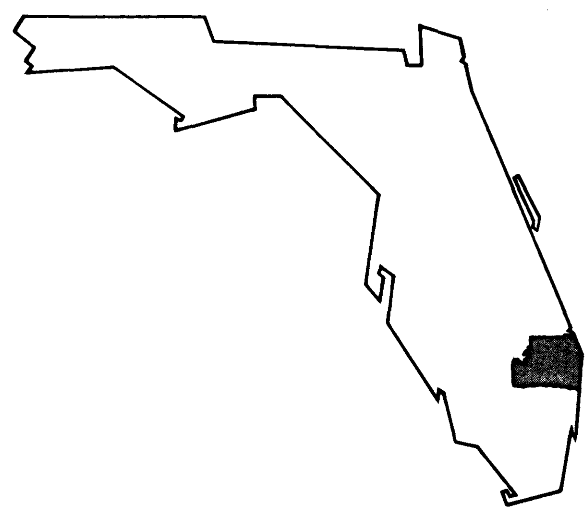
FLOOD INSURANCE STUDY

WAVE HEIGHT ANALYSIS

PALM BEACH COUNTY, FLORIDA
UNINCORPORATED AREAS



APRIL 15, 1982

Federal Emergency Management Agency

COMMUNITY NUMBER - 120192

ANALYSIS OF WAVE HEIGHTS
FOR
PALM BEACH COUNTY, FLORIDA
(UNINCORPORATED AREAS)

FEDERAL EMERGENCY MANAGEMENT AGENCY

TABLE OF CONTENTS

FIGURES

TABLES

EXHIBITS

1.0 INTRODUCTION

1.1 Background and Purpose

The Federal Emergency Management Agency recently adopted recommendations by the National Academy of Sciences to include prediction of wave heights in Flood Insurance Studies for coastal communities subject to storm surge flooding, and to report the estimated wave crest elevations as the base flood elevations on Flood Insurance Rate Maps (FIRMs).

Previously, FIRMs were produced showing only the stillwater storm-surge elevations due to the lack of a suitable and generally applicable methodology for estimating the wave crest elevations associated with storm surges. These stillwater elevations were subsequently stipulated in community flood plain management ordinances as the minimum elevation of the first floor of new construction. Communities and individuals had to consider the additional hazards of velocity waters and wave action on an ad hoc basis. Because there has been a pronounced tendency for buildings to be constructed only to meet minimum standards, without consideration of the additional hazard due to wave height, increasing numbers of people could unknowingly be accepting a high degree of flood-related personal and property risk in coastal areas subject to wave action. Therefore, the Federal Emergency Management Agency has pursued the development of a suitable methodology for estimating the wave crest elevations associated with storm surges. The recent development of such a methodology by the National Academy of Sciences (Reference 1) has led to the adoption of wave crest elevations for use as the base flood elevations in coastal communities.

Since 1871, 12 hurricanes have passed through Palm Beach County. Among the more severe were the storms of September 1928, September 1947, October 1947, and August-September 1964. The hurricane of September 1928 is considered one of the most violent ever to strike Florida. The center of the storm smashed into the West Palm Beach area with winds in excess of 100 miles per hour. Nearly 95 percent of the commercial and residential property in the West Palm Beach area was damaged. High tides ranged from 8 feet in Lake Worth to 10 feet at Palm Beach. Severe wave action was responsible for the washout of several bridges crossing Lake Worth. The hurricane of October 1947 climaxed an extremely wet rainy season in which precipitation in the county ranged from 70 to 85 inches.

Palm Beach County, Florida, is located on the open coast and is subject to flooding from tidal surges associated with hurricanes. The purpose of this study is to revise the FIRM for Palm Beach County to include the effects of wave action associated with flooding from the Intracoastal Waterway (including Jupiter Sound), Loxahatchee River (including the North, Northwest, and Southwest Forks), North Palm Beach Waterway, Lake Okeechobee, Little Lake Worth, Lake Worth, and the Atlantic Ocean at the open coast.

2.0 INVESTIGATIONS

2.1 Previous Studies

Stillwater elevations for hurricane surges with 10-, 50-, 100-, and 500-year return periods were determined by Tetra Tech, Inc. for all areas of Palm Beach County and its incorporated communities inundated by tidal flooding. The 100-year stillwater elevations were used as base flood elevations for the Flood Insurance Study now in effect for Palm Beach County (Reference 2).

These elevations were determined by the joint probability method (Reference 3). The storm populations were described by probability distributions of five parameters which influence surge heights. These parameters were central pressure depression (which measures the intensity of the storm), radius to maximum winds, forward speed of the storm, shoreline crossing point, and crossing angle. These characteristics were described statistically, based on an analysis of observed storms in the vicinity of Palm Beach County. Primary sources of data for the parameters were the National Weather Service (Reference 4); Cry (Reference 5); Ho, Schwerdt, and Goodyear (Reference 6); and, the National Hurricane Research Project (Reference 7).

A numerical hydrodynamic model of the region was used to simulate the coastal surge generated by any chosen storm (that is, any combination of the five storm parameters defined previously). By performing such simulations for a large number of storms each of known total probability, the frequency distribution of surge height can be established as a function of coastal location. These distributions incorporate the large scale surge behavior, but do not include an analysis of the added effects associated with much finer scale wave phenomena, such as wave height, setup, or runup. The astronomical tide for the region was statistically combined with the computed storm tide to yield recurrence intervals of total water level.

