Long Range
Beach Nourishment Plan

for

Village of Key Biscayne
Dade County, Florida

prepared for

VILLAGE OF KEY BISCAYNE

by

Coastal Systems International, Inc.
464 South Dixie Highway, Coral Gables, Florida 33146

August 1997

VILLAGE OF KEY BISCAYNE

Office of the Village Clerk

Village Council
John F. Festa, *Mayor*
Mortimer Fried, *Vice Mayor*
Martha Fdez-León Broucek
Gregory C. Han
Hugh T. O'Reilly
Michele Padovan
Betty Sime

Village Clerk
Conchita H. Alvarez

CERTIFICATION

STATE OF FLORIDA
COUNTY OF DADE

I, Conchita H. Alvarez, duly appointed Village Clerk of the Village of Key Biscayne, Florida, do hereby certify that the attached is a true and correct copy of:

Resolution No. 97-55, passed and adopted on October 28, 1997.

IN WITNESS WHEREOF, I hereunto set my hand and affix the Seal of the Village of Key Biscayne, Florida, this 23rd day of February, 1998.

Conchita H. Alvarez
Village Clerk
Village of Key Biscayne, Florida

RESOLUTION NO. 97-55

A RESOLUTION OF THE VILLAGE OF KEY BISCAYNE, FLORIDA; ADOPTING THE LONG RANGE BEACH NOURISHMENT PLAN, VILLAGE OF KEY BISCAYNE, DADE COUNTY, FLORIDA; PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the Village Council has historically supported beach preservation through dedicated funding, resolutions, and preparation for the pending beach nourishment; and

WHEREAS, the Village Council adopted Resolution 96-36, November 14, 1996, authorizing the preparation of the Long Range Beach Nourishment Plan; and

WHEREAS, the Village Manager executed the contract with Coastal Systems International, Inc. for the preparation of the Long Range Beach Nourishment Plan on February 14, 1997; and

WHEREAS, the Village Beach Resources and Management (BRM) Task Force presented the Long Range Beach Nourishment Plan, dated August 1997, to Council on August 26, 1997; and

WHEREAS, the Village Beach Resources and Management (BRM) Task Force presented detailed information on the Long Range Beach Nourishment Plan at a public workshop on September 16, 1997; and

WHEREAS, the Village Manager has directed the preparation of a newsletter summarizing the Long Range Beach Nourishment Plan, to be disbursed to all Village residents; and

WHEREAS, the Long Range Beach Nourishment Plan shall provide planning guidance for present and future Councils;

NOW, THEREFORE, BE IT RESOLVED BY THE VILLAGE COUNCIL OF KEY BISCAYNE AS FOLLOWS:

Section 1. The Village Council hereby adopts the Long Range Beach Nourishment Plan, to be utilized as a Municipal, County, State, and Federal planning device for future beach preservation.

Section 2. The Village Manager is authorized to disseminate the Long Range Beach Nourishment Plan to various County, State, and Federal officials.

Section 3. The Village Manager is authorized to pursue avenues for dedicated sources of sand and beach nourishment funding, including but not limited to reimbursement agreements with appropriate governmental agencies.

Section 4. The Village Council shall commence and proceed with such efforts as are necessary to implement the beach nourishment program, recommended in the Long Range Beach Nourishment Plan, by the year 1999, or as soon thereafter as is practicably achievable.

Section 5. This resolution shall take effect immediately upon adoption.

PASSED AND ADOPTED this 28th day of October, 1997

MAYOR JOHN F. FESTA

ATTEST:

CONCHITA H. ALVAREZ, VILLAGE CLERK

APPROVED AS TO FORM AND LEGAL SUFFICIENCY:

RICHARD J. WEISS, VILLAGE ATTORNEY

RESOLUTION NO. 98-55

A RESOLUTION OF THE VILLAGE OF KEY BISCAYNE, FLORIDA; ADOPTING ADDENDUM #1 TO THE LONG RANGE BEACH NOURISHMENT PLAN, VILLAGE OF KEY BISCAYNE, DADE COUNTY, FLORIDA; PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the Village Council has historically supported beach preservation through dedicated funding, resolutions, and preparation for the pending beach nourishment; and

WHEREAS, the Village Council adopted Resolution 97-55, dated October 28, 1997, adopting the Long Range Beach Nourishment Plan for the Village of Key Biscayne; and

WHEREAS, the Long Range Beach Nourishment Plan does not specifically identify the type and grain size of beach nourishment sand appropriate for Key Biscayne; and

WHEREAS, the Village Master Plan directly supports proper beach nourishment sand selection through environmental policies 1.7.1 which calls for "minimizing damage to offshore grass flats" through proper project design, and 1.7.6 which "limits activities that adversely affect habitat that may be critical to endangered, threatened or rare species or species of special concern", displayed in Master Plan Appendices A, B, and C; and

WHEREAS, the present and future selection of beach nourishment sand that is most naturally compatible with the existing and historic surrounding environment will promote longevity of both the beach nourishment project and the entire Key Biscayne ecosystem;

NOW, THEREFORE, BE IT RESOLVED BY THE VILLAGE COUNCIL OF KEY BISCAYNE AS FOLLOWS:

Section 1. The Village Council hereby adopts Addendum #1 to the Long Range Beach Nourishment Plan for the Village of Key Biscayne, Dade County, Florida, to be used as a guide to sand source selection for beach nourishment projects.

Section 2. Addendum #1 shall be used as a strong guideline within all realistic practicality, however, it will not supersede other factors or obligate the Village Council to expend more than what they deem reasonable on a nourishment project.

Section 3. The Village Manager is authorized to request estimates for appropriate quantities of beach sand for the Proposed Village Beach Nourishment, based on Addendum #1.

Section 4. This resolution shall take effect immediately upon adoption.

PASSED AND ADOPTED this 27th day of October, 1998

MAYOR JOHN F. FESTA

ATTEST:

CONCHITA H. ALVAREZ, VILLAGE CLERK

APPROVED AS TO FORM LEGAL SUFFICIENCY

RICHARD J. WEISS, VILLAGE ATTORNEY

VILLAGE OF KEY BISCAYNE

Office of the Village Clerk

Village Council
Joe I. Rasco, *Mayor*
Gregory C. Han, *Vice Mayor*
Scott Bass
Martha Fdez-León Broucek
Alan H. Fein
Mortimer Fried
Robert Oldakowski

Village Clerk
Conchita H. Alvarez, CMC

CERTIFICATION

STATE OF FLORIDA
COUNTY OF MIAMI-DADE

I, Conchita H. Alvarez, duly appointed Village Clerk of the Village of Key Biscayne, Florida, do hereby certify that the attached is a true and correct copy of:

Resolution 98-55 adopted by the Village Council on October 27, 1998

IN WITNESS WHEREOF, I hereunto set my hand and affix the Seal of the Village of Key Biscayne, Florida, this 1st day of December, 1998.

Conchita H. Alvarez
Village Clerk
Village of Key Biscayne, Florida

85 West McIntyre Street • Key Biscayne, Florida 33149 • (305) 365-5511 • FAX (305) 365-8936
MISSION STATEMENT: "TO PROVIDE A SAFE, QUALITY COMMUNITY ENVIRONMENT FOR ALL ISLANDERS THROUGH RESPONSIBLE GOVERNMENT."

SG

Sandra Goldstein
& Associates, Inc.

