

FLORIDA SEA GRANT PROGRAM

GUIDELINES FOR BEACHFRONT CONSTRUCTION WITH SPECIAL REFERENCE TO THE COASTAL CONSTRUCTION SETBACK LINE

by

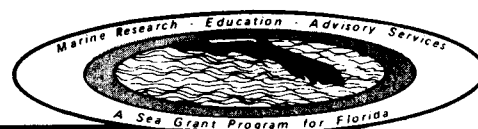
Courtland A. Collier, Kamran Eshaghi, George Cooper, and Richard S. Wolfe

Sponsored by:
State of Florida
Department of Natural Resources
Bureau of Beaches and Shores



Report Number 20

February 1977



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TABLE OF CONTENTS

	Page
INTRODUCTION	iii
I. THE COASTAL CONSTRUCTION SETBACK LINE.....	1
A. The Coastal Construction Setback Line Law.....	1
B. Variances to the Coastal Construction Setback Line Law.....	2
II. IMPACT OF NORMAL WIND AND WAVE FORCES ON FLORIDA'S BEACHES.....	3
A. Introduction.....	3
B. Florida's Shoreline.....	3
C. Wave Characteristics.....	4
D. Interaction of Waves, Beaches and Dunes.....	5
E. Littoral Transport.....	8
F. Beach Erosion.....	8
G. Blowout of a Dune Line.....	10
III. IMPACT OF HURRICANES ON COASTAL CONSTRUCTION IN FLORIDA.....	12
A. Introduction.....	12
B. Characteristics of a Hurricane.....	12
C. Sources of Hurricane Damage.....	17
D. Types of Structural Damage.....	22
IV. RECOMMENDED GUIDELINES FOR BEACHFRONT CONSTRUCTION.....	35
A. Introduction.....	35
B. Summary of Recommended Guideline for Beachfront Construction..	35
C. Details of Recommended Guidelines for Beachfront Construction.	39
V. CHECK LIST FOR BUILDING CONSTRUCTION ON SHORE-AREA PROPERTY.....	64
A. Location Checklist.....	64
B. Elevation Checklist.....	65
C. Design Wind Forces Checklist.....	65
D. Pile Foundations Checklist.....	66
E. Wood Frame Building Checklist.....	66
F. Concrete Block Building Checklist.....	67
G. Roof, Siding, Shutters and Trim Checklist.....	67
H. Utilities Checklist.....	68
VI. BIBLIOGRAPHY	69

INTRODUCTION

In 1971 the Florida Legislature passed the Coastal Construction Setback Line (CCSBL) Law designated as Florida Statute, Section 161.053. The intent of the law is to protect the state's coastal areas from the type of development practices that aggravate beach erosion problems and endanger shorefront property.

This legislation requires a study of the local characteristics of beach frontage in each coastal county before establishing a construction setback line. No new structures will be constructed seaward of that line without conforming to the special requirements of that area for a variance permit. Administration of the new law is the responsibility of the Department of Natural Resources which must hold public hearings, consider all of the input from all interested parties, and ultimately establish the CCSBL on the ground in the state's 23 coastal counties with sandy shorelines on the open coast.

In formulating the CCSBL Law, the Legislature conformed to the customary practice for laws that regulate property rights and provided for the granting of variances. To obtain a variance the proposed structure must be designed and situated in accordance with beach erosion control policies designated for that locale, and with due regard for the protection of upland properties.

This report discusses and illustrates some problems commonly encountered in beachfront construction, and criteria for evaluating variances that will uphold the purpose and philosophy of the CCSBL Law whenever construction seaward of the CCSBL is justified.

CHAPTER I
THE COASTAL CONSTRUCTION SETBACK LINE

A. The Coastal Construction Setback Line Law (CCSBL Law)

The CCSBL Law was enacted by the Florida Legislature in 1971 as a result of concern over the increased amount of "unguided development" of the state's beaches and shores and the resulting destruction and damage to a public asset which "accounts for a substantial portion of the state's annual tourist trade." The law provides for the establishment of an appropriate setback line for beachfront construction.

In the process of determining the CCSBL for any coastal county, the following information on local shore area characteristics is carefully evaluated.

1. Ground elevation in relation to historical storm and hurricane tides.
2. Predicted maximum wave uprush.
3. Beach and offshore ground contours.
4. The vegetation line.
5. Erosion trends.
6. The dune or bluff line.
7. Existing upland development.

Under contract to the Department of Natural Resources, the Coastal and Oceanographic Engineering Laboratory of the University of Florida carefully evaluates this information and recommends a specific location for the CCSBL designed to fit the individual characteristics of the beachfront areas in each county. Public hearings are then held and after considering both the

engineering recommendations and the opinions aired by interested citizens the Florida State Cabinet is empowered to finally establish the legal CCSBL for each county with sandy coastal beaches.

B. Variance to the Coastal Construction Setback Line Law

The law provides that after the CCSBL has been approved, land owners may obtain variances for new construction seaward of the line, providing approved procedures are followed to insure durable construction situated where no serious harm to the shore area will result (27).

CHAPTER II

IMPACT OF NORMAL WIND AND WAVE FORCES ON FLORIDA'S BEACHES

A. Introduction

The CCSBL is an important part of the total response of the State of Florida to the problem of damage to beach property due to faulty design and location of waterfront structures. The objective is to leave as much freedom of development as possible to the property owner, yet adequately protect Florida's beach areas including the lives and property of our people in these areas. Criteria used for evaluating requests for a variance to the CCSBL construction limits must assure that all permitted structures are designed and situated to provide adequate security for persons and property in the beachfront area as well as to protect the existing beach from artificially induced erosion.

B. Florida's Shoreline

The State of Florida has 8,426 miles of tidal shoreline, the longest of the 48 contiguous states (45). Much of this shoreline is composed of sandy beach which is particularly responsive to the natural influences of wind, waves, tides, currents, and long range tectonic variations in sea level. Large quantities of sand along these shores are moved annually by water currents washing across the near-shore sea bottom or the wind sweeping over the dry sand beach. The small particles of sand are carried along in whatever direction the predominating current of the moment happens to move. As the velocity or turbulence of the water or air current increases, the rate of sand movement in the shorefront area increases proportionately. The result

is a shoreline undergoing constant change. Typically these changes are gradual, but under the influence of high energy storm conditions the changes in shoreline can be dramatically swift. Some currents may cause erosion while others cause accretion of the land materials. In many areas of Florida erosion occurs during the stormier winter months followed by accretion in the calmer summer season (10).

C. Wave Characteristics

A typical water wave and its related terms are shown in Figure II-1. As the wave approaches shore and passes into shallow water, it forms a crest and breaks where the water depth diminishes to approximately 1.3 times the wave height (39). Thus a 5 foot wave breaks where the still water measures about 6.5 feet in depth.

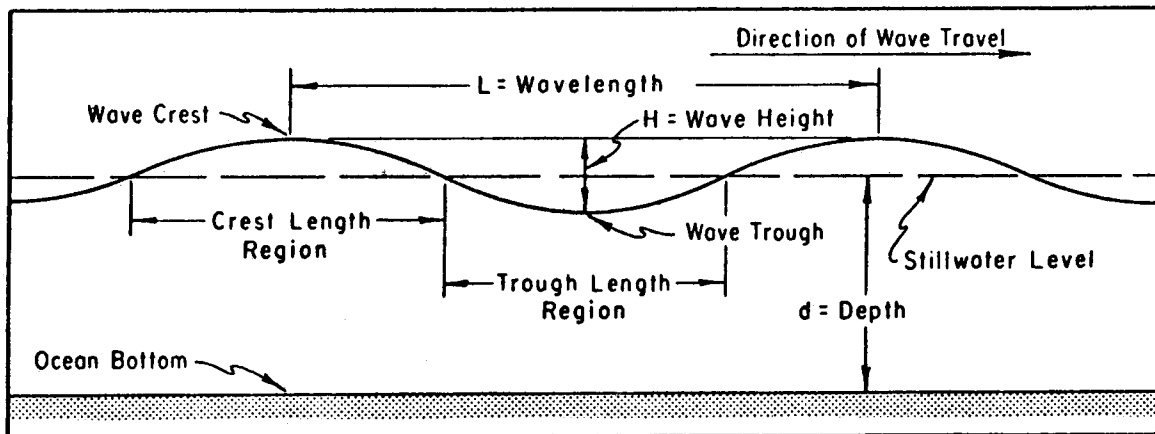


Figure II-1. Typical Ocean Wave and Its Related Terms (39)

As the wave breaks, much of its energy is dissipated in churning and frothing action. After breaking, the wave will often reform as a smaller wave and break again as the water depth approaches 1.3 times the wave's new and shorter height. Depending on the upward slope of the offshore beach

profile, this process can repeat itself several times before the wave finally uprushes on the beach with much less energy than it contained while out at sea. As is shown in Figure II-2, offshore bars are often formed due to the turbulence, and consequent loss of sand transport capacity, caused where the waves break. These bars serve as a natural defense mechanism against later waves approaching the beach because the shallower water at the bars will trip even smaller waves than the ones which initially created the bars (39).

D. Interaction of Waves, Beaches and Dunes

As the water uprushes on the beach and loses velocity, it deposits particles of sand which creates berms or sand bars. A beach may have several bars, each corresponding to uprushing waves at different tide levels. When this sand dries, it may be carried by sea breezes some distance inland to form sand dunes. These dunes can attain considerable height. In Florida dune heights of 20-30 feet are not uncommon. Unless stabilized by vegetation the prevailing sea breezes will continue to transport the sand particles inland, resulting in continued inland migration of the dunes. Since the dune system with its vegetation is the last of the natural defenses of the beach profile against wave attack and because it acts as a levee against high water, it is important to stabilize and protect the dunes in coastal areas. When the storm waves, mounted on high storm tides, attack and erode the dune system the sand removed by the wave action moves seaward until the offshore backslope becomes stabilized. In the process an offshore bar is often formed which acts to dissipate the storm wave energy. After the storm, the beach material removed to build the offshore bar is gradually returned to the beach under the favorable wave conditions shown in Figure II-2

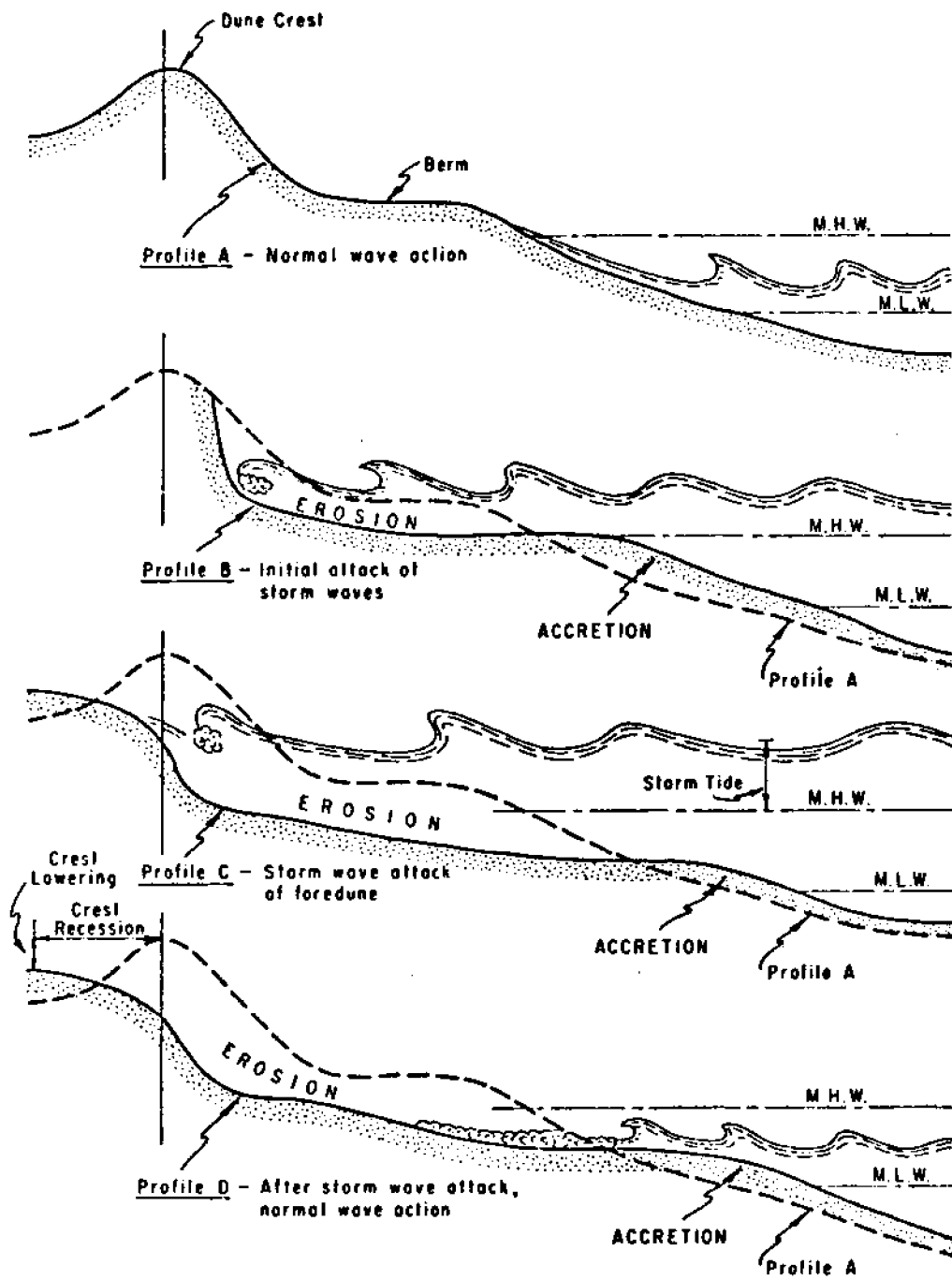


Figure II-2. Dune Response to Storm Waves (39)

(Profile D) and Figure II-3. This, however, is a slow process. Dunes eroded in several hours of heavy wave attack may take a great number of years to reform. Compounding this problem is the fact that sand along most of shorelines of the world is being lost more rapidly than it is being replaced. Therefore, the dune systems now in existence must be protected to insure that they will continue to serve as the last line of the natural defense of the beach profile. Further, the natural profile of a gently sloping beach of adequate width and height is still the most effective method known for dissipating wave energy, and therefore is important to preserve (39).