The stillwater elevations developed for the previous Flood Insurance Study were used as starting water-surface elevations for the wave height analysis presented herein.

This report is authoritative for purposes of the National Flood Insurance Program. Data presented herein supersede all previous flood elevation determinations.

2.2 Data Collection and Review

All available source data applicable for the wave height analysis were collected and reviewed. Because wave height calculations are based on such parameters as the size and density of vegetation, natural barriers (such as sand dunes), buildings, and other manmade structures, it was necessary to obtain detailed information on the physical and cultural features of the study area.

Officials of Palm Beach County were contacted for maps and other possible data sources to be used in the analysis. In addition, the Florida Department of Transportation; the Florida Department of Natural Resources, Bureau of Beaches and Shores; the U.S. Army Corps of Engineers, Jacksonville District; the National Ocean Survey; the U.S. Fish and Wildlife Service; the South Florida Water Management District; A.V. Strock and Associates; and Abrams Aerial Survey were contacted and all applicable data sources were obtained.

The principal source materials used for the wave height analysis are described below.

a. Topographic data (ground elevations, seawall elevations, and locations of physical features) were determined using U.S. Geological Survey topographic maps at a scale of 1:24,000, with a contour interval of 5 feet (Reference 8); National Ocean Survey storm evacuation maps at a scale of 1:62,500, with a contour interval of 5 feet (Reference 9); phototopographic maps at a scale of 1:10,800, with a contour interval of 2 feet (Reference 10); a spot elevation map of Herbert Hoover Dike at Belle Glade obtained from the South Florida Water Management District (Reference 11); beach profiles of the immediate Atlantic coast area obtained from the Florida Department of Natural Resources (Reference 12); a nautical chart of Lake Okeechobee at a scale of 1:80,000, obtained from the National Ocean Survey (Reference 13); and Florida Department of Transportation highway bridge plans (Reference 14).

b. Stereoscopic aerial photography at scales of 1:12,000 and 1:6,000 and National Wetlands Inventory Maps at a scale of 1:24,000 were used to determine vegetation and building parameters and to supplement the topographic maps for locations of physical features (References 15, 16, and 17).

2.3 Wave Height Analysis

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in the National Academy of Sciences report (Reference 1). This method is based on the following major concepts. First, depth-limited waves in shallow water reach a maximum breaking height that is equal to 0.78 times the stillwater depth. The wave crest is 70 percent of the total wave height above the stillwater level. The second major concept is that wave height may be diminished by dissipation of energy due to the presence of obstructions, such as sand dunes, dikes and seawalls, buildings, and vegetation. The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures prescribed in Reference 1. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

Wave heights were computed along transects (cross section lines) in accordance with the Users Manual for Wave Height Analysis (Reference 18). The transects were located along the coastline as shown in Figure 1. They were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Tran-