October 20, 1998

The Honorable Mayor and Members of Village Council
Village of Key Biscayne

Dear Mayor and Council Members:

The ocean beach of the Village of Key Biscayne is a centerpiece and valuable natural resource of the community. This beach is dynamic and subjected to erosive stresses from natural and human influences. As a result, the beach will need periodic placement of new sand to restore what has been lost through erosion. It is critical that the quality of new sand placed on the beach maintain the quality of the beach system with respect to: optimizing the stability in the beach-dune zone, minimizing release of muddy suspensions into the offshore waters, maintaining comfort for beach walkers, providing viability for nesting turtles and beach vegetation, and maintaining the aesthetics of the historic beach.

The following document defines and explains these criteria for quality of new beach sand to be placed on the ocean beach of Key Biscayne. Defined is both the quality of the sand and the methods to be used in assessing the quality. The character of the natural historical beach-dune sand of central Key Biscayne, together with fundamental principles of particle transport, were used to define specifications for future nourishment sands. A graph of the optimal and minimally-permitted sand size distribution was adapted from that used by Miami-Dade County for the beaches to the north. The slightly finer mean particle size and a smaller maximum particle size for the permitted sands for the ocean beach of Key Biscayne reflects the nature of the historical sands and the more protected setting than found to the north.

The natural sands of the ocean beach of Key Biscayne are a mixture of quartz sand and skeletal calcium carbonate fragments. The permitted future sands are also to be a mixture of quartz and skeletal calcium carbonate grains. The type of grains affect both the temperature of the dry beach-dune (important to turtle nesting) and the pore-water chemistry of the upland beach-dune (important to vegetation). Specifically prohibited are calcium carbonate particles derived from disaggregation (breaking apart) of fossil limestone. Such particles are commonly prone to releasing significant

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volumes of silt when subjected to abrasion in the beach zone and prone to cementing together under the influence of rainwater in the back-beach zone.

Included also are the required methods for analysis of sand proposed for placement on the ocean beach of the Village of Key Biscayne. This was prompted by pre-tests for a nourishment in 1998 that did not recognize the nature of the particles as they would occur when placed on the beach. Analyses include dry sieving, wet sieving and settling together with microscopic analysis by one trained in particle analysis. These analyses are designed to prevent placement of sand particles on the beach that will disaggregate into much smaller particles when wet, particles that are lightweight (common in some largely hollow skeletal calcium carbonate particles), and particles that are not durable in the beach zone, resulting in both loss of the particles and creation of large volumes of silt.

Sincerely,

Sandra Goldstein
Village Beach Resources and
Management (BRM) Task Force
Chair and Village Resources Volunteer

Dr. Hal Wanless
BRM Beach Nourishment Sand Quality
Subcommittee Chair and University of
Miami Geologist

LONG RANGE BEACH NOURISHMENT PLAN
VILLAGE OF KEY BISCAYNE
DADE COUNTY, FLORIDA
ADDENDUM 1

SAND QUALITY TO BE USED IN MAINTAINING
THE OCEAN BEACH OF KEY BISCAYNE, FLORIDA

APPROVED BY THE VILLAGE
BEACH RESOURCES AND MANAGEMENT (BRM) TASK FORCE
VILLAGE OF KEY BISCAYNE, FLORIDA
JUNE 17, 1998

ADDENDUM: Future sand nourishment of the ocean beach of the Village of Key Biscayne shall use only high quality sand that meets the requirements set forth below, so as to guarantee a beach system that will remain a top quality recreational and protective beach and have a positive environmental influence. Two types of sand specifications are provided within: Ideal and Minimum Quality Sand. Ideal is the desired beach fill material and should be used if it is available and economically feasible.

The ideal sand to be used for future nourishment of the Village of Key Biscayne beach (Figure 1) would be well mixed and have no material finer than 200 microns (0.2 mm), less than 50% material coarser than 500 microns (0.5 mm), and no material coarser than 1,000 microns (1 mm). In addition, appropriate sand would contain 25-60% durable natural (not manufactured/crushed rock) carbonate grains, verified by settling analyses, with the remainder consisting of natural quartz sand particles (Figure 2).

Minimum quality sand allowed for placement on the Village of Key Biscayne beach (Figure 1) should be well mixed and consist of less than 5% material finer than 80 microns (0.08 mm), less than 25% finer than 200 microns (0.2 mm), less than 10% coarser than 1,000 microns (1 mm), and no cohesive sediments and/or rock aggregate particles (including coral fragments) coarser than 5,000 microns (5 mm). Shell material should be no coarser than 3 cm. In addition, minimum quality sand would contain 20-70% durable natural (not manufactured/crushed rock) carbonate grains, verified by settling analyses, with the remainder consisting of quartz particles (Figure 3).

PURPOSE: This addendum is intended to provide assurance that the ocean shoreline of Key Biscayne is maintained as a top quality recreational and protective beach which will positively affect the offshore marine environment, the beach dune environment, the human and natural users of the beach-dune system, and the landward environment and developments.

BACKGROUND: The Key Biscayne Atlantic coastline, including the Village beach, is unique. Any attempt to manage or restore Key Biscayne beaches must be based upon knowledge of the differences between it and other Atlantic coast beaches.

Key Biscayne is the southernmost sandy barrier island along the Atlantic coast of the United States. The island and its unique ocean beach were formed over the past several thousand years as a finger of sand migrated from north to south into the subtropical *carbonate*[1] environments of Biscayne Bay and the Reef Tract. Sands comprising Key Biscayne and its beach are 30-80% quartz grains that have originated in the weathered Appalachian Mountains. The remaining 20-70% of the sand is skeletal grains of calcium carbonate (Figure 2). Part of the skeletal component is robust rounded fragments of mollusk shells that have been incorporated into the beach sands as they moved south from their origin to Key Biscayne. The remaining skeletal components, 40-60% of the carbonate sand component, are more delicate porous skeletal fragments of varied shapes derived from the more local marine environments offshore.

A net southward transport of sand along the beaches of Miami-Dade County, estimated minimally to be 80,000 cubic yards of sediment per year, is driven by the north and northeasterly winds following winter cold fronts and storms. The quartz-carbonate sand of the Key Biscayne shore system extends approximately five miles southeast of the island as a subtidal spit, and fades out to the east as mud banks.

The Key Biscayne beach, although exposed to numerous winter storms and hurricanes throughout many years, differs from the Atlantic beaches to the north of Government Cut in Miami-Dade County in that it lies in the complete protection of the Bahamas Bank and, therefore, does not normally receive Atlantic Ocean swells. In addition, seaward shallow water limestone ridges provide some protection from waves generated in the Straits of Florida. This more protected setting has permitted tidal processes to have greater influence on the morphology of the barrier island system.

Major natural inlets to the north and south of Key Biscayne (Bear Cut and Cape Florida/Biscayne Channels, respectively), maintained by tidal exchange with Biscayne Bay, have been permanent features throughout historic times. Southward drifting sand, caught in these tidal systems, has formed large flood and ebb tidal deltas. The ebb tidal deltas at both

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[1] *Carbonate* is used to describe environments where the sediment is locally produced from shell or skeletons of organisms such as *Halimeda* algae or coral, and/or chemical precipitation from sea water (oolitic grains and some mud). Skeletal carbonate sand grains may be whole skeletons or broken fragments. Calcium carbonate sediment can occur as gravel-, sand-, and mud-sized particles. Carbonate mud particles often form aggregates.

the northern and southern ends of Key Biscayne have formed broad, shallow *littoral*[2] sand platforms directly on the Atlantic side of the island that extend to approximately 5,000 feet offshore. These platforms are composed of quartz-carbonate sand of similar composition (but not necessarily grain size) as the beach, but of different composition from sand to seaward. Waves have smoothed the seaward margins of these ebb tidal deltas, and long shore currents have formed offshore bars extending the deltas southward and northward toward central Key Biscayne. The southward and westward movement of the Bear Cut ebb shoal has resulted in a significant sand spit in Crandon Park; this now prominent and unique feature has been building steadily since the 1920's. The Village of Key Biscayne shoreline is subject to much greater storm erosion, however, because the central section of the island is not protected by shallow littoral sand platforms to the seaward.