Figure II-3. Dune Erosion During Hurricane Eloise, 1975, Resulting In Seaward Accretion (follows the natural sequence illustrated in Fig. II-2)

E. Littoral Transport

In addition to the movement to or from the shoreline, sand particles move along the shoreline also, possibly following a zig-zag or other erratic pattern. This along-shore movement of sand particles is sometimes called littoral transport or littoral drift and is caused primarily by the water currents along the shoreline which in turn largely result from wind and wave action.

Beach erosion problems often involve the mechanisms of littoral transport and therefore, the effect on littoral transport of a proposed structure or an altered beach profile must be evaluated carefully. Sometimes attempts are made to trap some of the littoral drift of sand along a coastline by use of long low fingerlike walls, called groins, jutting out from the shore. Unfortunately as sand particles are collected on one side of the groins, erosion is frequently precipitated on the other side. Some groins have caused the deflection of significant amounts of littoral sand out to deeper waters where it becomes virtually unrecoverable. Attempts to overcome these disadvantages have involved groins used in parallel, groins with different profiles and configurations, and so on. Success has been far from uniform, and groins or other structures with groin-like features usually are not recommended for Florida beaches.

F. Beach Erosion

Historically beach erosion and depletion has been a problem in Florida since civilized man first laid claim to property along these shores. Now as beachfront areas become more intensely developed and conflicts increase between development and the natural forces of the sea the amount of resulting property damage also increases proportionately year by year. Continuous

efforts to control erosion and restore the beauty and usefulness of the beach have met with only partial success.

Beach erosion occurs when the equilibrium between gain and loss of the sand material comprising the beach areas of our coastline is upset.

Where erosion does occur it may be either one of two types (5):

1. Nature-induced erosion from natural causes such as storms, tides, rise in sea level, and currents flowing through natural inlets.
2. Man-made erosion resulting from improperly designed or incorrectly located coastal structures, or dredging of coastal inlets and entrance channels.

Natural erosion occurs at varying rates, ranging from gradual depletions caused by geological and climatological changes, to rapid scours accomplished in a matter of hours by powerful storms and storm tides. Long term increases in sea level have also produced significant recession of land area in low lying coastal zones. Present studies indicate a long term rise in sea level of approximately 1.5 mm (0.005 ft.) per year. However from 1964 to 1972 a noticeable increase in the rate of rise was noted. The average rise in sea level along the coasts of the United States was 6 mm per year (1/4 inch per year) (18). Along Florida's sand beaches this rise causes shoreline recession at a rate of about 150 mm to 760 mm (6 inches to 30 inches) per year (6).

Where man-made erosion occurs it is usually caused by man's interference with natural shore processes. Such activities often include dredging of inlets, construction of jetties, groins, retaining walls and other coastal defense structures that alter or block the natural movement of sand along the shore.

G. Blowout of Dune Line

In coastal areas experiencing a lot of pedestrian and off-road vehicular traffic, one of the greatest dangers facing dune systems is that of blowout, or the breaching of a dune line primarily due to artificial loss of dune vegetation followed by natural wind erosion. An intact dune line acts as a natural levee (see Figure II-4) and protects low areas against flooding during storms. If the dune line is breached by a blowout, no such natural protection is provided. In the event of storm attack and accompanying high storm tides, water can pass through the blowout, further erode the dune system and inundate the vulnerable areas behind the dune line. Blowouts frequently occur when the stabilizing dune vegetation is damaged by man as a result of using the dunes as an access path to the beach for pedestrian or vehicular traffic or as a construction or camp site. A typical blowout is shown in Figure II-5. To prevent this type of dune degradation, an elevated walkway across the dune should be provided (see Figure IV-6).

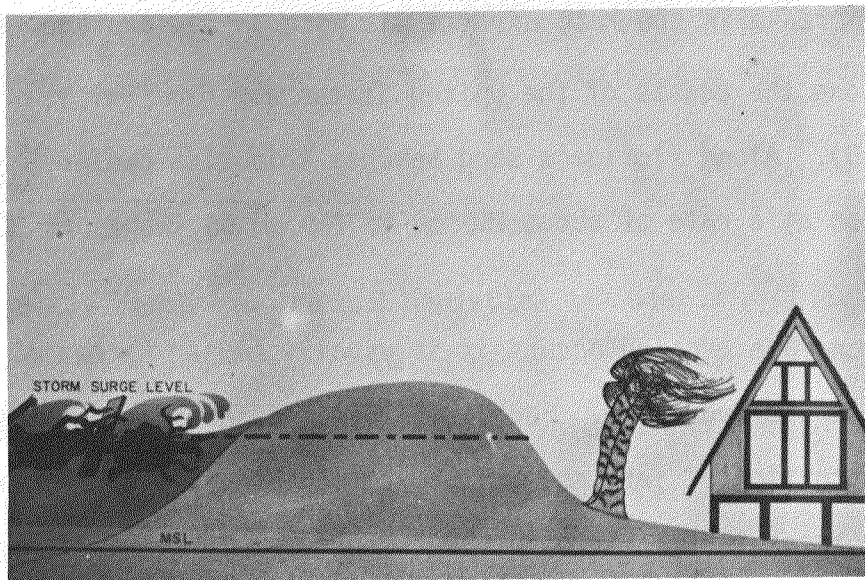


Figure II-4: Dune Line Acting as a Natural Levee Against Storm Attack (9)



Figure 11-5. Blowout of a Dune System (15)

CHAPTER III

IMPACT OF HURRICANES ON COASTAL CONSTRUCTION IN FLORIDA

A. Introduction

Hurricane resistant designs are ultimately judged by their ability to survive actual hurricane conditions. By their nature and frequency hurricanes often provide the final field test, revealing any weaknesses that may have slipped into the design and construction process. This chapter reviews some of the characteristics of hurricanes and their typical forms of attack on beachfront structures. Where failures have occurred, some of the apparent causes are discussed.

B. Characteristics of a Hurricane

Severe tropical cyclones, called hurricanes, are among the most intense storms of the world and have been known to erode literally millions of tons of beach sand in a matter of hours. Besides high winds and torrential rains, a hurricane over water typically induces an extremely high "storm surge", usually causing severe flooding in coastal areas.

1. Hurricane Winds

Hurricanes are differentiated from lesser tropical cyclones by the intensity of the wind. Tropical cyclones are classified as "tropical storms" if the winds are between 34 and 74 miles per hour, and "hurricanes" when the winds exceed 74 miles per hour. Frequently accompanying hurricanes are the smaller but more intense "tornadoes", described as small local whirlwinds with winds of very high velocity.

Stated very simply, hurricanes are giant whirlwinds in which air moves in a large, tightening spiral around a center eye of extremely low atmospheric pressure (Figure III-1). The winds of maximum velocity are typically confined to a circular band extending outward 20 or 30 miles from the rim of the eye. In the Northern Hemisphere the winds within this band circulate counterclockwise around the eye, while in the Southern Hemisphere the circulation is clockwise (40).

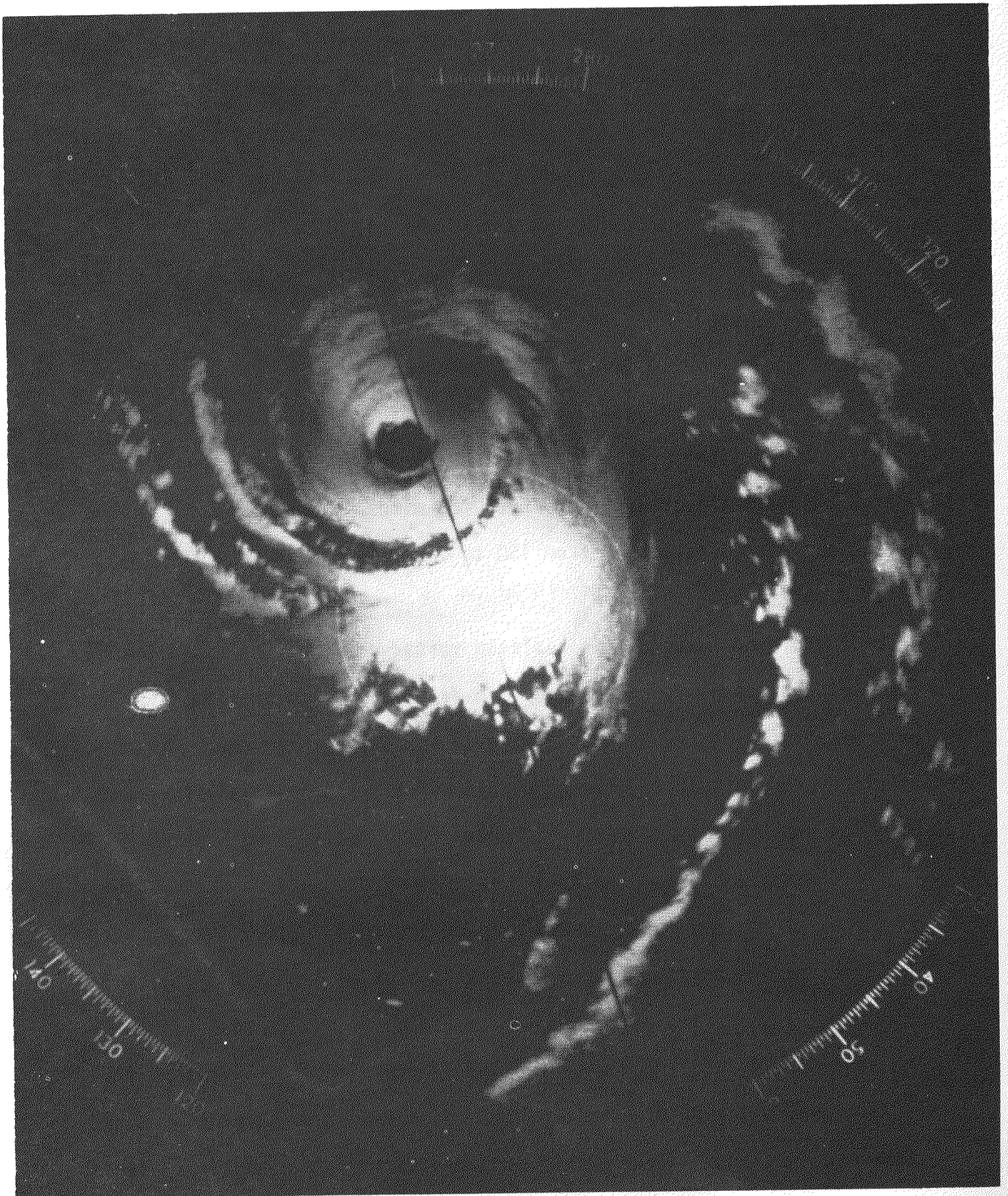
Although the entire hurricane area may be as much as 500 miles in diameter, hurricane damage is usually confined to a swath from 30 to 100 miles wide cut by the severe wind circling the center of the storm. The highest winds typically reach from 75 to 125 miles per hour, occasionally recording sustained velocities from 150 to 190 miles per hour, (Hurricane Camille, 8/69) (44).

The eye of the hurricane is a placid vortex or center of several miles in diameter and is unique to hurricanes. Here, winds are calm to light and skies are clear or partly cloudy. The eye moves along with the hurricane at varying speeds, typically from about 15 miles per hour in the tropics to 40 miles per hour in the temperate zones (4).

Hurricanes are accompanied by low barometric pressure, usually under 29.00 inches of mercury. The lowest reading recorded in the United States was 26.35 inches, occurring on the Florida Keys on September 2, 1935 (4).

2. Hurricane Paths

Hurricanes typically begin as tropical depressions in "Hurricane Alley", a breeding ground for tropical storms between the west coast of Africa and the Cape Verde Islands. They gather strength as they move westward across the Atlantic frequently toward Puerto Rico. From there they typically veer



"Eye" of Hurricane Donna, 0400 EST, September 10, 1960, Located Near Cape Sable—U. S. Weather Bureau Photo

Figure III-1.

northward into the Gulf or Atlantic (9). The path of any individual hurricane is difficult to predict. Some hurricanes follow generally straight paths, while some curve, loop or even hover for a while without forward movement. The tracks of typical Florida hurricanes are shown in Figure III-3.

3. Hurricane Waves

Even in normal weather, wave action in the Atlantic is usually more severe than in the Gulf of Mexico. Measured over a typical year the frequency of waves 12 feet and higher is about 4% on Florida's east coast, but is less than 0.5% on the west coast. Under normal weather conditions, east coast waves frequently reach 4 feet in height compared to a 1 to 2 feet wave height under similar conditions on the west coast. As winds rise toward hurricane velocities, storm waves on the east coast often reach a height of 10 to 15 feet, compared to a corresponding height of 5 to 6 feet above storm surge levels on the west coast of Florida (6).

4. Hurricane Spawned Tornadoes

Tornadoes are often associated with hurricanes but the number of tornadoes spawned by each individual hurricane will vary greatly.

A tornado is a violently rotating funnel shaped column of air varying in diameter from just a few yards to over 1/4 mile (average 300 yards). The funnel is pendent from a mass of black cloud, and contains destructive internal wind velocities estimated at 150 to 300 miles per hour (48). Tornado damage results from direct wind forces as well as flying debris along limited swaths of almost total destruction varying in length from several to many miles (average 16 miles). Few structures in their paths are safe.