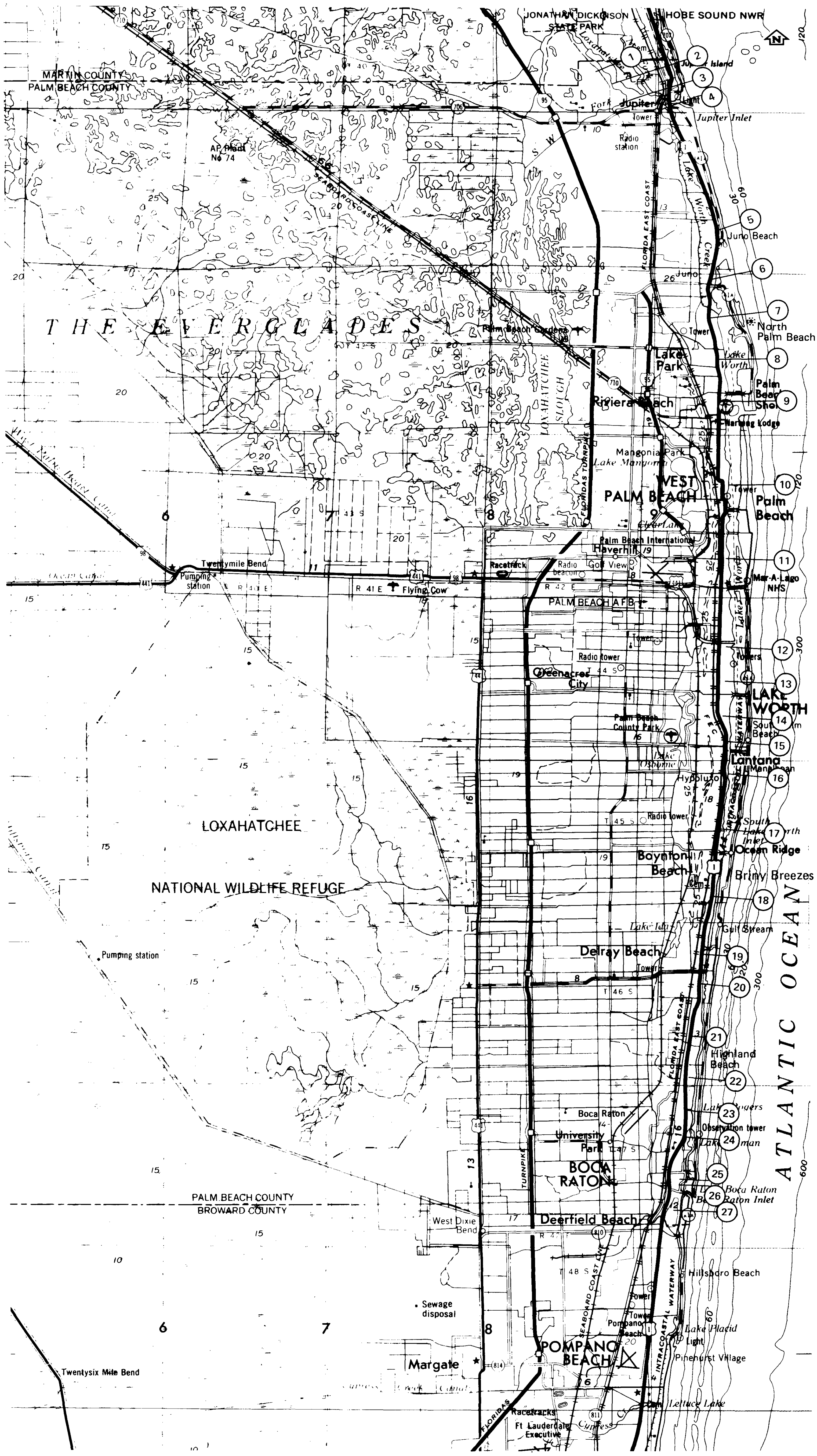


FIGURE 1A

FEDERAL EMERGENCY MANAGEMENT AGENCY

PALM BEACH COUNTY, FL

APPROXIMATE SCALE

4 0 4 8 12 MILES

TRANSECT LOCATION MAP

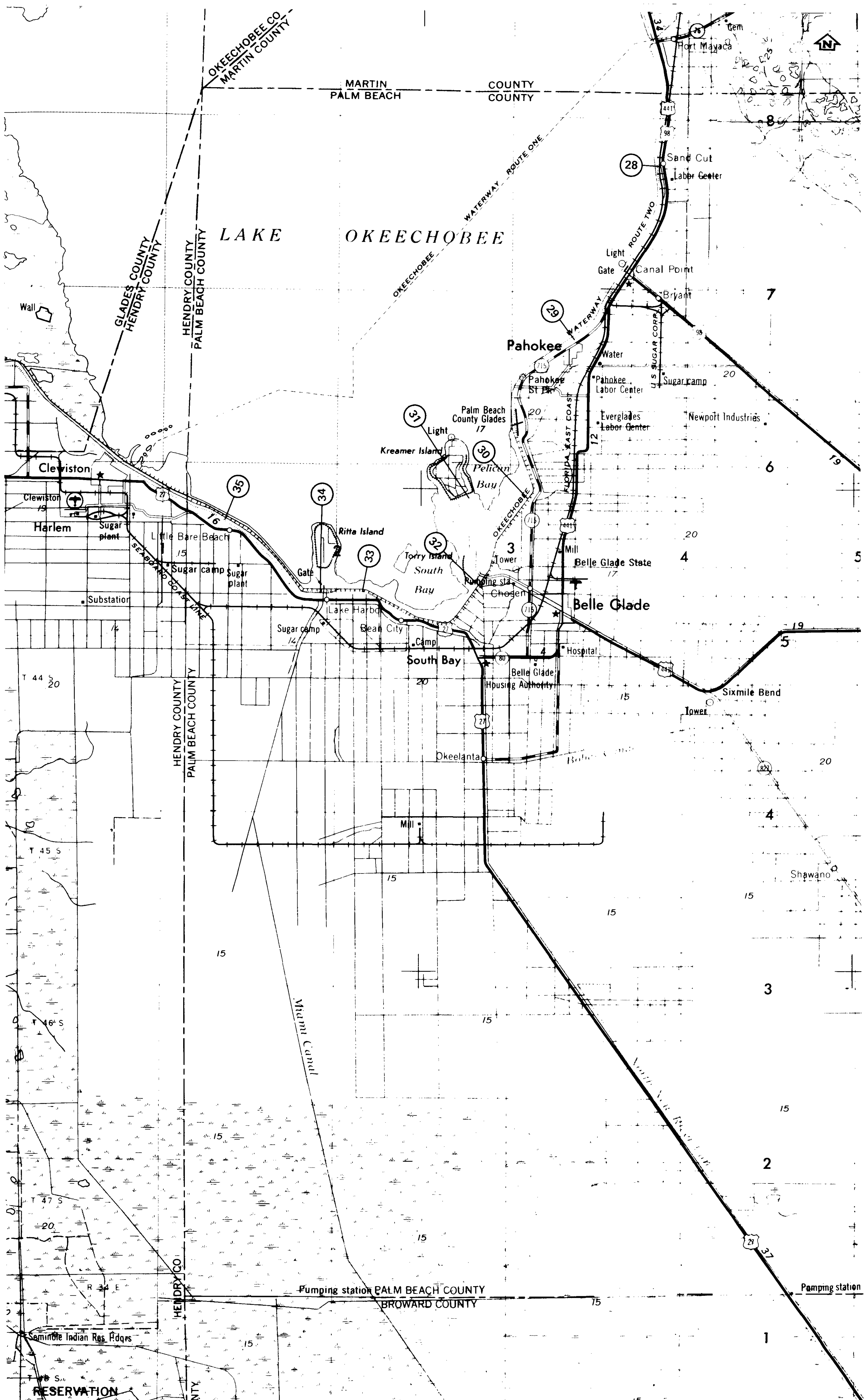


FIGURE 1B

FEDERAL EMERGENCY MANAGEMENT AGENCY

PALM BEACH COUNTY, FL

APPROXIMATE SCALE

4 0 4 8 12 MILES

TRANSECT LOCATION MAP

sects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, they were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Each transect was taken perpendicular to the shoreline and extended to the inland limit of tidal flooding. Along each transect, wave heights and elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The stillwater elevations for the 100-year flood were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were determined at whole-foot increments along the transects. The location of the 3-foot breaking wave for determining the terminus of the V Zone (area with velocity wave action) was also computed at each transect. Table 1 provides a listing of the transect locations and stillwater elevations, as well as maximum wave crest elevations in Palm Beach County.

Figure 2 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in Palm Beach County may not necessarily include all the situations illustrated in Figure 2.

After analyzing wave heights along each transect, wave elevations were interpolated between transects. Various source data were used in the interpolation, including topographic maps (References 8, 9, 10, and 11), beach profiles (Reference 12), and aerial photographs (References 15 and 16), along with engineering judgment. Controlling features affecting the elevations were identified and considered in relation to their positions at a particular transect and their variation between transects.

2.4 Results

Rapidly rising sand dunes and seawalls provide considerable protection along the open coast of Palm Beach County. These dunes and seawalls are expected to remain intact during the 100-year storm surge and are considered effective wave energy dissipators. Much of the shoreline along Lake Worth and the Intracoastal Waterway, and portions of Loxahatchee River, including its North, Northwest, and Southwest Forks, are protected by bulkheads. These bulkheads are capable of dissipating wave energy. The area adjacent to Lake Okeechobee is protected by the Herbert Hoover Dike, which is expected to remain intact during the 100-year storm surge. This structure will not be overtopped.

Wave heights greater than 3 feet associated with the 100-year storm surge on the Atlantic coast are diminished near the open coast by ascending ground slope and seawalls. The maximum wave crest elevation at the Atlantic Ocean shoreline is 11 feet.