The exposed seaward margin of the ebb tidal deltas and bars is barren rippled sand. The interior of the shallow littoral sand platform is sufficiently protected to allow seagrasses to colonize and flourish. Dominant species of seagrass include turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*). This seagrass cover provides a stable bottom which permits important bottom dwelling organisms and infauna to persist, acts as a wave baffling device that actively traps finer suspended sands, and stabilizes substrate against storm damage through the deeply penetrating rhizome and root mat. Areas of persistent seagrass cover have accumulated sands that are of much finer grain size than would be stable on the adjacent bare bottom areas or beaches.

Seaward of the central Key Biscayne beach and the littoral sand platforms of northern and southern Key Biscayne, the bottom deepens to an exposed limestone surface 20-25 feet in depth. The quartz-carbonate sands of the shore system do not extend out onto this deeper seaward shelf. Skeletal carbonate sands occur as subtidal deposits and fill depressions in the limestone in this seaward zone.

SAND QUALITY: Optimum and minimum acceptable sand qualities are defined to insure a high quality Key Biscayne beach as the result of any future beach nourishment projects. These recommendations are based on analyses of historical natural Key Biscayne beach sands, analysis and performance of materials used in previous Key Biscayne beach nourishment projects, and general sedimentologic, hydrodynamic, and environmental considerations.

Recommended Sand Quality Parameters: Grain size characteristics of an ideal sand to be used for future nourishment of the Village of Key Biscayne beach (Figure 1) would have no material finer than 200 microns (0.2 mm), less than 50% material coarser than 500 microns

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[2] *Littoral* refers to a shallow zone seaward of the beach subjected to waves and currents associated with shallowing waves, long shore drift, and tidal currents near inlets. Off Key Biscayne the shallow littoral sand platform extends as much as 1 mile seaward of the shore and is composed of quartz-carbonate sand similar in composition (but not necessarily grain size) to the beach.

(0.5 mm), and no material coarser than 1,000 microns (1 mm). In addition, appropriate sand would contain 25-60% durable natural (not manufactured/crushed rock) carbonate grains, verified by settling analyses, with the remainder consisting of natural quartz sand particles (Figure 2).

Parameters for the minimum quality sand allowed for placement on the Village of Key Biscayne beach (Figure 1) should consist of less than 5% material finer than 80 microns (0.08 mm), less than 25% finer than 200 microns (0.2 mm), less than 10% coarser than 1,000 microns (1 mm), and no rock aggregate particles coarser than 5,000 microns (5 mm). Shell material should be no coarser than 3 cm. In addition, minimum quality sand would contain 25-70% durable natural (not manufactured/crushed rock) carbonate grains, verified by settling analyses, with the remainder consisting of quartz particles (Figure 3).

Natural Beach Sands of Key Biscayne: The natural sand of Key Biscayne beach is 20-70% skeletal calcium carbonate grains and 30-80% quartz grains (Figure 2). Due to the high amount of skeletal carbonate grains, sieving and settling analyses give very different results (Figures 2 and 3). Sieving analysis shows that the sand has two modes of abundance with a broad fine-skewed unimodal peak. Settling analysis shows that the sand has a more narrow, generally symmetrical unimodal peak. As explained in the *Methods of Analysis* section, the difference occurs because many of the calcium carbonate grains settle together with finer quartz grains. In other words, the physical size and shape of many of the skeletal carbonate grains is misleading (i.e. they *behave* as finer grains than what sieve analysis would indicate). As a result, the following characterizations of natural and nourishment sands are given as the results of settling analyses. These results could be directly compared to sieve results of pure quartz sands or of non-porous, equant calcium carbonate sands (e.g. ooids or rounded mollusk fragments).

The natural sand of the berm and beach foreslope of Key Biscayne[3] is a well sorted quartz-carbonate sand with a unimodal peak at 220-350 microns (0.22-0.35 mm). Settling analyses show that essentially no material coarser than 500 microns (0.5 mm) exists in the berm and beach foreslope samples, and that quartz and carbonate fractions are essentially equivalent in size distribution. A coarser skeletal (mostly mollusk) component is present in the plunge zone (shallow active wave-washed part of the beach) samples. No material finer than 80 microns (0.08 mm) is present in any of the natural beach sands. Grains finer than 125 microns (0.125 mm) form 0-10% of the samples; grains finer than 175 microns (0.175 mm) comprise 5-30%.

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[3] Sands used to characterize natural Key Biscayne Beach sands were collected in October 1972 by H.R. Wanless as a part of a Sea Grant sponsored research project at the University of Miami. A beach nourishment project was undertaken in northern Crandon Park in 1969, therefore, only sands from the beach along the now Village of Key Biscayne and Cape Florida Park are used here. Samples were collected from (a) just landward of the berm crest, (b) the foreslope of the beach, and (c) in the plunge zone at the base of the beach.

Sands obtained from the natural beach along the central portion of Key Biscayne not protected by a shallow littoral sand platform were slightly coarser than to the north or south. Analysis showed a unimodal peak at 350 microns (0.35 mm) and no material finer than 125 microns (0.125 mm).

Character and Performance of Sands in Historical Beach Renourishment Projects: The principal sand renourishment project affecting the beach of the Village of Key Biscayne and Cape Florida occurred in 1987. The sand was derived from an offshore sand source on the littoral sand platform lying to the southeast of Cape Florida. The sand in the borrow area was sand that historically moved south from the Key Biscayne beach due to the natural process of long shore drift. This nourishment sand was very similar to the naturally occurring Key Biscayne beach in percentage of quartz and carbonate, constituent grain composition, and grain size.

Sand from the borrow site for the 1987 Key Biscayne beach nourishment was well sorted and unimodally distributed, with a peak at 250-350 microns (0.25-0.35 mm). The sands contained 0-4% material finer than 125 microns (0.125 mm), 1-12% material coarser than 700 microns (0.7 mm) by settling, and 0.5% coarser than 1 mm by sieving. The 1987 beach nourishment, upon construction completion, was anticipated to require nourishments of 154,000 cubic yards of sand on a schedule of seven year increments. The Village presently anticipates the use of 120,000 cubic yards for the Proposed 1999 nourishment, thus indicating the appropriateness of original nourishment sand.

Sedimentological and Hydrodynamic Considerations (Theory and Methodology): Three fundamental particle size boundaries (40, 200, and 650 microns, or 0.04, 0.2, and 0.65 mm) relate how particles move in a fluid to the energy required to initiate movement. These particles move either in suspension or as a bedload.

<u>Suspension</u>: If sufficient energy exists to move particles finer than 200 microns (0.2 mm), then sufficient turbulence is also present in the fluid to bring them into suspension. Thus, particles finer than 200 microns (0.2 mm) tend to move as suspended load in the fluid column.

a) *Short-term Suspension:* Particles between 200 and 40 microns (0.2 and 0.04 mm) tend to come out of suspension quickly following the end of the a period of wave or current energy, or when the energy is no longer affecting the bottom.

b) *Long-term Suspension:* Particles finer than 40 microns (0.04 mm) tend to remain in suspension long after the resuspending event, due to ambient turbulence in the water column.

<u>Bedload</u>: If sufficient energy exists to move particles coarser than 200 microns (0.2 mm), then they tend to move in contact with the bottom.

a) *Bed Load*: Particles between 200 and 650 microns (0.2 and 0.65 mm) tend to bounce (saltate) along the bottom.

b) *Traction Load*: Particles coarser than 650 microns (0.65 mm) tend to roll or slide and maintain constant contact with the bottom.

