.

U.S. Army Corps of Engineers. 1995a. *Coastal Geology*. Engineering Manual EM-1110-2-1810.

U.S. Army Corps of Engineers. 1995b. *Coastal Inlet Hydraulics and Sedimentation*. Engineering Manual EM-1110-2-1618.

U.S. Army Corps of Engineers. Various dates. *Wave Information Study* reports. Coastal Engineering Research Center.

U.S. Army Corps of Engineers. In preparation. *Coastal Engineering Manual*.

Washington Department of Ecology. 1998. *At Ocean's Edge: Coastal Change in Southwest Washington*. Coastal Monitoring and Analysis Program Publication 98-116 (video).

Williams, S. J.; S. Penland; A. H. Sallenger, Jr. 1992. Atlas of Shoreline Changes in Louisiana from 1853 to 1989. U.S. Geological Survey Miscellaneous Investigation Series. I-2150-A.

Zeizer Geotechnical, Inc. 1990. *Coastal Erosion Technical Report, City of Dana Point*.