In the vicinity of Jupiter, north of Jupiter Inlet, wave heights of over 1 foot are generated across the Intracoastal Waterway before being dissipated

Table 1.
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
1	Tequesta/Palm Beach County - From a point on the shore of Loxahatchee River in Tequesta approximately 760 feet south of the intersection of River Drive and Fairway North, westward across Loxahatchee River to the limit of inundation by the 100-year storm surge	6.0[1]	7[1]
2	Palm Beach County/Tequesta - From the Atlantic coastline westward across Jupiter Sound, North Fork Loxahatchee River, and Loxahatchee River to the limit of inundation by the 100-year storm surge; crosses River Drive in Tequesta at southernmost intersection with Point Circle	7.0[2]	11[2]
3	Palm Beach County/Jupiter/Tequesta - From the Atlantic coastline westward across Jupiter Sound and Loxahatchee River to the limit of inundation by the 100-year storm surge; crosses U.S. Highway 1 in Tequesta approximately 500 feet north of intersection with State Highway 707	6.0[1]	8[1]
4	Jupiter/Jupiter Inlet Colony - From the Atlantic coastline westward across Loxahatchee River and Lake Worth Creek to the limit of inundation by the 100-year storm surge; crosses U.S. Highway 1 just south of intersection with Ocean Boulevard (State Highway A1A) in Jupiter	7.0[2]	11[2]
5	Juno Beach - From the Atlantic coastline westward across Pelican Pond to the limit of inundation by the 100-year storm surge; crosses Celestial Way approximately 600 feet south of intersection with Galaxy Place	6.8[2]	11[2]

[1]Loxahatchee River
[2]Atlantic Ocean

Table 1. (Cont'd)
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
6	Palm Beach County/Palm Beach Gardens - From the Atlantic coastline westward across Little Lake Worth to the limit of inundation by the 100-year storm surge; crosses Landing Place approximately 200 feet south of intersection with Lake Shore Place in Palm Beach County	6.8[2]	11[2]
7	North Palm Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses Lakeside Drive just south of intersection with Fathom Road	6.8[2]	11[2]
8	North Palm Beach/Riviera Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses Castlewood Drive at intersection with Lehane Terrace in North Palm Beach	6.8[2]	11[2]
9	Palm Beach Shores/Riviera Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses Avenue B between 21st Street and 20th Street in Riviera Beach	7.0[2]	11[2]
10	Palm Beach/West Palm Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses North County Road at intersection with Coral Reef Road in Palm Beach	6.8[2]	11[2]
11	Palm Beach/West Palm Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses South County Road between Banyan Road and Via La Selva in Palm Beach	6.8[2]	11[2]

[2] Atlantic Ocean

Table 1. (Cont'd)

Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
12	Palm Beach/Lake Worth - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses the northern tip of Ibis Isle in Palm Beach	6.9[2]	11[2]
13	Palm Beach/Lake Worth - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses State Highway A1A in Palm Beach approximately 2500 feet north of intersection with Lake Avenue	6.9[2]	11[2]
14	Palm Beach/Lake Worth - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses Lakeside Drive just south of intersection with 8th Avenue in Lake Worth	6.9[2]	11[2]
15	Lantana/South Palm Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses South Ocean Boulevard (State Highway A1A) approximately 1600 feet north of intersection with East Ocean Avenue in South Palm Beach	7.0[2]	11[2]
16	Lantana/Manalapan - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses South Ocean Boulevard (State Highway A1A) approximately 2700 feet south of intersection with East Ocean Avenue in Manalapan	7.0[2]	11[2]
17	Ocean Ridge/Boynton Beach - From the Atlantic coastline westward across Lake Worth to the limit of inundation by the 100-year storm surge; crosses State Highway A1A approximately 500 feet south of intersection with Sabal Island Drive in Ocean Ridge	7.0[2]	11[2]

[2]Atlantic Ocean

Table 1. (Cont'd)
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
18	Briny Breezes/Boynton Beach - From the Atlantic coastline westward across the Intracoastal Waterway to the limit of inundation by the 100-year storm surge; crosses Old Ocean Boulevard near intersection with Hibiscus Drive in Briny Breezes	7.0[2]	11[2]
19	Gulf Stream/Boynton Beach - From the Atlantic coastline westward across the Intracoastal Waterway to the limit of inundation by the 100-year storm surge; crosses Avenue Au Soleil at intersection with Indigo Point	7.0[2]	11[2]
20	Delray Beach - From the Atlantic coastline westward across the Intracoastal Waterway to the limit of inundation by the 100-year storm surge; crosses Venetian Drive between Shulson Street and Langer Way	7.0[2]	11[2]
21	Highland Beach/Delray Beach - From the east side of the Intracoastal Waterway westward across the Intracoastal Waterway and Tropic Isle Harbor to the limit of inundation by the 100-year storm surge in Delray Beach	7.0[3]	8[3]
22	Highland Beach/Boca Raton - From the Atlantic coastline westward across the Intracoastal Waterway to the limit of inundation by the 100-year storm surge; crosses State Highway AlA between Highland Beach Drive and Bel Lido Drive in Highland Beach	7.0[2]	11[2]
23	Boca Raton - From the Atlantic coastline westward across Lake Rogers to the limit of inundation by the 100-year storm surge; crosses Northeast 6th Drive just north of intersection with Northeast 37th Street	7.3[2]	11[2]

[2] Atlantic Ocean
[3] Intracoastal Waterway (at Tropic Isle Harbor)

Table 1. (Cont'd)
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
24	Boca Raton - From the Atlantic coastline westward across Lake Wyman to the limit of inundation by the 100-year storm surge at a point east of Northeast 5th Avenue and between Northeast 18th Street and Northeast 17th Street	7.3[2]	11[2]
25	Boca Raton - From the Atlantic coastline westward across Lake Boca Raton to the limit of inundation by the 100-year storm surge; crosses Ocean Boulevard approximately 1800 feet north of intersection with Camino Real	7.3[2]	11[2]
26	Boca Raton - From the Atlantic coastline westward across Lake Boca Raton to the limit of inundation by the 100-year storm surge; crosses Southeast 5th Avenue approximately 725 feet north of intersection with Camino Real	7.3[2]	11[2]
27	Boca Raton - From the Atlantic coastline westward across the Intracoastal Waterway to the limit of inundation by the 100-year storm surge; crosses Ocean Boulevard at north side of intersection with Via Cabana	7.3[2]	11[2]
28	Palm Beach County - Crosses Lake Okeechobee to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike approximately 1.4 miles south of the Palm Beach-Martin County Limits	23.0[4]	30[4]
29	Palm Beach County/Pahokee - Crosses Lake Okeechobee to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike approximately 750 feet north of the intersection of Pahokee Road and Larrimore Road in Pahokee	23.0[4]	30[4]

[2] Atlantic Ocean
[4] Lake Okeechobee

Table 1. (Cont'd)
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
30	Palm Beach County - Crosses Lake Okeechobee and Pelican Bay, through the northeastern portion of Torry Island to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike	24.8[4]	31[4]
31	Palm Beach County - Across Lake Okeechobee to a dike in the north-central portion of Kreamer Island	24.8[4]	31[4]
32	Palm Beach County/Belle Glade - Crosses Lake Okeechobee and the southern tip of Torry Island to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike in Belle Glade	25.3[4]	31[4]
33	Palm Beach County - Across Lake Okeechobee to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike approximately 1.5 miles east of Lake Harbor	24.6[4]	30[4]
34	Palm Beach County - Across Lake Okeechobee, through Ritta Island to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike just east of Miami Canal at Lake Harbor	24.3[4]	30[4]
35	Palm Beach County - Across Lake Okeechobee to the limit of inundation by the 100-year storm surge at Herbert Hoover Dike at Little Bare Beach	23.2[4]	29[4]