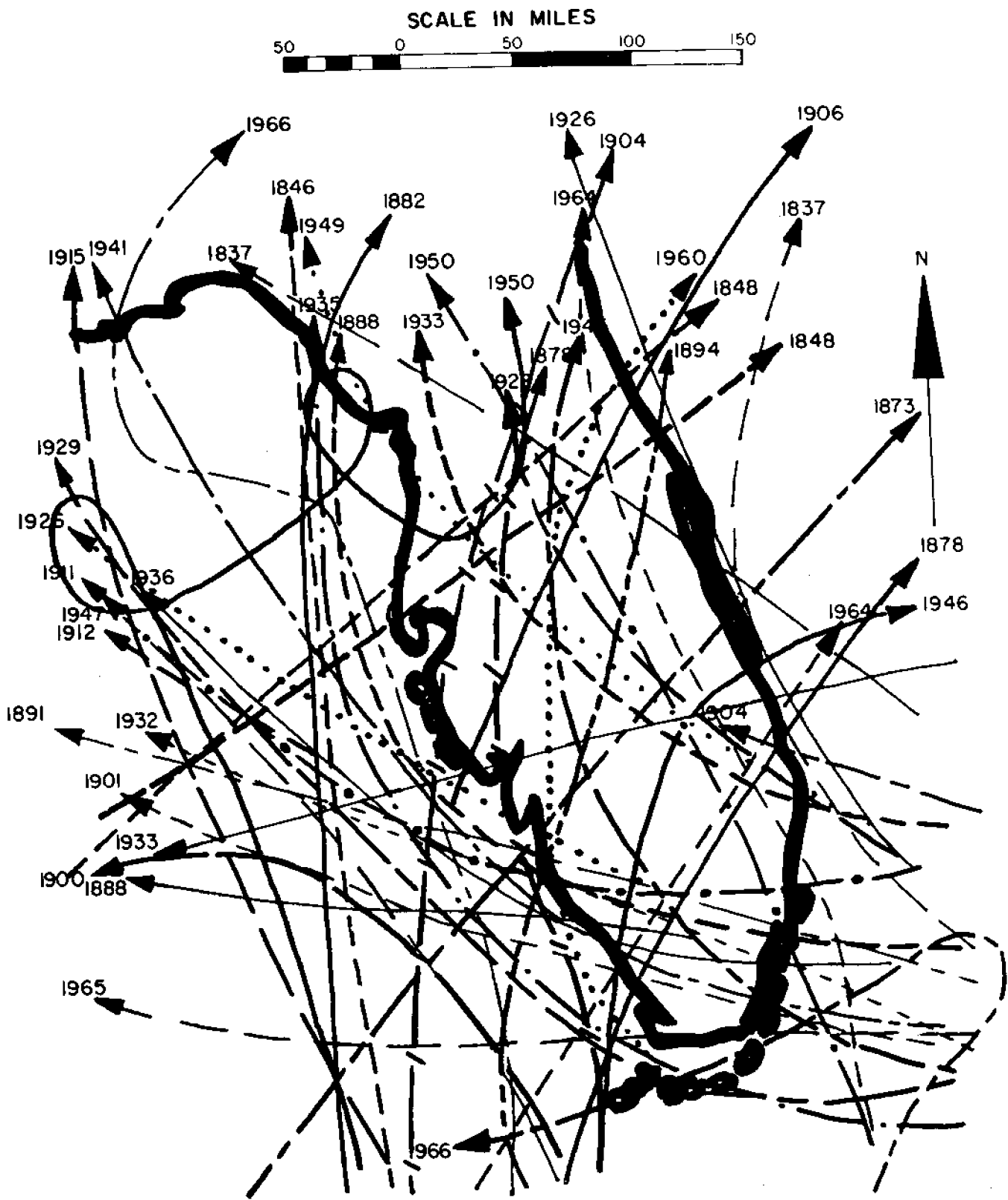


Figure III-3. Major Hurricanes Affecting Florida (8)

Additional tornado damage is caused by the sudden decrease in atmospheric pressure associated with their passing. If most of the windows and doors in the building are closed when the tornado occurs, the pressure inside the building may remain significantly higher than the suddenly lowered outside pressure. This intense pressure differential has caused walls to collapse violently outward during the passage of a tornado.

C. Sources of Hurricane Damage

After researching a number of hurricane related structural failures in buildings, the Army Corps of Engineers found that the damage is usually attributable to one or more of the following causes:

- a. Direct wind forces in excess of design criteria.
- b. Flying debris consisting of loose objects, failed material, and temporary structures in the vicinity including unsecured construction material at project sites.
- c. Structural elements weakened due to inadequate maintenance following corrosion, wear-and-tear, repeated exposure, fatigue, decay, and termites.
- d. Penetration of wind driven, salt-laden rainwater into the interior of the structures.
- e. Direct attack by high ocean waves and/or storm surges generated by the hurricane.
- f. Still water wetting or flowing water pressures due to floods that accompany hurricanes.
- g. Inadequate design and/or poor construction of structural elements and other features comprising the facility (12).

1. Hurricane Wind Damage

Experience indicates that the most potent winds are those in the fore-front of hurricanes as they move in from the sea (eg. from the Atlantic, Dora, 1964 or from the Gulf of Mexico, Eloise, 1975). These winds are especially dangerous when the center passes inland or off-shore near a

developed area, because the strong on-shore winds may produce serious flooding in addition to direct wind damage.

In areas which are not affected by hurricane waves or flooding, wind forces are usually responsible for the major losses in a hurricane. At wind velocities up to 100 miles per hour the windows and roofing are the most vulnerable areas subject to damage in buildings. As winds exceed 100 miles per hour damage to structural members occurs more frequently, especially to buildings not specifically designed to withstand these forces. The maximum anticipated velocity of hurricane winds will vary with geographic location and other factors. A recommended design standard is the wind velocity of a 100 year storm. This is the highest sustained velocity that has no more than a 1% probability of occurring in any year. To be assured of an adequate design at the lowest cost, structures in shore areas susceptible to hurricane attack should be designed by an engineer or architect especially qualified by training and experience in this specialized professional area.

2. Windblown Debris

Flying debris contributes significantly to the damage inflicted on buildings subject to hurricane force winds. Common structural debris reported flying through the air in the midst of hurricanes include roofing tile or gravel, sheets of corrugated metal, brick, timber, concrete blocks or slabs, and steel or wood structural units. Non-structural debris typically includes tree limbs, lawn and porch furniture, glass, and sometimes even air conditioning units, boats, and cars (Figure III-5).

3. Water Damage

Water damage during hurricanes may result from the destructive wetting action of rising storm tides, the pounding force of wave action, or the



Figure III-5. Windblown Debris Includes Sizeable Objects, such as this Mobile Home Viewed After Hurricane Camille 8/69 (44)

damage to building interiors due to entry of rainwater or spray through ruptured roof surfaces, windows, doors or other openings.

When strong storm winds drive the seawater shoreward, the water tends to pile up along the shore, particularly where offshore waters are relatively shallow and interfere with the free return of the outflow. A temporary local rise in sea level usually results. In addition, the reduced atmospheric pressure associated with storms causes a further rise in sea level. This storm-induced combination of increments in sea level is termed "Storm Surge" or "Storm Tide". The resulting flooding of low lying coastal areas may seriously increase the toll of storm damages. As the storm moves across the coastline, tides may reach as high as 20 feet above normal sea level. For any specific location the actual height of storm generated tides depends on a combination of factors such as wind force, water depth, offshore profile, barometric pressure, and others. Figure III-6 gives examples of tidal heights recorded during major hurricanes in Florida.

Flooding can result not only from wind-driven storm tides near the coast but also from rain-induced flooding of inland water courses due to a hurricane's torrential down pours. Acting together, the rising storm tides back-up water into rivers and bays, retarding the flow of rain-swollen inland water courses. In addition to structural damage caused by undermining and the heavy pressures of moving floodwaters, the flooding typically causes severe wetting damage to the interior and furnishings of homes and other buildings. Other sources of flood damage include softening of road base materials, back-up of sanitary sewers and septic tanks, disruption of other utilities and similar damage to other publicly owned improvements.

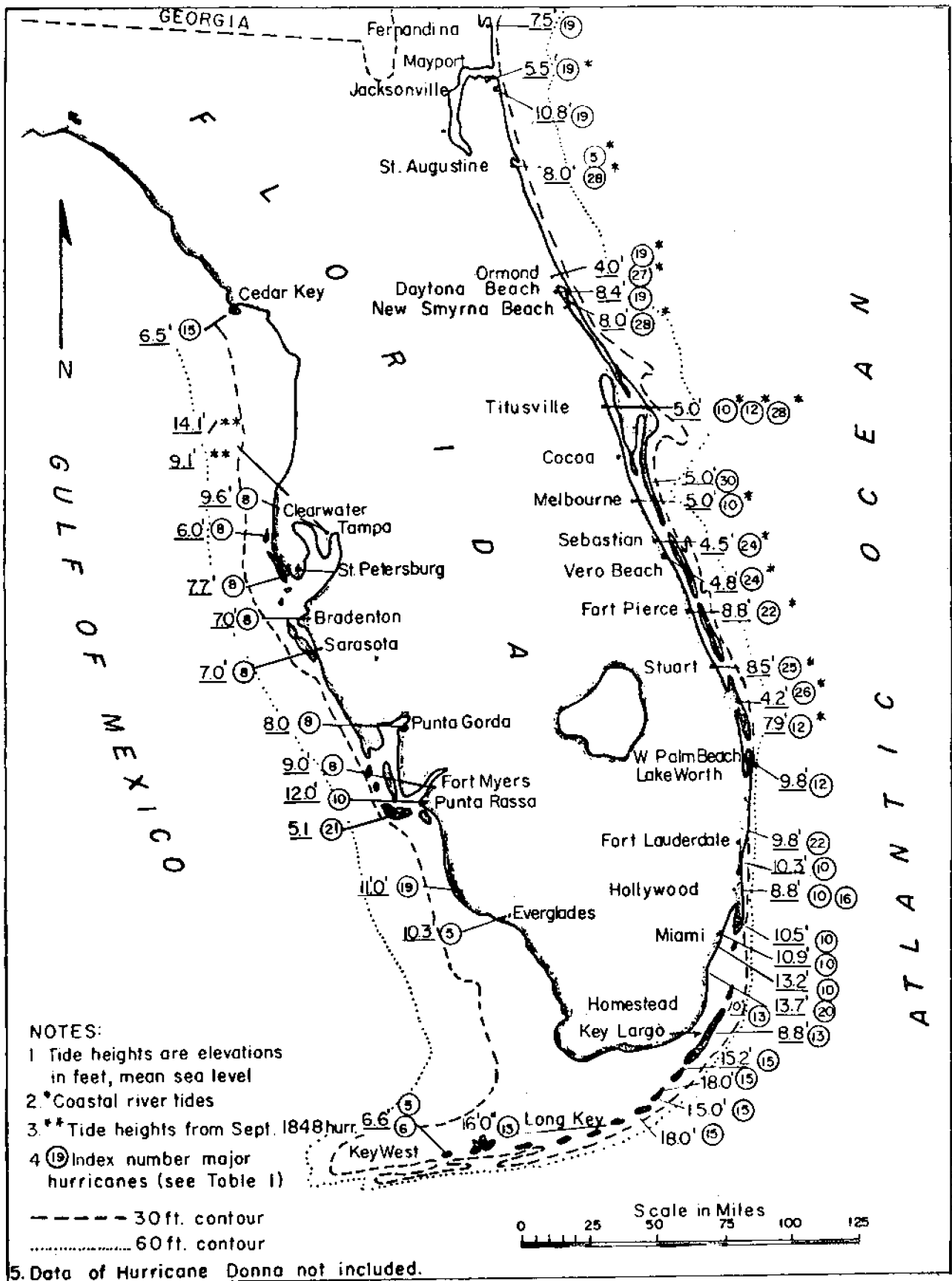


Figure III-6. Maximum Tidal Heights During Storms on Florida Shores

4. Wave Action. Storm waves cresting on storm tides along coastal areas can exert very high lateral and uplift pressures on structures in their path, resulting in awesome destruction (Figure III-7, and 8). In some areas boats, cargo, building components, and other heavy debris have been washed considerable distances inland by the heavy wave action.

In shore areas fortunate enough to have well developed and intact primary dune systems, the destructive energy of the waves may be completely absorbed by the dunes, thereby protecting any man-made structures located landward of the dune. If the structures are located too close to the water, the waves may erode the sand and undermine the structure, causing subsequent collapse (Figure III-9 and 10). Observations after Hurricane Eloise (1975), indicate that a great deal of the damage to beachfront houses built on concrete slabs resulted from the action of waves undermining the supporting sand from under the slabs.

D. Types of Structural Damage

Generally the most severe damage to structures in hurricanes is caused when foundations fail or the structure is torn loose from its foundation. Next in severity is roof failure caused by improper ties between the structure and the roof. Less severe but accounting for a large total monetary loss value are failures in siding, broken windows, loss of porches, garages, and steps (4). The following discussion of losses involved with each component is intended to lead to a better understanding of hurricane design requirements.

1. Roof Damage

The high winds and flying debris associated with hurricanes frequently causes considerable damage to roofs, and in extreme cases, may cause separation



Figure III-7. Structural Failure Due to Wave Action. Roadside Rest Area, approximately 250 feet from the Shoreline, Panama City Beach, Florida, Hurricane Eloise, Shallow Foundation, No Piling (9/75)



Figure III-8. Landward Side of a Motel Showing Furniture, Appliances and Other Non-Structural Debris Moved Through the Windows by Wave Forces. Hurricane Eloise (9/75)



Figure III-9. Waves washed the supporting sand from under the slab on grade, causing the slab to fracture and the house to fall. Hurricane Eloise (9/75)



Figure III-10. Another slab on grade house. Wave action eroded the supporting sand from under the slab causing collapse. Hurricane Eloise (9/75)

of the entire roof from the remaining structure. The greatest single source of roof damage during hurricanes occurs from the loss of roof covering materials such as asphalt and shingles. The roof sheathing itself usually survives intact. However, damage to the roof covering permits entry of rainwater and sea spray into the building with resulting damage to interior surfaces, furniture and fixtures (4).

As hurricane force winds pass over and around a building, areas of reduced pressure occur due to the airfoil effect over the roof and outside of the side and leeward walls. The difference in pressure between the inside and the outside exerts a lifting force on the roof, particularly along the windward eaves of roofs with a small incline. Any breaks or openings in the windward wall, such as broken windows or open doors, permit wind forces to increase the interior pressure which in turn aggravates the lifting forces on the roof.

Roof with slopes of less than 7 on 12 through 12 on 12 typically undergo increased pressure on the windward surface and reduced pressure suction on the leeward surface (Figure III-11 and 12) (29).

Carport roofs and overhangs are particularly vulnerable to wind damage in a considerable number of residential buildings. Upward wind pressures on cantilever roof sections may reach 150% or more of the wind pressure on a vertical face. In some buildings, failures will begin with a loss of carport roofs or roof overhangs and will then progress to failure of the complete roof structure.