With increasing energy and turbulence traction load will begin to move as bed load, and bed load as suspension load.

Suspended load material, finer than 200 microns (0.2 mm), is unsuitable as beach sand. A small amount of finer than 200 micron (0.2 mm) material is common on beaches, but can easily be suspended and does not remain on the beach. Vegetated coastal dunes are commonly largely built of 100-200 micron (0.1-0.2 mm) sands, as vegetation traps the finer wind blown particles. Suspended load material that moves seaward from the beach will move off of the littoral sand platform unless trapped by seagrass beds.

The quartz sand on Key Biscayne has been transported southward from the Appalachian Mountains over the last several hundred-thousand years. In the process, most of the coarser sands have been left behind. The upper limit of natural quartz sand on Key Biscayne beaches is thus limited in part by what is provided, not by what would be stable on the beach.

Coarse pebbles and gravel on a beach are unpleasant or injurious to walkers, joggers, and beachcombers, and become dangerous and damaging projectiles during hurricanes. Irregularly shaped pebbles commonly become fixed on the beach slope. Flat mollusk shells, in contrast, are generally swept to the base of the beach by wave backswash. Thus shell fragments poss less of a problem than irregular pebbles.

METHODS OF ANALYSIS: Methods of analysis are discussed so that standard minimum investigation of appropriate sand sources remains consistent. All potential beach sand samples should be evaluated for evidence of grain aggregation by binocular microscope before and after dry sieving. Sands that are mostly quartz naturally disaggregate into individual grains, and are cohesionless. These may be dry sieved according to standard methods. Samples containing more than 15% carbonate grains (i.e. according to *Recommended Sand Quality Parameters*, all potential Key Biscayne sources) should be analyzed both by sieving and by settling analysis in which the settling system has been calibrated with respect to quartz sand.

Dry Sieving: Quartz sands, which are naturally disaggregated into individual grains and are cohesionless, may be dry sieved according to standard methods. However, all samples should be evaluated for evidence of grain aggregation by binocular microscope before and after dry sieving. Regardless of the results from microscopic examination, samples containing a significant fraction of material less than 62 microns (0.062 mm) should be wet sieved. Samples containing more than 15% carbonate grains should be analyzed both by sieving and by settling analysis, in which the settling system has been calibrated with respect to quartz sands. Reporting of results should be as weight percentage according to standard methods for sieving.

Wet Sieving: This method is necessary for those samples in which laboratory drying has aggregated (stuck or cemented together) particles, or in which the sample is provided dry and particles are aggregated. Small amounts of mud, especially carbonate mud, aggregate larger grains together. Dry sieving commonly will not disaggregate these grains into their individual components, as they occur in the aqueous environment.

The sand and gravel fractions should be wet sieved out first, dried and weighed. It is important that tap water be used in a wet sieve, as distilled water will cause dissolution of carbonate mud particles. The wet sieving method must use adequate water and agitation on each sieve to assure particles have adequate opportunity to pass through each sieve, with all test water being retained. The less than 62 micron (0.062 mm) particles must be allowed to settle, the clear water decanted, and the remaining fraction dried and weighed. Reporting of results is as weight percentage according to standard methods for sieving.

Settling Analysis: This method is used to approximate the hydrodynamic behavior of particles, and must be utilized when the particles have a shape or *effective excess density*[4] different from that of subrounded quartz. It is imperative to analyze grains by settling in

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[4] A particle's *effective excess density* (*eed*) is the net density of a particle above that of the fluid (density of the grain minus the density of the fluid). Thus, in water (~density = 1.00 g/cm^3), a solid quartz grain (density = 2.65 g/cm^3) will have an effective excess density of 1.65. Quartz is the standard for which settling analyses are calibrated and from which the hydrodynamic implications of sieving and settling analyses are understood.

There are two important considerations of effective excess density. First, different mineral grains have different densities, and solid grains of different density will behave very differently in water. Second, and most important to considerations here, many carbonate grains have internal pore spaces, and this will dramatically affect the particles' effective density and behavior in a fluid.

For example, a calcareous algal *Halimeda* grain, composed of aragonite of density = 2.93 g/cm^3, is commonly about 50% pore space. The effective excess density of a *Halimeda* particle will be:

eed = (0.5 x density of aragonite) + (0.5 x density of water) - density of water

$eed = (0.5 \times 2.93) + (0.5 \times 1.00) - 1$

$eed = 1.465 + 0.5 - 1 = \mathbf{0.965}$

Thus, the carbonate *Halimeda* grain has a much lower effective excess density in water, even though it is made of a more dense mineral than quartz. As a result, a *Halimeda* particle will behave like a smaller grain, and settle together with much smaller quartz grains than if it had no internal porosity. The *Halimeda* grain will be moved and resuspended much more easily than would be anticipated by its physical size.

samples containing significant carbonate grains.

When settling analysis is used, sieving must also be done on the sample. This is to document the physical size of the coarse fraction, which is important to the comfort of beach users. The initial volume of the sand should be measured so that the settling grain size can be expressed as a volume per cent. The sediment should be thoroughly wetted so that no air is in the internal grain pore spaces. As most settling tubes are only calibrated for grains finer than 1 mm, it may be necessary to sieve the sample through a 1 mm mesh sieve prior to settling. All fluid must be retained from this pre settling sieve separation and used in the settling analysis.

There are numerous settling methods including visual accumulation tube, electromagnetic field distortion, and light attenuation. Regardless of the method used, it is important that results are not affected by internal grain porosity. Most settling results are as volume per cent, as opposed to weight per cent for sieving.

CONCLUSION: It is the opinion of the Village Beach Resources and Management (BRM) Task Force that the previous guidelines will help to insure the highest quality sand for future Key Biscayne beach nourishments. These recommendations have taken into consideration, to the greatest extent practicable, beach preservation, recreational amenities, aesthetics, seagrass and sea turtle impacts, coastal vegetation, beach system enhancement, and storm protection. Although the suggested "Ideal Sand Quality" spectrum is slightly out of Dade County specifications, we feel that Key Biscayne is subject to unique hydrodynamic conditions, supported by historic data, and, therefore, should secure a sand source that uniquely accommodates these naturally imposed requirements.

Task Force Members feel that these specifications should act, within all reasonable physical and economic constraints, as the best possible guide to sand source selection for the Village of Key Biscayne. These specifications are also anticipated to ease the environmental and construction permit processes.

This **Addendum 1** to the Long Range Beach Nourishment Plan for the Village of Key Biscayne Dade County, Florida is submitted in good faith by the members of the Village of Key Biscayne Beach Resources and Management (BRM) Task Force.