[4]Lake Okeechobee

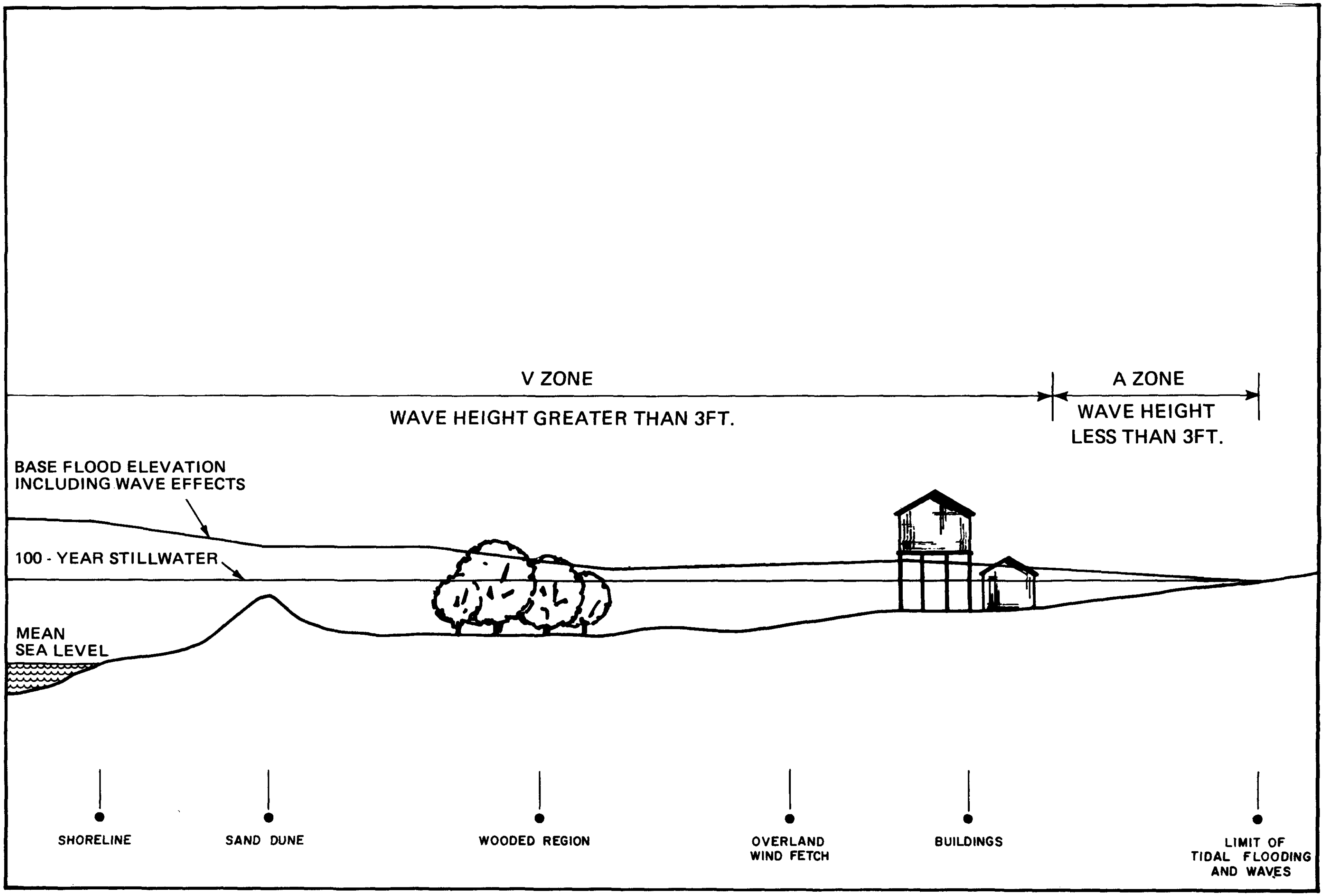


FIGURE 2
TYPICAL TRANSECT SCHEMATIC

by ascending ground elevations, bulkheads, and buildings and vegetation on the western shore. Much of the Intracoastal Waterway is not wide enough to allow wave generation except in local areas, where wave crest elevations of 8 feet occur.

Wave heights of from 1 to 2 feet, with wave crest elevations of up to 8 feet, are generated across Loxahatchee River and its North, Northwest, and Southwest Forks. These waves are dissipated by ascending ground elevations, bulkheads, and buildings and vegetation on the leeward shore.

Wave heights greater than 1 foot are generated over Little Lake Worth and Lake Worth with wave crest elevations of up to 8 feet. These waves are diminished by dense development and higher ground elevations west of the lake.

Breaking wave crest elevations at the shoreline of Lake Okeechobee range from 26 to 31 feet. These elevations are diminished somewhat by levees and vegetation on Ritta, Kreamer, and Torry Islands, and Halifax Bank. All wave action stops abruptly at the Herbert Hoover Dike.

3.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

A prime purpose of the National Flood Insurance Program is to encourage local governments to adopt sound flood plain management programs designed to reduce future flood losses. The FIRM for Palm Beach County has been revised to incorporate the latest available information, including wave height data, to assist this community in developing the most appropriate and effective flood plain management measures.

3.1 Flood Boundaries

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by the Federal Emergency Management Agency as the base flood for purposes of flood plain management. This flood has a 1 percent chance of being equalled or exceeded each year and is expected to be exceeded once on the average during any 100-year period. The risk of having a flood of this magnitude or greater increases when periods longer than 1 year are considered. For example, over a 30-year period, there is a 26 percent chance of experiencing a flood equal to or greater than the 100-year flood. The 500-year flood plain is also shown on the FIRM to indicate areas of moderate flood hazards.