2. Damage to Walls, Siding, and Sheeting

Walls are susceptible to damage directly from the forces of wind and wave, or indirectly from loss of support caused by storm damage to other

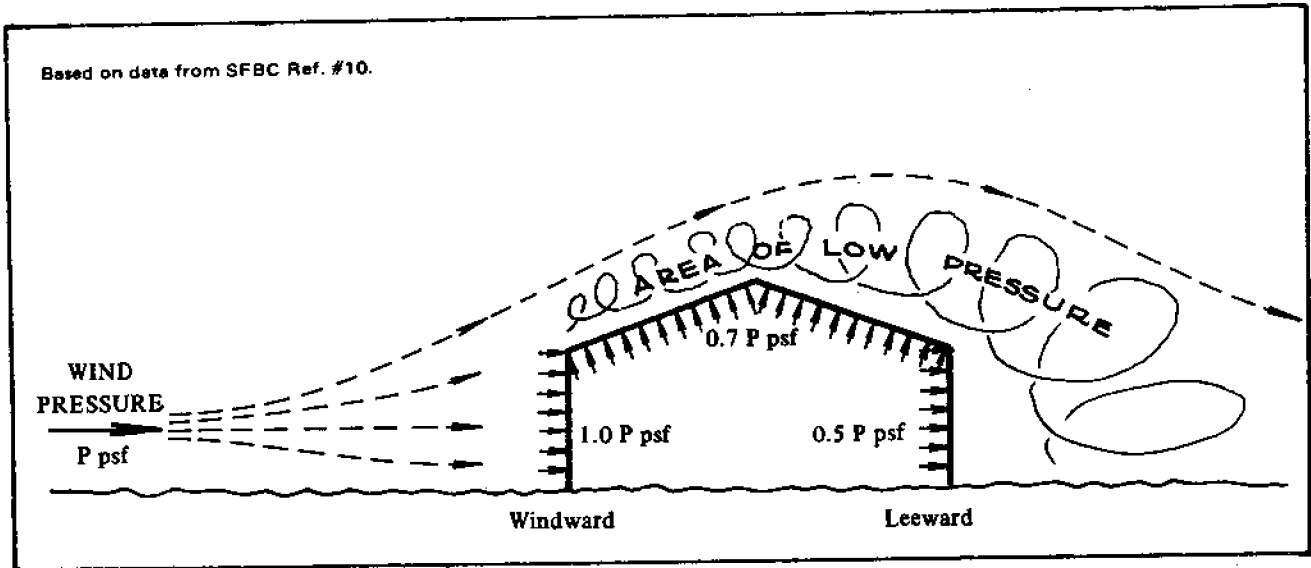


Figure III-11 Wind Pressure Acting on a Rectangular Building, for Roof Slopes Less than 7 on 12. (29)

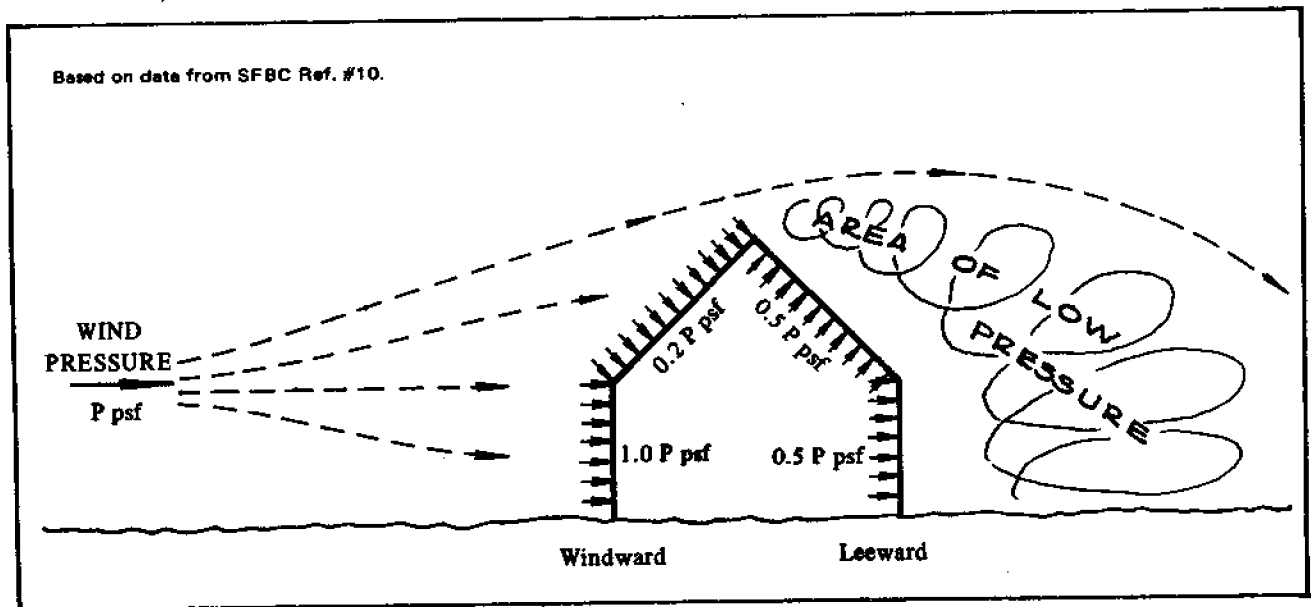


Figure III-12 Wind Pressure Acting on a Rectangular Building, for Roof Slopes 7 on 12 to 12 on 12. (29)

components of the structure. For instance, when the roof is blown off, the wall loses its top lateral support and becomes vulnerable to horizontal forces. Undermining of the wall may decrease the amount of vertical support available which in turn can lead to diagonal cracking and subsequent collapse of the wall.

Non-reinforced concrete block wall construction is sturdy under normal conditions when subject only to compression forces. Under hurricane conditions, however, the walls may be subject to tensile stresses which could lead to failure (Figure III-13 and 14).

In concrete block construction, a common source of failure occurs at the joint between the base of the block wall and top of the footing. Where vertical reinforcing between footing and wall is omitted, the strength of this joint is dependent solely upon the strength of the mortar in the joint. Where joints between footing and wall have failed under hurricane conditions, subsequent inspections seldom reveal any signs of vertical reinforcement joining the supporting footings to the concrete blocks above. Without vertical reinforcement throughout the entire height of the wall the tensile, beam, or buckling strength of the wall is also wholly dependent upon the strength of the mortar. Unreinforced concrete block walls are subject to failure in all three of these modes when subject to hurricane forces. To qualify as hurricane resistant they should contain adequately designed vertical reinforcing tied into both footing below and roof structure above, at regular intervals along the walls. Reinforcing is also recommended at all corners and around all openings (Figure III-15 and 16).

Storm damage reports indicate that properly designed reinforced concrete walls, with good anchorage to the supporting footing, generally withstand hurricane forces well. This is true only where the foundation itself is not undermined and continues to provide adequate support.

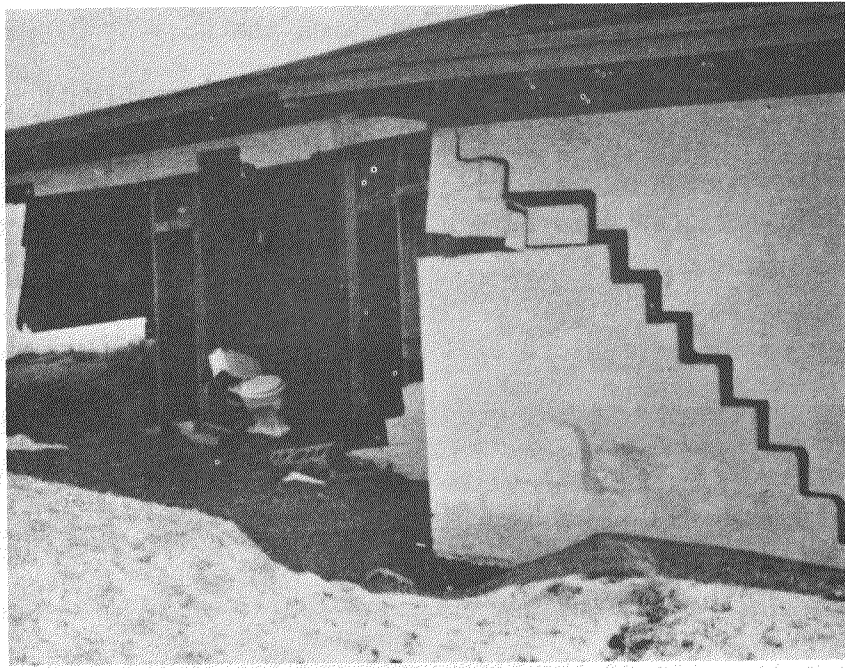


Figure III-13. Non-Reinforced Concrete Block Wall Failure in Tension After Loss of Support (4)

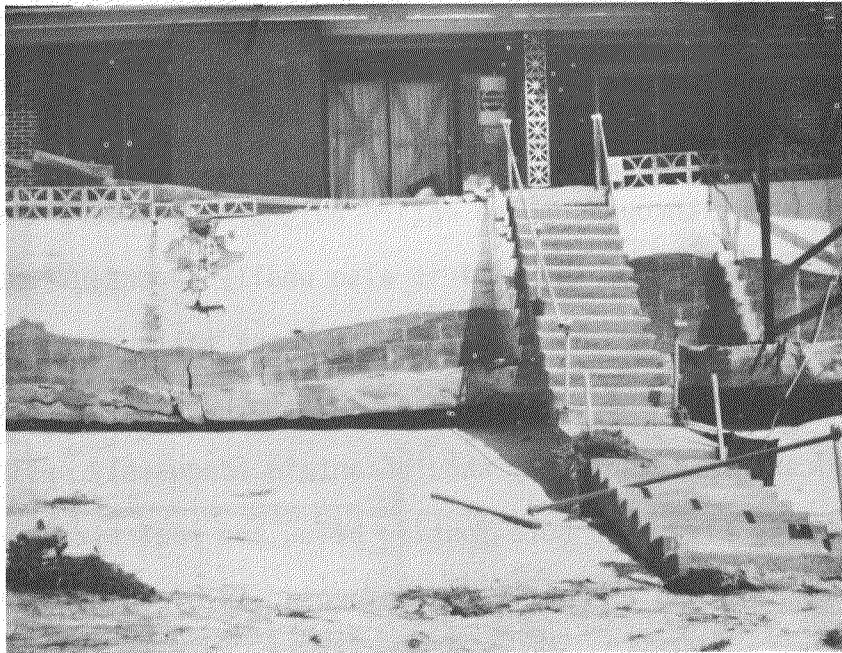


Figure III-14. Concrete Block Sea Wall Fails in Tension After Loss of Supporting Sand That Previously Reached Partway Up the Wall



Figure III-15. Failure of Corner Walls Due to Wave Action and Loss of Support

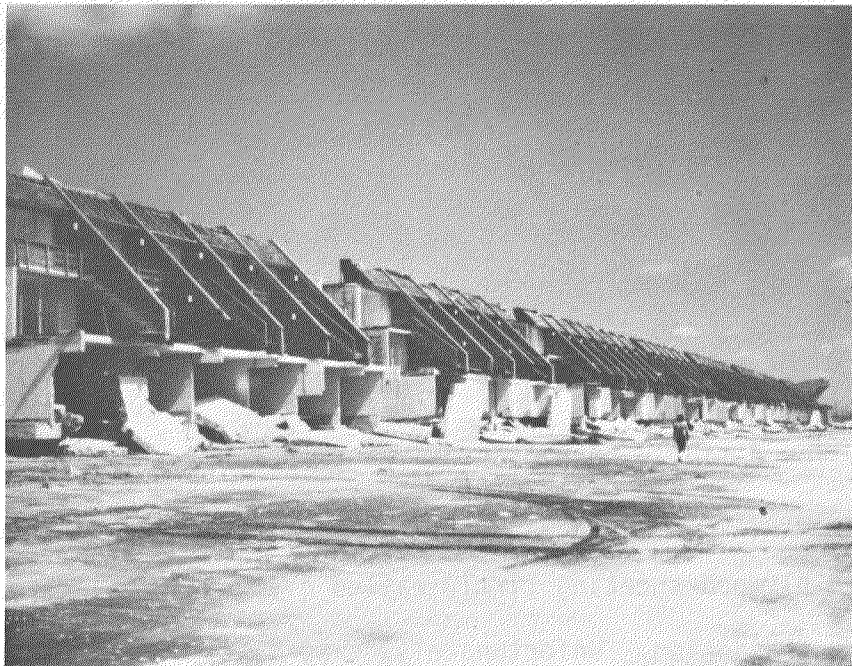


Figure III-16. Wall Failures Resulting From Hurricane Eloise September 1975

Wood frame construction also holds up well under hurricane attack except where inadequate ties cause components of the structure to separate, or loss of foundation support occurs as a result of water action (Figure III-9 and 10).

House sheathing, plywood or planking fastened to the outside of the studs, when properly selected and installed, gives considerable rigidity to the structure and serves as a base for fastening of the siding. The siding gives additional protection from the elements and usually contributes to the appearance of the house. Boards, plywood, wood shingles, brick veneer, and asbestos shingles are common siding material used in beach areas. Brick veneer provides a hardened surface covering for resistance to damage by wind blown debris. Brick veneer may be subject to failure from wind suction or other storm forces, if not firmly tied to the sheathing. Particular care is required when fastening exterior veneer at the building corners since wind, passing the corner of a building, creates a suction along the leeward wall adjacent to the corner (4) (Figure III-17 and 18).

3. Damage to Windows and Doors

Breakage of windows and doors is common during hurricanes, and while the value of individual losses is relatively minor, the aggregate losses in this category for a single hurricane can be very large. Breakage may result from wind, wind driven debris or wave action. Hurricane designed shutters or plain plywood sheathing firmly nailed over all openings usually provides adequate protection. Unfortunately, experience indicates that the majority of citizens do not apply these simple protective measures even in areas where adequate warnings have been issued. Window breakage on the windward side of a building may lead to more serious problems. Once storm



Figure III-17. Hurricane Damage to Brick Veneer Siding Resulting From Wave Action. Diagonal Sheathing Provided Excellent Rigidity As Well As A Good Tie Between Wall and Floor Framing (4).



Figure III-18. Club House Roof Failure by Wind Force. Further Damage is Evident to the Siding Materials on the Walls at Corner of the Building Caused by Wind Suction. This Building Was Subsequently Evaluated As A Total Loss (Eloise, 1975).

winds are admitted to the building interior, a corresponding increase occurs in the interior uplift pressure on the roof as well as the outward pressure on the lee and side walls.