Task Force Members:

Sandra Goldstien, Chairperson
Betty Sime, Village Councilmember
C. Samuel Kissinger, Village Manger
James D. DeCocq, Assistant to the Village Manager
Brian Flynn, Coastal Programs Administrator - Miami-Dade County Department of Environmental Resources Management (DERM)
Henny Groschel-Becker, Marine Geologist - University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS)
John Hinson, President - Ocean Club Development Company
Sam Houston, Meteorologist - National Oceanic and Atmospheric Administration (NOAA)
Kris McFadden, Village Coastal Zone Management Intern - University of Miami , Rosenstiel School of Marine and Atmospheric Science (RSMAS)
Harold R. Wanless, Geologist - University of Miami

Ex Officio:

Lee Niblock, Park Manager - Bill Baggs Cape Florida State Recreation Area

Sand Quality Sub-Committee:

Harold R. Wanless, Geologist - University of Miami - Chairperson
James D. DeCocq, Assistant to the Village Manager
Brian Flynn, Coastal Programs Administrator - Miami-Dade County Department of Environmental Resources Management (DERM)
Henny Groschel-Becker, Marine Geologist - University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS)
Sam Houston, Meteorologist - National Oceanic and Atmospheric Administration (NOAA)
Kris McFadden, Village Coastal Zone Management Intern - University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS)

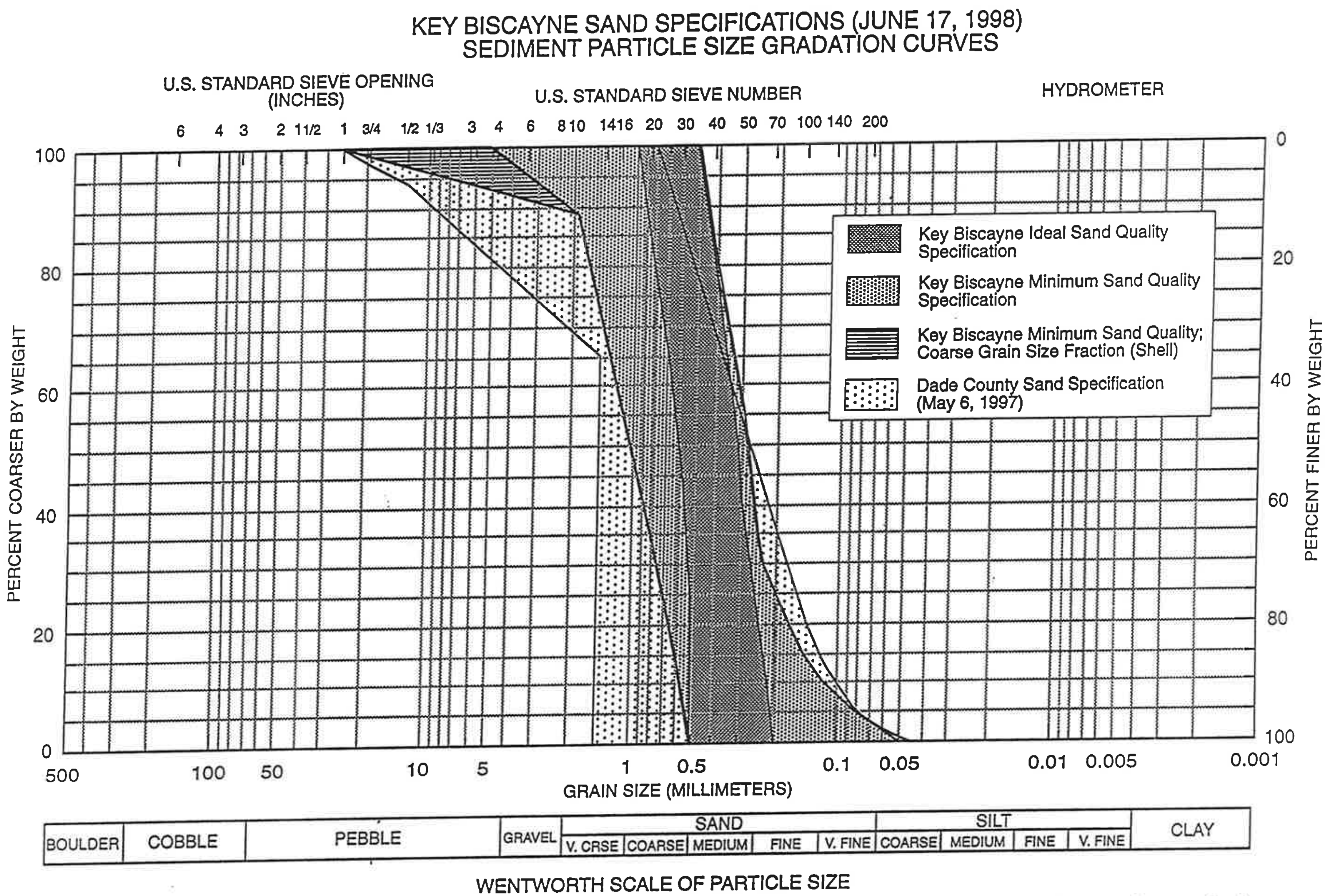
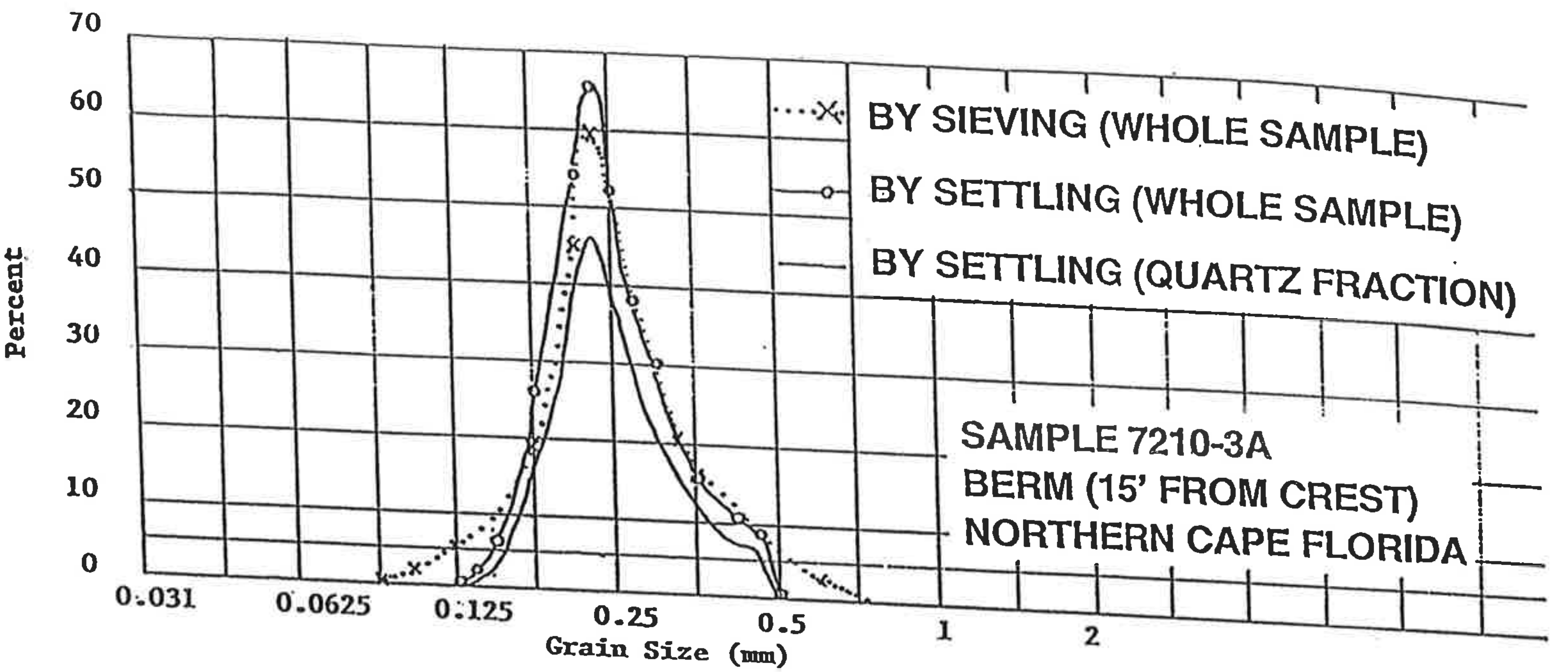


Figure 1. Graphical depiction of sand quality specifications for the ocean beach of Key Biscayne according to this resolution. The grain size range represented by the black filled area is the ideal sand to be used in future renourishments (no material finer than 0.2 mm, less than 50% coarser than 0.5 mm, and no material coarser than 1 mm). The fine dot pattern represents the grain size range of minimum quality sand for Key Biscayne (less than 5% of material finer than 0.08 mm, less than 25% finer than 0.2 mm, less than 10% coarser than 1 mm, and no rock aggregate particles coarser than 5 mm). The line pattern (upper left) shows up to 5% fraction in the minimum Key Biscayne sand specification that may consist only of shells or shell fragments no coarser than 3 cm. The Miami-Dade County sand specifica ı as of May 6, 1997 is shown by the widely spaced dot p‑ ern.