Areas inundated by the 100-year flood are shown as A and V Zones on the community's FIRM. It is in these areas that the Federal Emergency Management Agency requires local communities to exercise flood plain management measures as a condition for participation in the National Flood Insurance Program.

3.2 Base Flood Elevations

Areas within the communities studied by detailed engineering methods have base flood elevations established in A and V Zones. These are the elevations of the base (100-year) flood relative to the National Geodetic Vertical Datum of 1929. In coastal areas affected by wave action, base flood elevations are generally maximum at the open coast shoreline. These elevations generally decrease in a landward direction at a rate dependent on the presence of obstructions capable of dissipating the wave energy. Where possible, changes in base flood elevations have been shown in 1-foot increments on the FIRMs. However, where the scale did not permit, 2- or 3-foot increments were sometimes used. Base flood elevations shown in the wave action areas represent the average elevation within the zone. Current program regulations generally require that all new construction be elevated such that the first floor, including basement, is above the base flood elevation in A and V Zones.

3.3 Velocity Zones

The U.S. Army Corps of Engineers (Reference 19) has established the 3-foot breaking wave as the criterion for identifying coastal high hazard zones. This was based on a study of wave action effects on structures. This criterion has been adopted by the Federal Emergency Management Agency for the determination of V Zones. Because of the additional hazards associated with high-energy waves, the National Flood Insurance Program regulations require much more stringent flood plain management measures in these areas, such as elevating structures on piles or piers. In addition, insurance rates in V Zones are higher than those in A Zones with similar numerical designations.

The location of the V Zone is determined by the 3-foot breaking wave as discussed previously. The detailed analysis of wave heights performed in this study allowed a much more accurate location of the V Zone to be established. The V Zone generally extends inland to the point where the 100-year flood depth is insufficient to support a 3-foot breaking wave.

4.0 INSURANCE APPLICATION

The assignment of proper actuarial insurance rates requires that frequency and depth of flooding be estimated as accurately as possible. Because waves can add considerably to expected flood depths, it is important that insurance rates consider this additional hazard. The Federal Emergency Management Agency has developed a process to transform the data from this study into flood insurance criteria. This process includes the determination of Flood Hazard Factors and the designation of flood insurance zones.

4.1 Flood Hazard Factors

The Flood Hazard Factor (FHF) is the device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHF are used to set actuarial insurance premium rate tables.

The FHF is shown as a three-digit code that expresses the difference between the 10- and 100-year flood elevations to the nearest 0.5 foot. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year water-surface elevations is greater than 10.0 feet, the FHF is computed to the nearest foot.

4.2 Flood Insurance Zones

After wave elevations for the 100-year storm surge were determined and mapped, the study areas were divided into zones, each having a specific flood potential and FHF. Each zone was assigned one of the following flood insurance zone designations:

Zones V8 and V10:	Special Flood Hazard Areas inundated by the 100-year flood, and that have additional hazards due to velocity (wave action); base flood elevations shown, and zones subdivided according to FHFs.
Zones A5, A7, and A8:	Special Flood Hazard Areas inundated by the 100-year flood, with base flood elevations determined and zone designations assigned according to the FHFs.
Zone B:	Areas between the Special Flood Hazard Areas and the limits of the 500-year flood plain, including areas that are protected from the 100- and 500-year floods by dike, levee, or other water control structure; and areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot, or where the contributing drainage area is less than 1 square mile. Zone B is not subdivided.
Zone C:	Areas not subject to flooding by the 500-year flood. Zone C is not subdivided.

Table 2, "Flood Insurance Zone Data," summarizes the FHFs, flood insurance zones, and base flood elevations for each flooding source in the study area.

4.3 Flood Insurance Rate Map

After flood insurance zones were established for the study area, the FIRM for Palm Beach County was revised to incorporate the new zone information. This map (Exhibit 1) contains the official delineation of flood insurance zones and base flood elevations.

In preparing the revised FIRM, updated topographic information was used to revise the open coast shoreline and some zone boundaries in areas not affected by the wave height analysis. Corporate limits and cultural features were

Table 2. Flood Insurance Zone Data

Flooding Source	Stillwater Elevation 10-Year	50-Year	100-Year	500-Year	FHF	Zone	Base Flood Elevation (Feet NGVD)*
Atlantic Ocean Open Coast	4.3-4.6	6.0-6.5	6.8-7.3	8.1-8.7	040	V8	9 to 11
					035	A7	7 to 9
Intracoastal Waterway	3.4-4.4	5.4-6.4	6.0-7.0	7.5-8.5	035	A7	6 to 8
					025	A5	6, 7
Lake Worth and Little Lake Worth	4.5-4.7	6.3-6.5	7.0-7.4	8.7-9.1	035	A7	7, 8
					025	A5	7
Loxahatchee River (including North, Northwest, and Southwest Forks)	3.4	5.4	6.0	7.5	035	A7	6 to 8
					025	A5	6
North Palm Beach Waterway	4.4	6.3	7.0	8.7	025	A5	7
Lake Okeechobee	20.5-21.5	22.4-24.2	23.0-25.3	24.5-26.8	040,050	V8,V10	23 to 31
					040	A8	23 to 27

*Due to map scale limitations, base flood elevations shown on the FIRM may represent average elevations for the zones depicted.

revised using community maps and related information obtained from the incorporated communities within the county.