4. Foundation Damage

Storm tides and erosion sometimes permit wave action to reach previously inaccessible beachfront structures. Many of these existing beachfront structures consist of a building constructed over a simple slab on grade supported only by the sand under the slab. When subject to wave action the sand washes out from under the slab, the slab breaks due to lack of support, and the building collapses (Figures III-19 and 20). Because of these inherent shortcomings, slab on grade construction is not recommended for beachfront areas subject to storm tide water action. As a rule all floor slabs should be structurally supported by piling or deep footings based on firm material well below the lowest possible scour elevation of the beach in that vicinity.

Many houses in beach areas are currently being built on foundations of treated timber piling. This usually proves satisfactory providing the piling and the house are designed and constructed by competent professionals. The piling in particular must be designed to withstand hurricane forces under maximum scour conditions and loss of surrounding material down to the elevation of stable soil. In general, anchorage requirements for construction in hurricane-exposed areas must be carried from the roof down directly to the supporting foundation.

A good foundation must resist forces other than water and wind. A great deal of debris is carried by hurricane waves, some of it very heavy, such as broken piling, parts of houses, boats, and appliances. Such items serve as battering rams to beat repeatedly on the house foundation or any other part of the structure exposed to wave action.

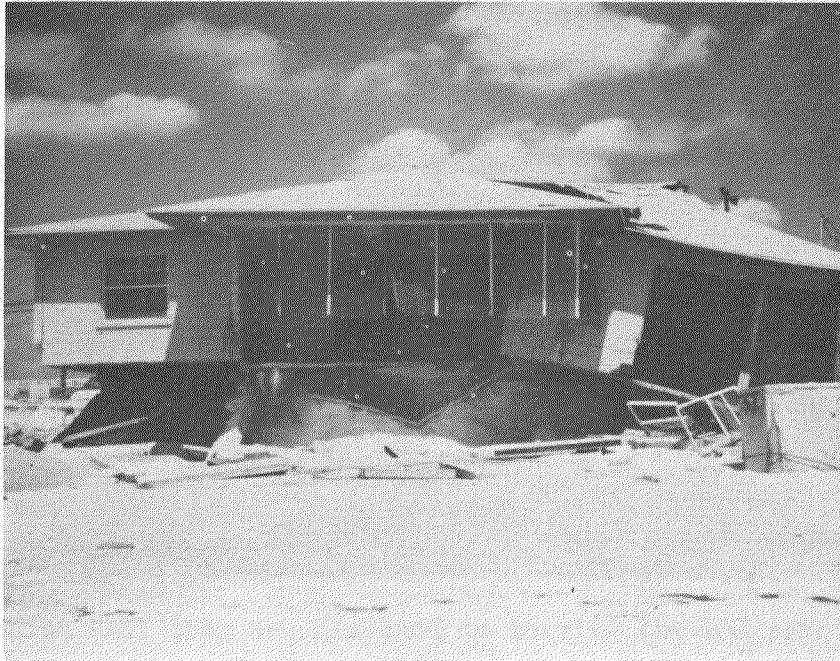


Figure III-19. Example of Slab on Grade Failure as a Result of Undermining by Wave Action. Hurricane Eloise (9/75)



Figure III-20. Structural Failures Caused by Undermining Wave Action. Panama City Beach, Hurricane Eloise (9/75)



Figure III-21 Example of Slab on Grade Failure as a result of underming by wave action. Note the building to the right surviving intact on Pile Foundation. Hurricane Eloise (49).

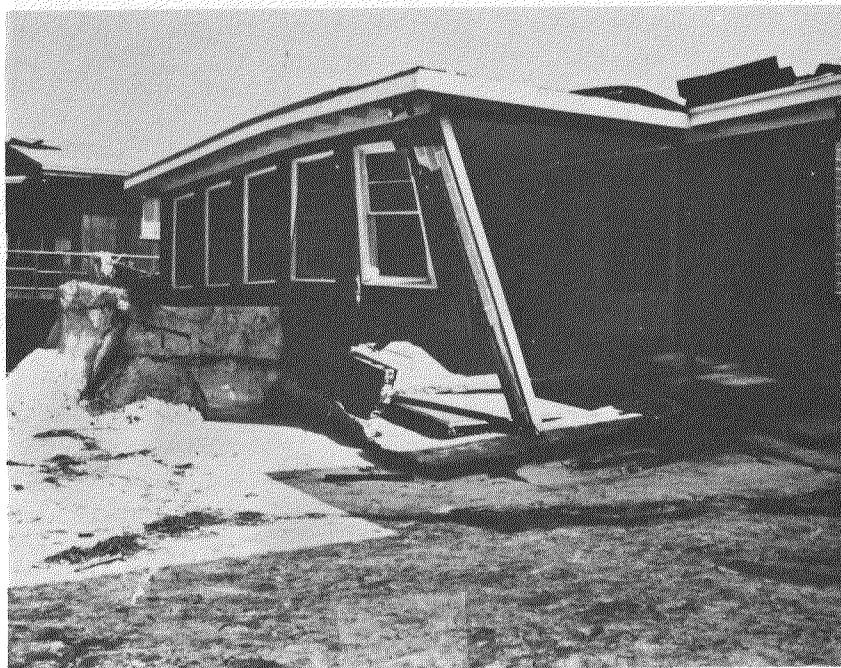


Figure III-22 Wave action undermined this slab on grade causing severe structural damage. Notice the building to the left survives intact on pile foundation. Hurricane Eloise (49)

CHAPTER IV
RECOMMENDED GUIDELINES FOR BEACHFRONT CONSTRUCTION

A. Introduction

According to the Coastal Construction Setback Line Law, the Department of Natural Resources is not only charged with the responsibility of establishing the Coastal Construction Setback Line, but must also administer the procedures for the granting of variances to permit construction or excavation seaward of that line. Variances may be granted for structures even in high hazard areas, providing that they are designed to survive the 100 year hurricane and will have a minimum adverse impact on the beach-dune system. The guidelines recommended in this chapter are based on the experience of a number of distinguished engineers who have contributed freely of their knowledge of hurricane-resistant design gathered over a number of years of professional practice dealing with the unique natural hazards that periodically threaten beachfront structures.

B. Summary of Recommended Guidelines for Beachfront Construction

1. Design and Construction by Competent Professionals

Since beachfront construction typically affects the safety and welfare of human life as well as the value and security of major investments in nearby property, all structures along coastal beach areas should be designed by competent professionals with special qualifications for this type of work. Of equal importance are adequate construction supervision, inspection, and certification to insure that the design is carefully followed on the job site. Merely locating the building landward of the CCSBL does not

guarantee complete security and the help of experienced professionals in selecting a secure location and elevation is recommended.

2. Preservation of the Natural Beach System

The natural beach system usually represents a state of reasonable equilibrium in nature, and should not be permanently altered within the active beach zone without a thorough engineering analysis under the supervision of the Department of Natural Resources and subsequent approval by that agency. This does not preclude the use of piling or temporary excavation in this zone.

3. Wind Force Design, 100 Year Frequency

As a recommended minimum, all elements of buildings and other beachfront structures, especially those seaward of the CCSBL, should be designed to safely withstand the forces exerted by a storm of 100 year frequency. In Florida coastal areas, wind velocities for the 100 year storm vary from 110 MPH over most of the coast to 130 MPH in the Keys. (See Figure IV-1) (25). The 100 year frequency is intended as a minimum standard and designers are encouraged to design to more conservative standards whenever appropriate.

4. Wave Force Design, 100 Year Frequency

All structural elements in the zone of possible wave action should be designed to safely withstand the forces generated by the highest wave forces generated by a 100 year storm. The structure should be capable of resisting these forces after maximum erosion and scour have taken place around the pile foundations.

5. Building Location and Elevation

As a general guide to the location of beachfront construction the following factors are particularly important.

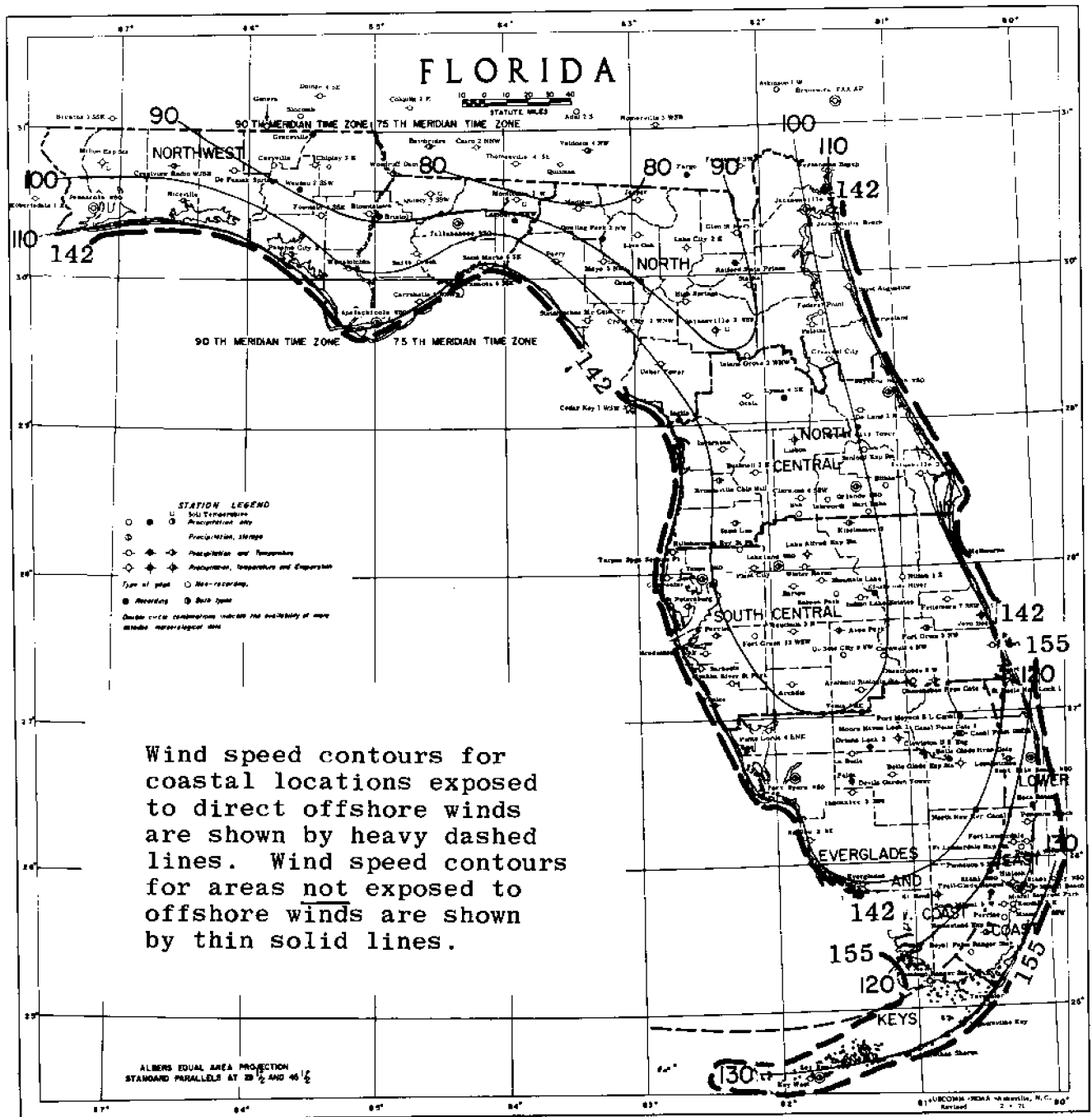


Fig. 6.3
 Basic Wind Speed in Miles per Hour
 Annual Extreme Fastest-Mile Speed 30 Feet Above Ground, 100-Year
 Mean Recurrence Interval

Figure IV-1 Reference 25.

a. Location. All new construction should be located substantially landward of the active beach-dune system. The fact that existing structures on adjacent property are located too far seaward is a very weak excuse for subjecting a new structure to the unnecessarily high risk of a similar ill advised location. In addition to the short term fluctuations of the shoreline caused by periodic storms, one must consider the long-term trends of erosion, recession, or accretion. Development on accreted land should be done with extreme caution. In some areas of the state there have been repeated examples of massive accretion over a period of five to fifteen years, followed by periods of equally massive erosion.

When siting the new structure, long term trends of erosion, recession, or accretion should be taken into account. The structure should not be located in areas that predictably may become a part of the active beach during the foreseeable life of the structure.

b. Elevation. The elevation of the first habitable floor should be above the level of the highest calculated breaking wave crested on a 100 year storm tide.

6. Foundations

All structures seaward of the CCSBL should be supported on piles designed to withstand at least wind and wave forces anticipated with a 100 year storm. The piles should be designed to withstand maximum horizontal and vertical forces while subject to the worst predictable scour conditions associated with a 100 year storm. In addition, piles should be considered for any beach area structures located landward of the CCSBL as well.

7. Superstructure

All structural elements including the roof, walls, floors and foundation should be firmly tied together and be designed to survive at least a 100 year storm.

C. Details of Recommended Guidelines for Beachfront Construction

1. Design and Construction by Competent Professionals

The design and construction of exposed seafront structures is probably one of the most exacting tasks confronting the modern-day professional. Founded on a constantly changing coastal topography, beachfront structures are exposed to a combination of nature's mightiest forces, as wind and wave act in concert under some of the worst structural loading conditions imaginable. Floating debris may pound the foundations while swift water currents scour the supporting material from around the base. Wind and wave acting separately or together may exert impulse or continual dynamic loads on a structure cantilevered up from the ground, often with horizontal projections as well. The possibility of harmonic amplification and flutter must be considered plus many other sources of stress familiar only to the design specialist in this professional area.

Each shore profile is unique, and an error in analysis can result in considerable loss. Overdesign wastes funds and other scarce resources, while underdesign can lead to the collapse of the entire structure, with consequent danger of bodily injuries and deaths, as well as considerable property loss.

In addition to the structure itself, many miles of irreplaceable Florida beaches have already been lost as a result of faulty location of shorefront

buildings and other structures. Frequent instances of accelerated erosion and serious retardation of normal beach recovery following storm attack can be traced to improper location of beachfront structures. For these reasons, the work of design and construction of structures in the coastal zone on either side of the CCSBL should be entrusted only to specially qualified professionals. In addition, state law requires a variance and permit from the Department of Natural Resources for all construction of any kind seaward of the CCSBL.