Figure 2.
GRAIN SIZE OF NATURAL BEACH SAND ON KEY BISCAYNE



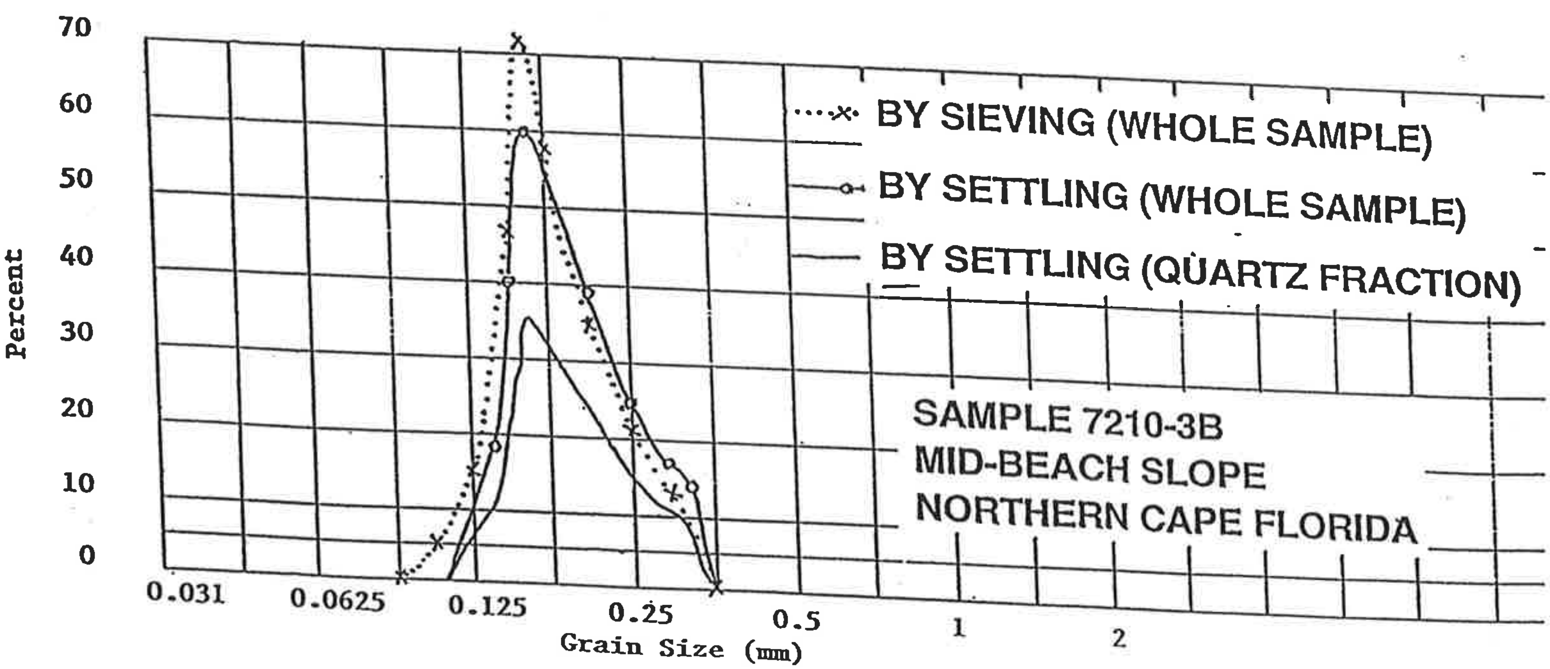
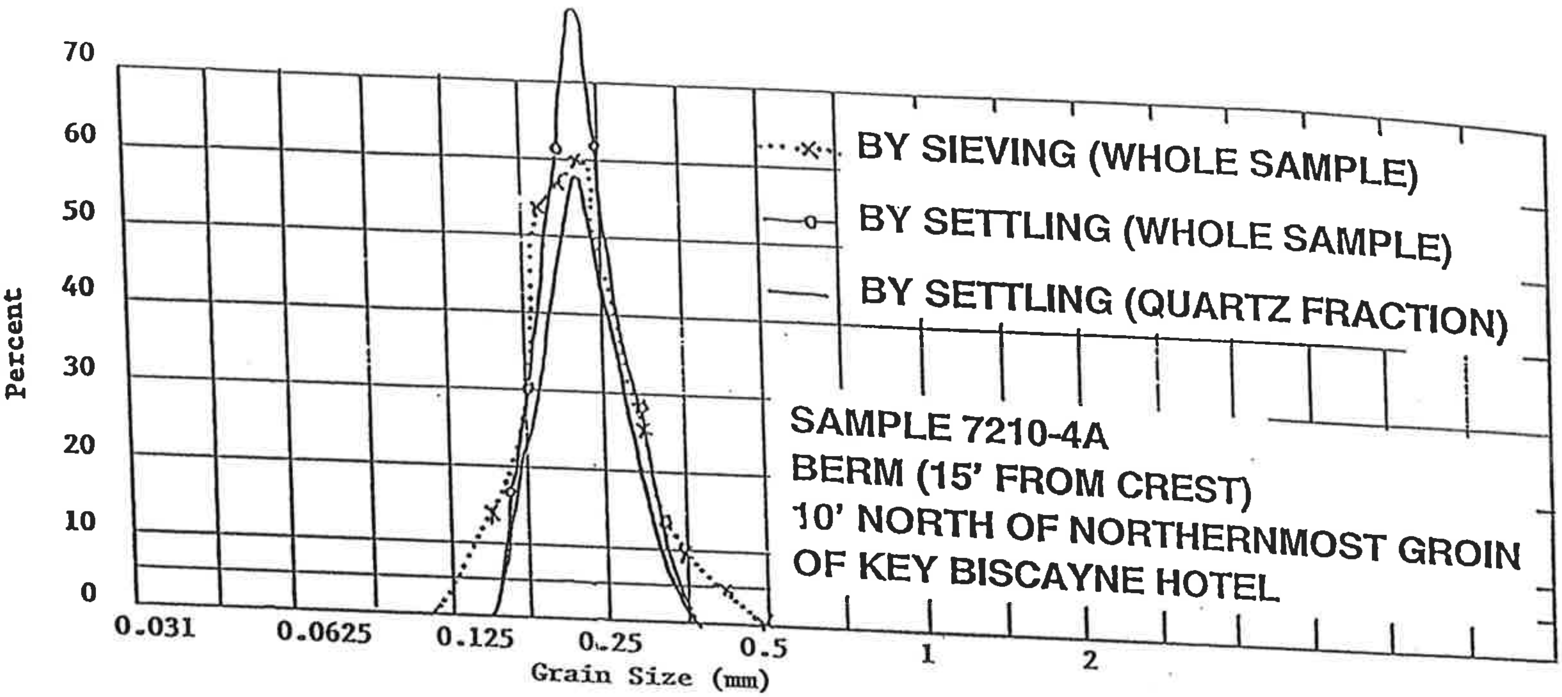
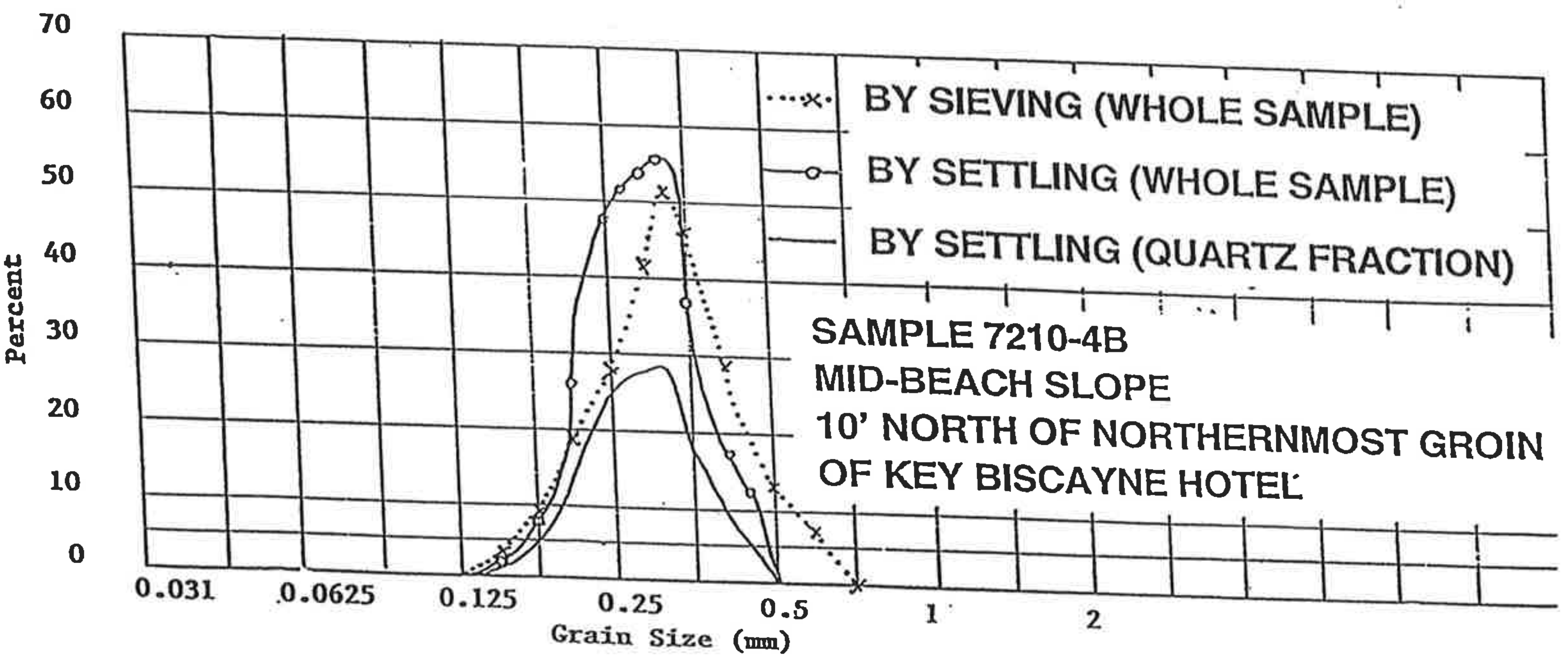