5.0 OTHER STUDIES

FIRMS for the incorporated communities of Belle Glade, Boca Raton, Boynton Beach, Briny Breezes, Delray Beach, Gulf Stream, Highland Beach, Juno Beach, Jupiter, Jupiter Inlet Colony, Lake Worth, Lantana, Manalapan, North Palm Beach, Ocean Ridge, Palm Beach, Palm Beach Shores, Pahokee, Riviera Beach, South Palm Beach, and Tequesta; and adjacent communities of Jupiter Island (Martin County) and Martin County are being revised concurrently with Palm Beach County to include wave height analysis. The revised studies for these communities, with the exception of Jupiter Island, will be in agreement with this study. The difference in base flood elevations between Jupiter Island and Palm Beach County at Jupiter Sound is attributed to a combination of diminishing surge elevations and averaging wave crest elevations in the area.

The Flood Insurance Studies for Hypoluxo, Lake Park, and West Palm Beach are not being revised at this time to include wave height analysis, and will not be in agreement with this study.

6.0 REFERENCES

1. National Academy of Sciences, Methodology for Calculating Wave Action Effects Associated With Storm Surges, 1977

2. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Palm Beach County, Florida, 1978

3. U.S. Department of Commerce, Environmental Science Services Administration, Technical Memorandum WBTM Hydro 11, Joint Probability Method of Tide Frequency Analysis, V.A. Myers, April 1970

4. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Tropical Cyclone Deck 993, 1975

5. U.S. Department of Commerce, Weather Bureau, Technical Paper No. 55, Tropical Cyclones of the North Atlantic Ocean 1871 - 1963, G.W. Cry, 1965

6. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Technical Report NWS-15, Climatological Characteristics of Hurricanes, F.P. Ho, R.W. Schwerdt, and H.V. Goodyear, July 1975

7. U.S. Department of Commerce, National Hurricane Research Project, Report No. 5, Survey of Meteorological Factors, March 1957

8. U.S. Department of the Interior, Geological Survey, 7.5-Minute Series Topographic Maps, Scale 1:24,000, Contour Interval 5 feet: Belle Glade,

Florida (1970); Boca Raton, Florida (1962), Photorevised (1969), Photoinspected (1973); Bryant, Florida (1970); Delray Beach, Florida (1962), Photorevised (1973); Jupiter, Florida (1948), Photorevised (1967), Photoinspected (1973); Lake Harbor, Florida (1970); Lake Worth, Florida (1945), Photorevised (1967), Photoinspected (1973); Pahokee, Florida (1970); Palm Beach, Florida (1946), Photorevised (1967), Photoinspected (1973); Port Mayaca, Florida (1970); Riviera Beach, Florida (1946), Photorevised (1967), Photoinspected (1973)

9. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Storm Evacuation Maps T-15088, T-15057, T-15090, T-15087, and T-15056, Scale 1:62,500, Contour Interval 5 feet: Belle Glade, Florida (1978); Fort Lauderdale, Florida (1976); Okeechobee, Florida (1978); Stuart, Florida (1978); West Palm Beach, Florida (1976)

10. Abrams Aerial Survey, Aerial Photograph Topographic Maps of Palm Beach County, Florida, Scale 1:10,800, Contour Interval 2 feet, January 1976

11. South Florida Water Management District, Map showing spot elevations at Belle Glade Marina and Herbert Hoover Dike at Belle Glade, Scale 1:2400, July 1981

12. Florida Department of Natural Resources, Bureau of Beaches and Shores, Palm Beach County, Florida, Beach Profiles, Scale 1:600, 1974

13. National Oceanic and Atmospheric Administration, National Ocean Survey, Nautical Chart 11428, St. Lucie Inlet to Ft. Myers and Lake Okeechobee, Florida, Scale 1:80,000, 1980

14. Florida Department of Transportation, Highway Bridge Plans, State Highways 5 and AlA, Bridge Over Loxahatchee River, 1956 and 1972

15. Federal Emergency Management Agency, Aerial Photography of Palm Beach County, Florida, Scale 1:12,000, March 1981

16. U.S. Army Corps of Engineers, Aerial Photography of Lake Okeechobee, Florida, Scale 1:6,000, December 1975

17. U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory Maps, Scale 1:24,000: Belle Glade, Florida; Boca Raton, Florida; Bryant, Florida; Delray Beach, Florida; Jupiter, Florida; Lake Harbor, Florida; Lake Worth, Florida; Pahokee, Florida; Palm Beach, Florida; Port Mayaca, Florida; and Riviera Beach, Florida, unpublished

18. Federal Emergency Management Agency, Users Manual for Wave Height Analysis, Revised February 1981

19. U.S. Army Corps of Engineers, Galveston District, Guidelines for Identifying Coastal High Hazard Zones, June 1975

U.S. Department of Housing and Urban Development, Federal Insurance Administration, Coastal Flooding Handbook, Parts I and II, Tetra Tech, Inc., May 1977