2. Preservation of the Natural Beach System

While many of Florida's beaches are already subject to gradual erosion due to natural forces, the existing beach system is usually the most stable configuration available under the current interaction of dynamic shoreline influences. Therefore, to be considered for a variance, the proposed construction should not cause adverse changes to the beach profile, dunes, protective vegetation, or any other significant parts of the beach system. Beneficial changes, such as beach nourishment, dune restoration and stabilization, and the like should be designed by qualified professionals and submitted to the Department of Natural Resources for consideration.

Where a variance for construction is granted, temporary alterations of the beach system may be permitted, providing the profile and protective vegetation are restored upon completion of construction.

3. Wind Force Design Using 100 Year Frequency

Florida lies in one of the most hurricane prone regions of the world. The chance of hurricane force winds striking in any given year averages about 1 in 18 for the inhabitants of all coastal Florida, and range from 1 in 7 for the Key West-Miami area to 1 in 50 for the Jacksonville area (14).

These exposed coastal regions are already the most densely populated as well as the fastest growing parts of the state as more and more new residents are attracted to the sun, sea and sand of Florida's fabulous beaches. As the number of residents and the value of development in these exposed coastal regions increases, the potential for hurricane-related losses grows correspondingly higher every year. Further, as density and congestion increases along the coastline, the possibilities of successful mass evacuation from the path of a hurricane become increasingly remote. Thus, every year there is increasing need to expect and require buildings in exposed coastal areas to safely sustain hurricane force winds of a reasonable frequency.

In addition to the obvious risk of loss of life, limb and property beachfront residents are increasingly subject to hurricane-related liability suits claiming negligence for damage caused by debris blown loose from one building and impacting on another building or person. Roofing, siding, trim, and other building components may tear loose during the fury of a storm and go sailing off with the wind. If any of these flying missiles strikes a neighboring structure or person, the damaged party may find evidence of negligent design, construction or maintenance and decide to sue. Courts and juries have awarded significant damages in cases of this type and continue to probe ever more carefully into the chain of responsibility for failure of any building component. In order to protect their own interests as well as those of others, owners, designers, contractors, suppliers, and building officials must all anticipate realistically the kinds of problems that can occur under the stress of hurricane wind and wave forces.

As coastal development increases in density and value the hurricane-related loss potential rises correspondingly higher with every passing year. As a result a structural design standard for wind velocity in beachfront areas becomes increasingly important to all concerned. Any acceptable design standard for wind velocity should provide reasonable safeguards against loss, yet not result in prohibitively high construction costs. Comparisons were made of design storm frequencies used for coastal installations in other nations and were found to be as high as a 500 year design storm frequency. The extra cost of high design frequency standards usually is not as great as might be expected. For example, one warehouse designed for a 200 mile per hour wind is estimated to cost 17% more than a comparable warehouse designed for a 100 mile per hour wind (40). In another case the City of New Orleans compared the cost of alternative designs for four basic school buildings. The cost of designing for 150 mile per hour winds plus fallout protection was only 2% to 7% higher than the counterpart alternative unprotected design. The higher design standards often compensate somewhat for higher first costs by reducing repair and replacement costs (25).

As a result of these and other considerations, the design wind force recommended for buildings in the beachfront areas of Florida seaward of the CCSBL is the force associated with maximum wind speeds for a storm of 100 year frequency. All members in the structure should be designed not to exceed safe allowable design stresses under these loading conditions. Figure IV-1 contains a map showing these 100 year wind speeds for all coastal areas of Florida (25). Use of the 100 year frequency infers odds of 99 out of 100 that winds of no higher velocity will occur in any given year. Conversely there remains a 1 in 100 chance that higher winds will

occur in any given year (by contrast fire safety code provisions have reduced the average risk of fire to about 1 in 10,000). Therefore, designing for the 100 year storm should not be construed as a guarantee that the structure will be completely safe from storm damage even in its first year. (For example, several newly constructed buildings in the Florida panhandle were destroyed by Eloise in September, 1975, estimated as a 135 year storm.) Owners and designers are encouraged to design to higher standards wherever appropriate.

Wind Loads. Having determined the design wind velocity, the resulting wind loads on the building must be calculated before the structural frame and other components can be designed. Experience indicates that the wind pressures on localized areas of the building vary with the shape, exposure, and height of the component under consideration. Exposed components such as siding, roofing, windows, doors and other non-structural components are the first part of the building to feel the impact of storm winds. From there the wind forces are transmitted to the building frame and then through the foundation to the ground. Since the frame receives a composite of forces from the exposed components, the unit load on some of the components will naturally exceed the average unit load used to design the structural frame. Therefore, the non-structural components should logically be designed to resist higher unit loads than the structural frame. In designing individual members it has long been recognized that a simple static load on the windward side of the member does not adequately represent actual storm wind loading conditions (42). Subsequent investigation resulted in the publication of wind loading equations that account for such factors as exposure, height above ground, shape factors, gust factors, dynamic response

characteristics, as well as wind velocity. Such equations have been incorporated into several popular building codes, such as the American National Standards Institute (ANSI), "Building Code Requirements for Minimum Design Loads in Buildings and Other Structures", and the South Florida Building Code. With regard to wind loading, the ANSI code appears to be the most comprehensive and conservative. The basic equations for effective velocity pressures (pounds per square foot pressures related to wind velocity) are subdivided into:

- i) effective velocity pressures used for design of the structural frame for ordinary buildings and structures,
- ii) effective velocity pressure used for the design of individual components, parts, and portions of buildings and structures

Using the 100 year frequency storm, and the exposure classification appropriate for beachfront buildings, representative pressures are shown in the following table (from Table 5 and 6, reference 1). These figures are presented here to exemplify order of magnitude, and are not intended for use in design without the usual thorough analysis by experienced design professionals.

	Ordinary Buildings		Parts and Portions of Buildings	
	110 mph	130 mph	110 mph	130 mph
Basic Wind Speed at 30 ft. height				
Effective Velocity Pressure Corresponding to Basic Wind Speed	40 psf	56 psf	46 psf	64 psf

Wind loads calculated by the ANSI code are usually higher in terms of psf than either of the 2 most popular codes in Florida, the South Florida Building Code or the Southern Standard Building Code. Comprehensive as they are, the ANSI wind loading tables illustrated above still do not account for unusual building shapes, abnormal exposures or structural characteristics which might lead to wind-excited oscillations, vortex shedding, or instability due to galloping or flutter. In such cases special investigation by a qualified design professional is required for safe and economical design.

4. Wave Force Design Using 100 Year Frequency

In addition to hurricane winds, beachfront structures in Florida must contend with the possibility of storm waves acting on the crest of storm tides. Since each location is unique, calculation of these wave forces and the elevations at which they occur should be done by a specially qualified professional engineer. Factors that affect the maximum design wave height include the beach profile, both offshore and onshore, the configuration of the shoreline, the probable effect of beach erosion and scour, and other storm related conditions. Based on this data, the magnitude and location of the design wave forces are derived and applied to the design of the structure under consideration. Since the elevation of the first habitable floor should be above the crest of the 100 year design wave, only the piling and other foundation structural members should be exposed to these wave forces. However, these exposed members must be capable of withstanding the full shock of the 100 year wave forces plus the impact of a reasonable amount of floating debris. In addition to the usual horizontal forces, uplift forces should be considered when flat surfaces or bouyant objects

(part empty fuel tanks, boats, etc.) may be located below the crest elevation of the highest wave (20). The uplift pressures typically act as from a moving horizontal plane passing under the structure in the same direction as the incoming storm waves.

When considering design stresses, all vertical design loads, including vertical effects of wind load (but excluding roof live load and wave uplift forces) should be considered acting simultaneously with horizontal wind and wave loads (19). Building codes often permit an increase in allowable stress due to the short duration anticipated for storm loading, but the designer is cautioned to consider the risk of loss compared to the cost for each individual building.

For some example calculations of horizontal wave forces, refer to the U. S. Army Corps of Engineers "Shore Protection Manual" (39).

5. Building Location and Elevation

a. Location. When locating a structure in a beachfront area, the effect on the complex processes by which the beach system survives must be carefully evaluated. In particular, when locating a structure seaward of the CCSBL, the effect of the structure on the stability of the beach system must be accounted for both during times of high storm wind and tide as well as under normal conditions.

As the name implies, the active beach area is a topographically active area of the shoreline. Beaches in Florida typically recede in the windier winter months and accrete during the balmy summers. Over a span of years the beach may show either long term accretion or erosion. Dramatic short term changes may occur during a few hours' exposure to storm conditions.

In all of these instances, continued change is characteristic of the active beach area. When a man-made structure is interjected into this environment, the effect is usually harmful. Structures typically become stress points in the active beach system causing concentrations of wind and wave energy with corresponding scour and erosion (Figure IV-4). Therefore, all new construction should be located landward of the active beach area.

The noted coastal consultant, Professor John H. Davis, Jr. considers the vegetation line as one of the more important factors in determining the location of coastal construction.

He states, "For many reasons the ...(construction location)... should be related to the kind of vegetation because the plant cover indicates stability or lack of stability of the dunes. Favorable conditions of vegetation assure much protection against storm and other erosion factors.

Where the Pioneer plants are dense and growing well and there is one high dune ridge or two or more low dune ridges with few to no signs of erosion, the ...(construction)... is positioned just interior to the crest of either the one high ridge or just back of the crest of the second of the lower ridges (Figure IV-5).

The recommended ...(construction)... is located where vegetation is dense enough and has been established long enough to indicate good stability of the dune field. It is located where the storm surge would probably not reach for many years if at all. Usually this position is in the Scrub zone but may be farther inland in the Forest zone (11)."

Beach Access by Dune Walkways. Where dune systems exist, they are often dependent upon vegetation as the stabilizing influence that determines the location and survival of the dunes. For this reason whenever walkways

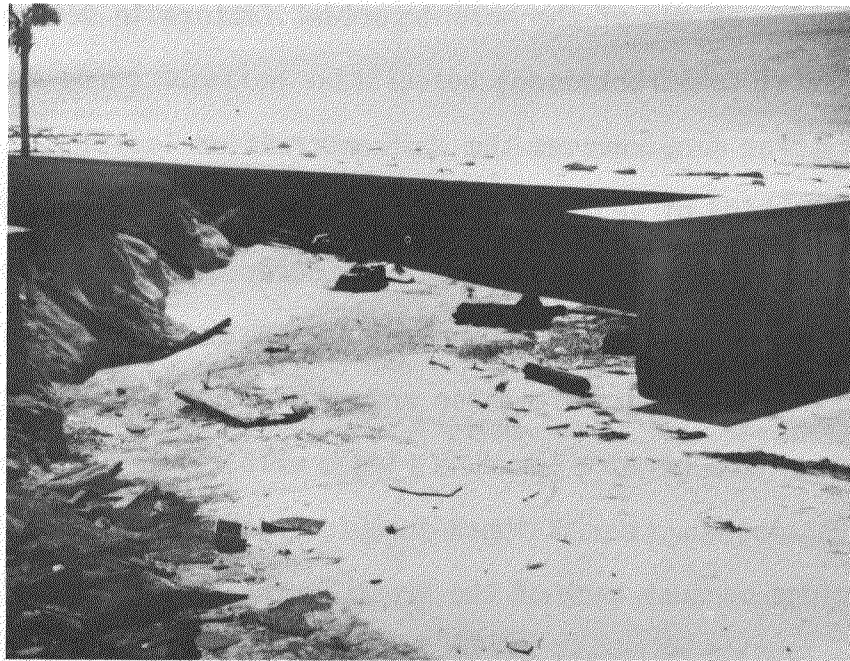
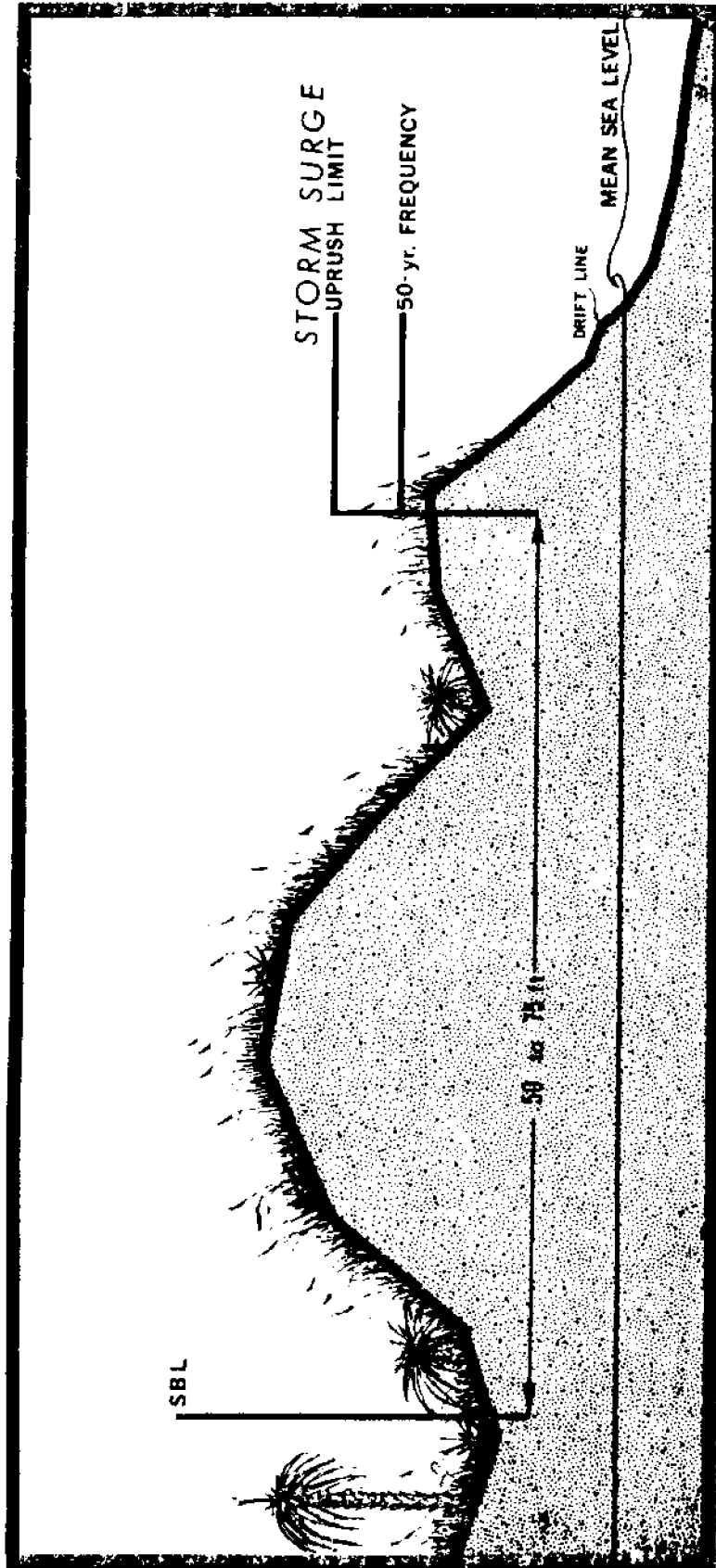


Figure IV-4. Retaining Wall Causing Erosion in Adjacent Areas

Fig. IV-5. Beach profile indicating Acceptable position of construction setback line (11).