Figure 3.
GRAIN SIZE OF NATURAL BEACH SAND ON KEY BISCAYNE





EXECUTIVE SUMMARY

LONG RANGE BEACH NOURISHMENT PLAN

for

THE VILLAGE OF KEY BISCAYNE, DADE COUNTY

Purpose: This report presents a long-range beach nourishment plan to address the eroded shoreline along the Village of Key Biscayne, Dade County, Florida. This proposed project represents the first planned nourishment since the 1987 beach restoration project which placed a reported 420,000 cubic yards of sand from monuments R-101 to R-108.

Influence of Government Cut: This proposed nourishment will help to mitigate the long-term downdrift impacts associated with Government Cut to the north. The construction of this navigational inlet in 1904 caused significant erosion along Key Biscayne, Virginia Key, and Fisher Island as determined by the historical mean high water shoreline data. The most significant long-term shoreline erosion has occurred within the Village and near the tip of the Island with both of these locations eroding more than 400 feet by 1945.

Wave Focusing Effects: The shallow littoral sand platform that borders much of Key Biscayne and Virginia Key is largely absent along the Village shoreline making this area much more vulnerable to wave impacts. A numerical model study of the refraction/diffraction effects based on the nearshore and offshore bathymetry showed that the focusing of nearshore wave energy may be influenced by submerged bathymetric features several miles offshore. The results, in particular showed wave energy focusing occurring along the Village shoreline under northeast (winter), east, and southeast (summer) wave conditions in concurrence with the known erosional "hot spots."

Longshore Sediment Movement: Based on the results of the refraction/diffraction wave analysis, the longshore movement of sediment was examined using the energy flux of the breaking waves in the surf zone. The resulting southward littoral movement associated with the dominant northeast and east wave conditions suggest that the total annual net drift is predominantly towards the south. An average erosion rate of approximately 12,000 cubic yards per year occurring since the 1987 fill project was established along the Village shoreline based on examination of the April 1996 survey data. This corresponds to a total loss of approximately 107,000 cubic yards from the Village since the 1987 beach fill.

Beach Nourishment Design: The design of the beach fill template was developed based on the historical erosion rate (based on performance of 1987 fill), critical areas of erosion, location of nearshore seagreasses, and projected nourishment interval. It was determined that a design based on the footprint of the 1987 project would address the above considerations while potentially simplifying the permitting process, since this design essentially represents a restoration of the beach and dune to the pre-existing conditions accurately specified by the 1987 design. The proposed nourishment design, as of 1997, consists of approximately 120,000 cubic yards of fill placed from Commodore Club, approximately 350 feet south of R-101, to the Towers, 500 feet south of R-107, with a berm height of +9 feet NGVD and slope of 1V:14H. Nourishment life is expected at 10 years.

Storm Protection: Potential benefit from increased storm protection of the proposed fill was examined using the same storm surge and numerical model implemented by Florida DEP in establishing the statewide Coastal Construction Control Lines (CCCL). Results show that with the proposed fill in place, the landward limit of the erosion may be reduced by approximately 90 feet at the Sands Condo (monument R-105) under a statistical 100-year storm event. This reduction in the landward encroachment may represent a substantial benefit through reduced undermining and wave impact on upland structures.

Sand Sources: Due to the moderate quantity of sand needed for this project, no clear cost advantages exist between the potential offshore, upland and foreign sources. However, both offshore dredging and imported foreign sources may involve more complicated permitting requirements due to the need for additional environmental, monitoring, and/or geotechnical, archaeological investigations. Numerous upland sand sources are available throughout south and central Florida mines, many of these possessing excellent quality and compatibility. Material and trucking costs of these upland sources ranges from about $13.00 to $17.00 per cubic yard with in-place costs estimated at $16.00 to $20.00 per cubic yard. Total duration of the beach construction utilizing an upland sand source is estimated at 10 to 14 weeks.

Permitting Requirements: Permitting processing is currently underway and is expected to reach completion by spring 1999. Prior to the construction, extensive field investigations will be required including surveying of the nearshore/offshore topography/bathymetry and environmental resource mapping of nearshore seagreass and hardbottom areas to address the Environmental Impact Assessment (EIA). In general, long-term physical and environmental monitoring will be required, annually for a 5-year duration after the construction.

Costs/Funding: Total estimated cost for the proposed nourishment is $2.67 million, including construction, engineering, design, permitting, and monitoring. Currently, chances for receiving Federal funding is considered to be very small since this is not an existing authorized project. The Village may be eligible for State funding up to 37% of the total costs, or approximately $988,000. The County may potentially fund the entire non-state cost of approximately $1.68 million based on the County's funding of beach projects at other local municipalities. Further consultation between the Village and Dade County is recommended. The annual amortization cost for local share will be $330,000 over the next 50 years for a total of five beach nourishment projects.