SBL - The setback line suggested should be in the swale behind the high second dune ridge, which would not be topped by storm surge.

The fore dune profile shows the calculated height of storm surge in a northeastern coastal area.

The front Pioneer dune would be topped and destroyed probably within a 50-year period.

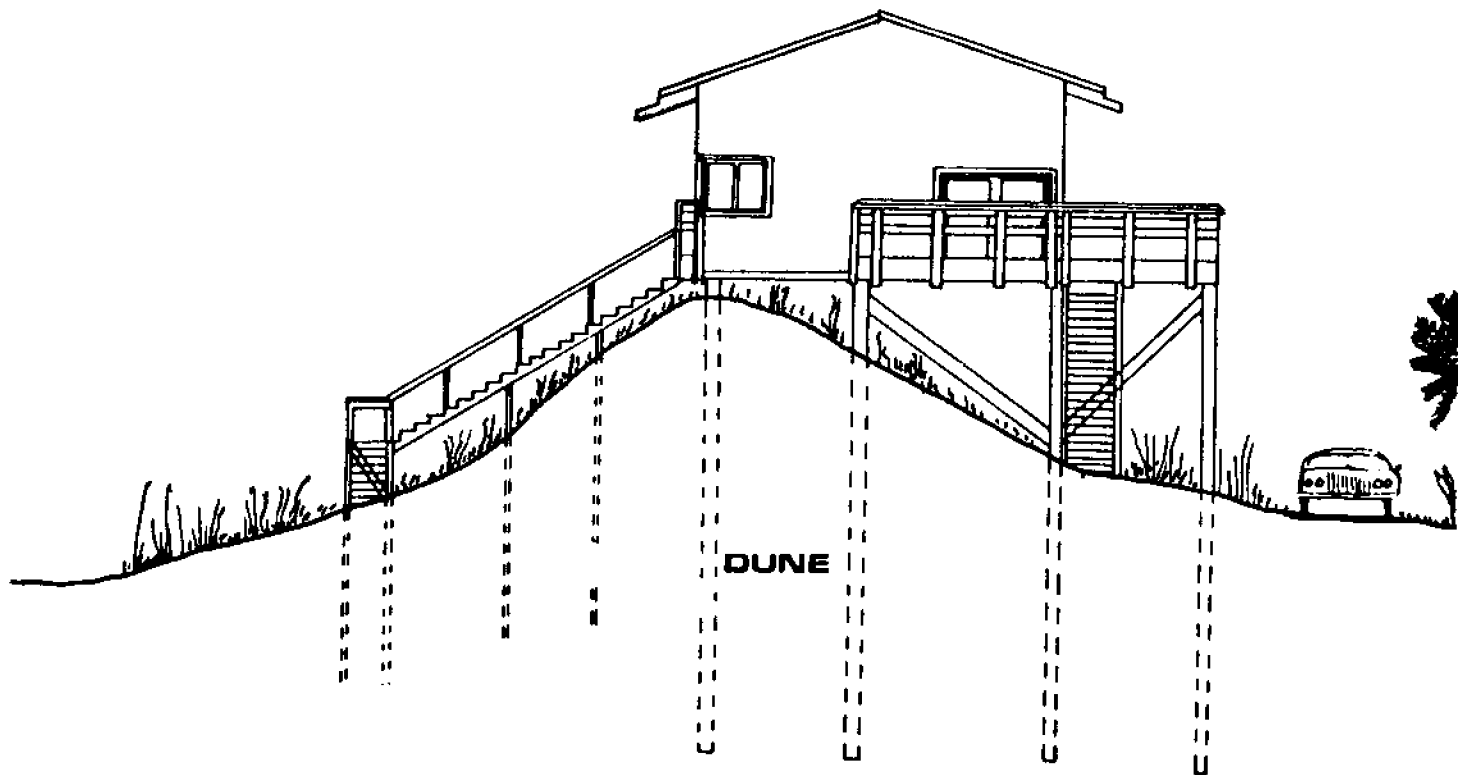
and platforms are located over the dune system, they should be elevated sufficiently to provide for the continued healthy growth of the vegetation below. (Figure IV-6) (15).

b. Elevation. Determining a reasonable floor elevation for habitable floors takes on added significance when considering that risk of property loss, injury, and death increases greatly if the water level rises above the floor elevation. If wave forces occur above the floor elevation, they impinge upon the full face of the structure instead of just on the limited area of the pile foundation. Therefore, the elevation of the first habitable floor should be established above the elevation of the highest calculated breaking wave cresting on a 100 year storm tide.

Since there is a 1 in 100 probability that waves will exceed this height in any given year, designers who feel the 100 year height is not sufficiently conservative are encouraged to specify higher floor elevations wherever appropriate. The calculation of the maximum wave crest elevation involves beach profile, wind velocity, incident wave steepness, fetch, angle of approach, and a number of other factors. Since accurate results are so important, the services of a qualified professional engineer are recommended. All structural members below the wave crest elevation should be designed to withstand anticipated wave forces.

6. Foundations

Foundations for beachfront structures are required to perform the traditional functions of a foundation plus several functions that are unique to their location near the sea. Both categories are included in the list that follows:



Beach Access Requires Elevated Walkways to
Preserve Dunes and Associated Vegetation

Figure IV-6 (Reference 15)

- i) the foundations must raise the first habitable floor to an elevation above the highest wave crest predicted for a 100 year storm, and permit water to pass unimpeded under the structure;
- ii) the foundation must safely transmit to the ground the full vertical and horizontal loads imposed on the superstructure by a 100 year design storm;
- iii) the foundation must present as slender a profile as possible, to reduce the effect of storm waves impacting it, and must be durable enough to safely resist these loads plus those from floating debris;
- iv) the foundation must be as small as possible to minimize induced concentration of wave forces and consequent erosion and scour at the ground line;
- v) the foundation must penetrate deeply enough and have sufficient strength to safely support the superstructure when the surrounding material is eroded down to the lowest predicted level.

And while performing all of these functions, the foundation must resist deterioration in a corrosive marine environment and be as economical as possible. Given these requirements, designers usually specify piling as the foundation type best suited to meet these needs. Figure IV-7 shows a typical pile-supported structure built in a coastal zone.

a. Pile Forces. Pile foundations seaward of the CCSBL should be designed to safely withstand the horizontal loads due to a wave front



Figure IV-7. Typical Pile Supported Structure (43).

breaking against any single row of piles lying in a line parallel to any possible direction of wave attack. This lateral force is determined by the breaking wave load of the 100 year storm wave, acting at a calculated elevation upon the exposed profile of the piles plus any other supporting members subject to wave forces.

Since the sand that surrounds the pile at the time of construction is often subject to removal by scour under storm conditions, the pile should be designed to withstand storm wind and wave forces without benefit of lateral support from sand above a certain minimum stable soil level. The piles may be analyzed as columns loaded vertically with the live and dead loads of the superstructure, and loaded horizontally with whatever combination of storm wind and wave loads are applicable to the particular location (19).

b. Pile Spacing. Adequate spacing should be left between piles to insure that not more than one row of piles is subject to significant wave forces at any one time. In addition, pile spacing should provide for unhindered movement of water and debris between the piles since obstructions to water movement may cause concentration of wave energy and consequent acceleration of erosion of the adjacent soil material. Seaward of the CCSBL the suggested minimum spacing between piling center lines is eight feet. The suggested maximum density of piling profile is 1:8 (46). That is, for every one foot diameter of pile, there should be an opening of at least eight feet between adjacent piles. The pile spacing and density is measured in two directions, first parallel to the shore or direction of maximum wave attack to allow for wave uprush, and secondly perpendicular to the shoreline to allow maximum passage of littoral drift in the event the littoral zone extends to the area between the pilings. This is illustrated in Figure IV-8.

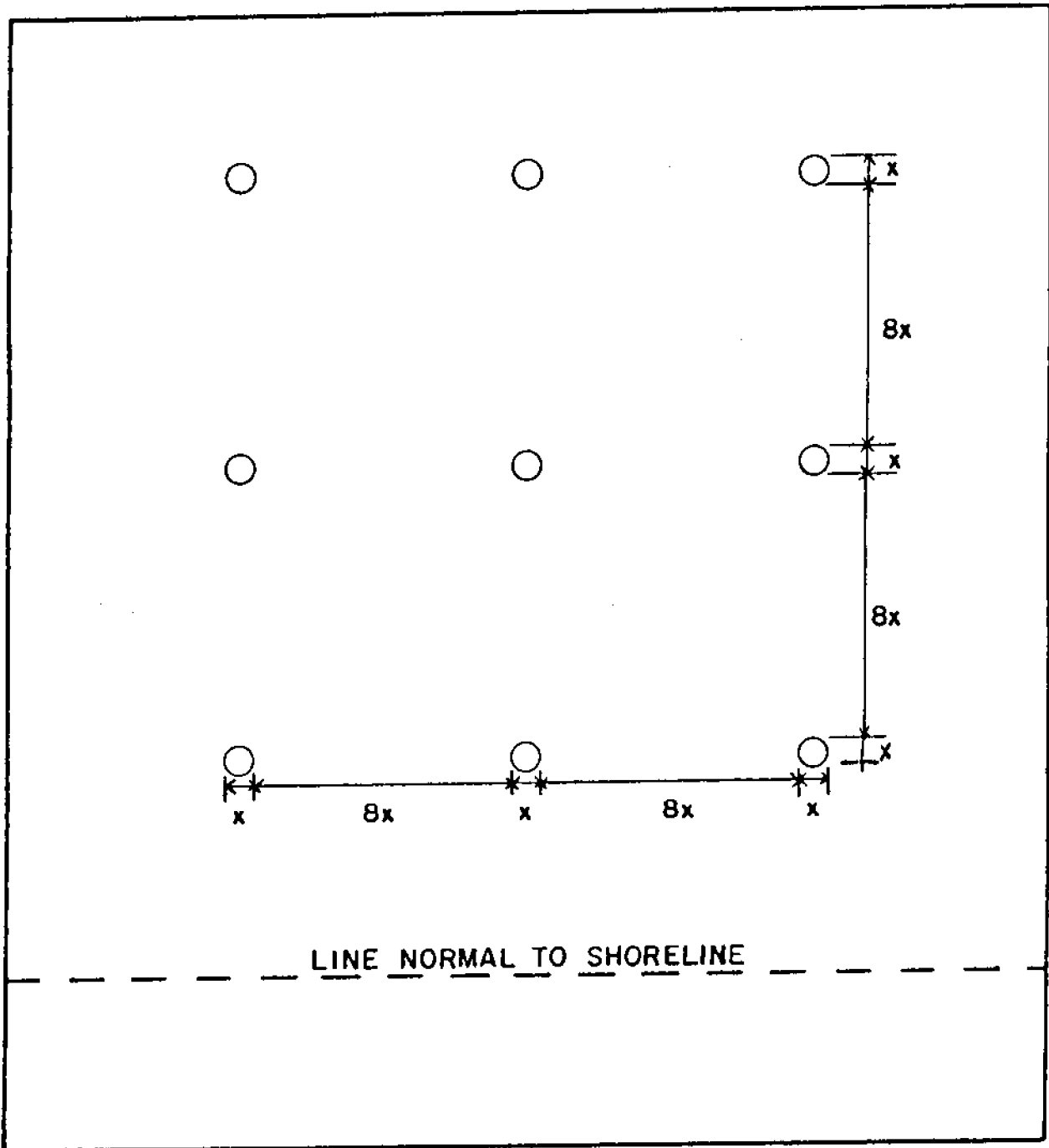


Figure IV-8. Suggested Method of Measuring Pile Density, Reference 46.

c. Pile Clusters and Pile Bracing. If a foundation design involves pile clusters, the pile cap should be kept sufficiently low to prevent it from forming a solid obstruction in the areas of maximum wave force.

In the event that lateral or diagonal bracing between piles is needed parallel to the shoreline, both pile and bracing should be specifically designed to withstand this increased horizontal load against the pile system.

Except for unusual circumstances this provision need not apply to diagonal bracing in the vertical plane perpendicular to the shoreline, or thin cable or rod type tension resisting bracing in any plane (19).

d. Pile Embedment. Piles should be designed to survive loss of surrounding beach or dune sand down to a stable soil level. Many beaches undergo periods of erosion, either rapidly during storms or gradually even in normal weather. In either case the structure should have foundations deep enough to provide support after maximum predicted loss of sand.

In many instances, substantial sand dunes with heights of 15 feet or more above sea level and base width of several hundred feet have been swept away in a matter of hours by storm surge and accompanying waves (17). The pile tip elevation should be deep enough to safely support the structure in case of the complete erosion and scour. This depth should be calculated by a qualified professional equipped to evaluate the soil type, beach profile, topography, sand erosion, and other pertinent data. Depending on the location, the tip elevation typically penetrates to an elevation of 5 feet below mean sea level datum and under some circumstances may be required to penetrate as low as 20 feet or more below.

e. Pile Material and Treatment. To prevent or retard the deterioration and corrosion of piles located in waterfront areas, proper treatment should be specified.

- i) Wood. A variety of wood treatments are available for wood piles designed for service in marine environments. For instance, round Southern Pine timber piles exposed to moderate or severe marine borer hazards require a dual treatment of preservative consisting of a retention of 1 pcf of ACA (1 pcf infers that 1 pound of preservative is retained in the pile for each cubic foot of timber in the pile) 1 pcf of CCA, 20 pcf of creosote, and 20 pcf of creosote-coal tar. For further details contact the American Wood-Preservers' Institute (3).
- ii) Concrete. Concrete piles for use in marine environments require special consideration during design and construction. The concrete must be of sufficient density and thickness to prevent penetration by oxygen and moisture to the steel reinforcing. Concrete exposed to a marine environment should have a water-cement ratio of 0.44 or more and provide at least 3 inches cover for all reinforcement (26).
- iii) Steel. Piles fabricated of special corrosion resistant steels are available for marine environments. For instance U. S. Steel publishes test results that show their USS Mariner Steel corrodes only 1/2 to 1/3 as much as Standard ASTM A-328

Steel under corrosive Marine environments (42). Also, special protective coatings are effective in some installations.

f. Slab Foundations Not Recommended. Where moving water encounters a hardened surface, such as a slab, in contact with the ground, scour frequently develops with consequent undermining and erosion. To avoid scour failure, no structures with large surfaces in contact with the ground should be permitted in areas subject to wave uprush, return backwash, or moving surface water of any type. All structures in these areas should be elevated to provide free passage of water under the structure. Structures with large areas in contact with the ground, such as swimming pools, decks, and slab foundations, should not be permitted seaward of the CCSBL. The effects of undermining typical concrete floor slabs are shown in figures IV-9 and 10.

g. Seawall Protection Often Inadequate. Seawalls sometimes provide a false sense of security to beachfront property owners. Experience indicates that seawalls often are overtopped under storm tide conditions. The overtopping sea water then proceeds to wash the sand from behind the walls, flowing out either around the ends of the walls, or through cracks in the wall. Under storm conditions Florida's fine beach sands combine easily with turbulent seawater and sometimes flow out from behind seawalls with surprising ease. The effect of Hurricane Eloise on typical seawall construction is shown in Figures IV-11 and 12.

7. Superstructure

From an engineering point of view, the primary function of the superstructure is to provide shelter to persons and property under the normal conditions expected during the service life of the building. In addition, the



Figure IV-9. Slab Failure Due to Undermining Action. Hurricane Eloise 9/75.



Figure IV-10. Slab Failures Due to Undermining of Concrete Floor Slabs Poured on Grade. Hurricane Eloise 9/75.



Figure IV-11. Seawall Construction did not prevent sand from washing out from behind it resulting in structural failure of the building, Hurricane Eloise (9/75).



Figure IV-12. This seawall failed to prevent sand erosion from behind the wall and subsequent failure of the slab and supported building, Hurricane Eloise, (9/75).

structure requires sufficient durability to weather the infrequent and temporary but extremely heavy loads imposed by the design year storm. When hurricane warnings do occur every effort should be made to evacuate exposed buildings, since there is always a 1% probability that hurricane forces will exceed the 100 year design standards in any given year.

a. Individual Components and Fastenings. To maintain the integrity of the whole building, each individual component should be designed to meet storm load requirements without exceeding design stresses or separating from the rest of the building. All connections should be designed to hold firm and transfer the storm loads through the structural frame to the foundations and ultimately to the supporting ground. Since these components and connections are expected to perform in a corrosive marine environment, special attention should be given to durability and life expectancy of each element of the building. In addition, special care should be given during the construction process to insure that all design requirements are met during the actual installation.

b. Shape Factors and Roofs. Unusually shaped buildings, and buildings with long overhangs (either cantilevered or supported) should be examined for susceptibility to unusual wind force effects such as flutter, harmonic oscillation, and fatigue failure.

The effect of roof slope on suction uplift and downward pressure should be calculated carefully. The uplift force may be especially critical along the windward eaves and corners of roof overhangs and on flat or slightly inclined roofs.

c. Space Below Design Wave Crest. All structural members extending below the elevation of the crest of the highest calculated breaking wave superimposed upon a 100 year storm tide should be designed to withstand whatever wave forces may be expected to impinge upon those members. In addition, some impact pounding from floating debris may be anticipated.

Regarding space below the lowest habitable floor, the National Flood Insurance Program (section 1910.3, e.4) provides "That all new construction and substantial improvements within the designated coastal high hazard area have the space below the lowest floor free of obstructions or are constructed with 'breakaway wall' intended to collapse under stress without jeopardizing the structural support of the building so that the impact on the building of abnormally high tides or wind-driven water is minimized. Such temporarily enclosed space shall not be used for human habitation".

Permitted uses of the understructure space includes car ports, temporary storage areas and screened patios. The forementioned requirements shall not preclude the construction of 1) open stairways, 2) wind/sand screens constructed of fabric or wire mesh, and 3) light open lattice partitions (19).

The ground below the first habitable floor should not be paved or altered, since solid on-grade construction within this zone generally accelerates erosion losses and leaves adjacent areas more susceptible to losses. This, however, does not preclude the use of shell or marl to stabilize driveways.

The use of wooden floors on the grade below the first floor are also discouraged in order to minimize potential damage due to floating or flying timbers in case of storm. If such floors are used they should not be secured to the structural members unless the structural members are designed to carry the anticipated additional storm loads.

d. Safeguard Requirements for Breakaway Elements. Where temporary partitions, walls, or platforms are desired below the wave crest elevation consideration may be given to design of "breakaway" elements to separate and break away, providing that adequate safeguards are present to assure the following:

- i) adequate safeguards must be employed to prevent breakaway elements, separating under storm conditions, from becoming dangerous floating or flying objects.
- ii) adequate warning must be provided to subsequent users and owners that the breakaway element is not secure against design storm forces.
- iii) adequate safeguards must be provided against the natural tendency of subsequent users and owners to later reinforce and secure the breakaway element, thereby defeating the original purpose of the breakaway element.

CHAPTER V

CHECK LIST FOR BUILDING CONSTRUCTION ON
SHORE-AREA PROPERTY

Prospective buyers or current owners of shore property naturally are concerned about the specialized problems involved in shore area construction. The following is a summary check list of a number of items of importance in evaluating the effects of predictable storm forces and long term erosion on property in the shore area. The list includes most major concerns, but is not exhaustive. Before committing to any major expenditures, a competent professional engineer experienced in shore area design and construction should be retained. He should then be requested to supply satisfactory answers to the following checklist of questions.

Checklist for Owners, Designers and
Builders of Shore Area Buildings

A. LOCATION CHECKLIST

YES NO

- ___ ___ 1. Local Zoning Regulations. Does the building site plan conform to local city or county zoning regulations regarding setback lines and other code provision? (Contact the City or County Engineer for details.)
- ___ ___ 2. State Coastal Construction Set-Back Line (CCSBL).
- ___ ___ a. Has a state CCSBL been adopted for this county? (Inquire from the County Engineer.)
- ___ ___ b. If the CCSBL has been adopted for this county, is the selected building site seaward of the CCSBL?
- ___ ___ c. If the selected site is seaward of the CCSBL has application for a variance been made to the Department of Natural Resources, Bureau of Beaches and Shores, 202 Blount Street, Tallahassee, FL 32304?
- ___ ___ 3. Off-beach Site. Is the building site located off of the active beach zone and behind the major vegetated dune line?
- ___ ___ 4. Evacuation Route. Does the location have a suitable evacuation route to a safe inland refuge in case of severe storm tide and high wave conditions? (Check the elevation of low points in the road compared to anticipated storm tide levels at the County Engineer's Office.)

YES NO

- ___ ___ 5. Elevated Walkways. If there are dunes located between the building and the beach, have elevated walkways for beach access been provided to prevent damage to the stabilizing vegetation on the dunes?
- ___ ___ 6. Check all Jurisdictions. Does the proposed location conform to all applicable governmental regulations by all jurisdictions, including Local, State and Federal? (Approval of one agency does not necessarily imply approval by other agencies.)
- ___ ___ 7. Site Vegetation. Is finished site provided with adequate natural or planted vegetation to protect against soil erosion from wind and surface water runoff?

B. ELEVATION CHECKLIST

YES NO

- ___ ___ 1. Storm Tide Elevation. Has the elevation of the 100 year storm tide (or flood plain) been determined and compared with the existing ground elevation at this building site? (Call City or County Engineer for information on 100 year storm tide elevation. Existing site elevation can be found by a local surveyor.)
- ___ ___ 2. Floor Above 100 Year Tide Level. If this location is subject to flooding during the 100 year storm is the lowest habitable floor raised above the top of the highest storm wave cresting on the 100 year storm tide?

C. DESIGN WIND FORCES CHECKLIST

YES NO

- ___ ___ 1. 100 Year Wind Speed. Has the wind velocity for a 100 year storm been found for this building site? (See map in Sec. 1205 Southern Standard Building Code, or call City or County Engineer.)
- ___ ___ 2. Frame Design. Is the structural frame designed to withstand at least a 100 year storm wind with an adequate safety factor?
- ___ ___ 3. Element Design. Is each element of the building designed to withstand both pressure and suction forces associated with at least a 100 year storm wind while remaining attached to the building?
- ___ ___ 4. Shape Factor. Has the effect of shape factors and roof slope been accounted for when calculating wind pressure and suction? (See South Florida Building Code or Southern Standard Building Code for more details.)

D. PILE FOUNDATIONS CHECKLIST

YES NO

- ___ ___ 1. Consider Piles. Are piles the best foundation for raising the structure to the proper elevation and preventing any surface water flow from undermining the structure?
- ___ ___ 2. Post-Scour Ground Elevation. If subject to wave scour, has the elevation of stable soil after 100 year storm scour been determined for this site by a qualified consultant?
- ___ ___ 3. Post-Scour Pile Loadings. Have the piles or other foundations been designed to sustain the horizontal and vertical loads associated with at least a 100 year storm after the supporting soil has been scoured down to the 100 year storm scour elevation?
- ___ ___ 4. Pile Spacing. If subject to water flow beneath the structure during the 100 year storm, are the piles or other foundations spaced wide enough apart to provide relatively free flow under the building?
(Clearance between piles or other foundations suggested as 8 feet or more where piles are subject to scouring action.)
- ___ ___ 5. Wave Forces. If subject to wave attack during the 100 year storm, have the piles or other foundations been designed to withstand wave forces impacting on them?
- ___ ___ 6. Debris Impact. Does the design of piles or other foundations allow some reserve to allow for the impacting forces of floating debris?
- ___ ___ 7. Corrosion and Insect Resistance. Is the selected type pile or other foundation specially designed, constructed or treated to provide maximum service life with minimum maintenance in a corrosive marine environment with anticipated exposure to moist warm salt air, marine borers, and rot?

E. WOOD FRAME BUILDING CHECKLIST

YES NO

- ___ ___ 1. Tie Studs and Sills to Foundations. Are studs fastened to sill plates and sill plates fastened through supporting members to the foundations well enough to withstand a 100 year storm?
- ___ ___ 2. Tie Rafters and Plates to Studs. Are rafters or trusses fastened to top plates and studs with metal straps or framing connections well enough to withstand a 100 year storm?

YES NO

- ___ ___ 3. Outside Wall Sheathing. Are studs sheathed on the outside with plywood or other durable sheathing material?
- ___ ___ 4. Tie From Roof to Foundations. Is there a positive sequence of connections fastening all members together from the roof on down through the foundations?
- ___ ___ 5. Secure Cantilevers. Are all cantilevered and other projecting members adequately supported and braced to withstand a 100 year storm?

F. CONCRETE BLOCK BUILDING CHECKLIST

YES NO

- ___ ___ 1. Masonry Wall Reinforcement. Does the concrete block wall contain vertical reinforcement firmly anchored into the tie beam on top and the footing at the bottom?
- ___ ___ 2. Reinforcement of Corners and Openings. Is the vertical reinforcement in the concrete wall placed at all corners, all openings in the wall, and at periodic intervals throughout the length of each wall?
- ___ ___ 3. Tie Beam. Are the concrete block walls topped with a reinforced concrete tie beam extending continuously around the outside of wall of the building?
- ___ ___ 4. Secure Roof to Tie Beams. Are all rafters or trusses firmly fastened to the supporting concrete tie beam?
- ___ ___ 5. Tie From Roof to Foundations. Is there a positive system of ties extending from the roof on down through the foundations to firm anchorage into the earth that is designed to safely withstand a 100 year storm?

G. ROOF, SIDING, SHUTTERS AND TRIM CHECKLIST

YES NO

- ___ ___ 1. Reduce Shingle-Tile Exposure. If the roof is shingle or tile, have the overlaps been increased and the fastening strengthened to account for 100 year storm pressures and suction?
- ___ ___ 2. Secure the Corners. Has particular attention been given to securing roof ridges, edges, eaves, corners, trim, and any other angular or irregular surfaces exposed to the wind?
- ___ ___ 3. Insure Adhesion. If built-up roof is used, are special measures specified to eliminate possible areas of inadequate adhesion or fastening between layers which could lead to subsequent uplift and failure?

YES NO

- ___ ___ 4. No Flying Gravel. Has gravel surfacing been eliminated to protect against pitting or cracking of finish and glass on nearby structures?
- ___ ___ 5. Secure the Roof Panels. If the roof is of panel construction, has this installation been specially designed to withstand 100 year storm forces at this site?
- ___ ___ 6. Secure the Siding. Has the siding been fastened securely enough to withstand a 100 year storm?
- ___ ___ 7. Reinforce the Corners. Has the fastening between siding and wall been reinforced at the corners of the building to account for the increased suction forces in these areas?
- ___ ___ 8. Shutters. Have hurricane shutters been provided for all windows and other vulnerable openings?
- ___ ___ 9. Fast, Easy Closure. Are the shutters designed for quick, simple closure in time of need?
- ___ ___ 10. Account for Corrosion Losses. Are all the fastenings and hardware used in this building designed to withstand storm loadings after suffering anticipated corrosion losses over the entire service life of the building?
- ___ ___ 11. Secure All Parts. Is this building with all its components adequately secured from roof through foundation and firmly anchored into the ground so as to safely withstand both wind and wave forces associated with at least a 100 year storm?

H. UTILITIES CHECKLIST

YES NO

- ___ ___ 1. Storm Proof the Telephone and Electric. Are telephone and electric lines located underground in waterproof conduit laid in protected areas not subject to erosion?
- ___ ___ 2. Protect the Water and Sewage. Are the water supply and sewage facilities located in protected areas not subject to erosion?

I. DESIGN-CONSTRUCT-INSPECT CHECKLIST

YES NO

- ___ ___ 1. Contractor Qualifications. Is contractor experienced in constructing shore area construction?
- ___ ___ 2. Plans and Specifications. Does contractor have fully detailed plans and specifications? Do plans and specifications bear the seal and signature of a registered professional engineer? Is engineer experienced in type of design specified?
- ___ ___ 3. Inspection. Have provisions been made to have the work inspected by a registered professional engineer?

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