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1.0 - INTRODUCTION

1.1 Authorization

Pursuant to Resolution No. 96-36 (Appendix F), Coastal Systems International, Inc. (Coastal Systems) was authorized by the Village of Key Biscayne (Village) for professional services in preparing a Long-Range Beach Nourishment Plan for the Village shoreline at Key Biscayne located in Dade County, Florida (Figure 1.1).

1.2 Purpose

The purpose of this report is to present a long-range beach nourishment plan to address the severely eroded shoreline along the Village of Key Biscayne. This particular region of central Key Biscayne has historically experienced the highest erosion rates on the island. Based on the 1987 U.S. Army Corps of Engineers (USACE) beach fill for this area compared to recent 1996 Dade County profile surveys, the project beach has eroded approximately 70 feet at The Sands (monument R-105) representing an average erosion rate of approximately 8 feet per year at this location.

This proposed project, located approximately between DNR monuments R-102 and R-108 (Figure 1.2), is intended to eliminate the "hot spot" erosion currently existing in the vicinity of monuments R-103 and R-105 as well as providing for increased storm protection to the upland hotels and multifamily/commercial developments. This project will also help to mitigate the long-term downdrift impacts associated with Government Cut which creates a complete littoral barrier for these islands to the south.

1.3 Background

Key Biscayne is the southernmost and largest of the natural sandy barrier islands lying south of Miami Beach and Government Cut. These series of barrier islands including neighboring Virginia Key and Fisher Island are separated by tidal inlets Bear Cut, Norris Cut, and Government Cut connecting north Biscayne Bay to the Atlantic Ocean. Sands Key and Elliott Key are located approximately 10 miles south of Key Biscayne.

The Village of Key Biscayne lies within the central and most developed part of Key Biscayne comprising approximately 1.2 miles of the total Atlantic shoreline. Dade County's Crandon Park is located to the north with nearly 2 miles of Atlantic shoreline and Bill Baggs Cape Florida State Recreation Area is to the south comprising approximately 1.2 miles of Atlantic shoreline.

Historically, with the urban development of the Miami area, Key Biscayne, Virginia Key, and Fisher Island have all been expanded westward through the filling of dredge spoil material. By the early 1930's, much of the western mangrove habitat along Key Biscayne was destroyed by this fill construction (Flynn, et al, 1991). Despite these significant manmade changes occurring in this region over the last century, all of these islands represent portions of naturally existing shoreline.

Due to the combined wave and current influences and the diverse character of the region, different shoreline stabilization approaches have been utilized for different segments of these project shorelines. These approaches have included hard structures such as terminal groins and T-head groins, that have been used at both Fisher Island and Virginia Key, and beach nourishment without structures such as used on Key Biscayne in 1987.

The first shoreline nourishment project dates back to 1969 when 196,300 cubic yards of sand was placed in Crandon County Park on Key Biscayne and 176,800 cubic yards of sand was placed on the Virginia Key shoreline (Figure 1.3). Subsequent rapid erosion of the beach fill from Virginia Key resulted in the 1974 construction of 13 granite groins in combination with 110,000 cubic yards of sand placed along the northern 5,000 feet of shoreline from monuments R-79 to R-84.

A study was initiated in September, 1971 to determine the need for beach erosion control and shore protection measures along the 4.4 miles of shoreline of Key Biscayne. This study was in response to a request from Metropolitan Dade County (local sponsor) pursuant to Section 103a of the River and Harbor Act of 1962. From April to June of 1987, a total of approximately 420,000 cubic yards of sand was placed in the Village of

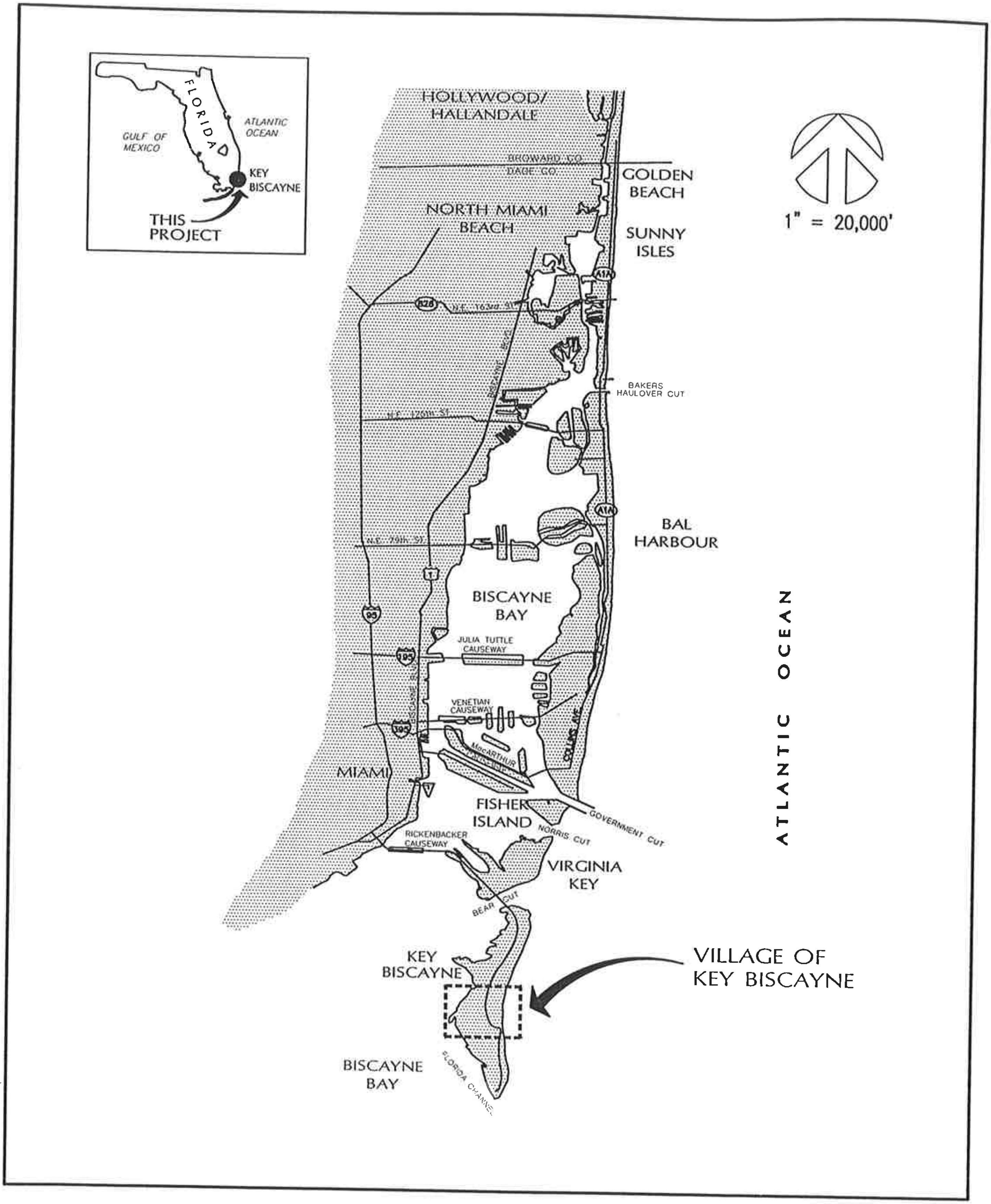

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FIGURE 1.1
LOCATION MAP

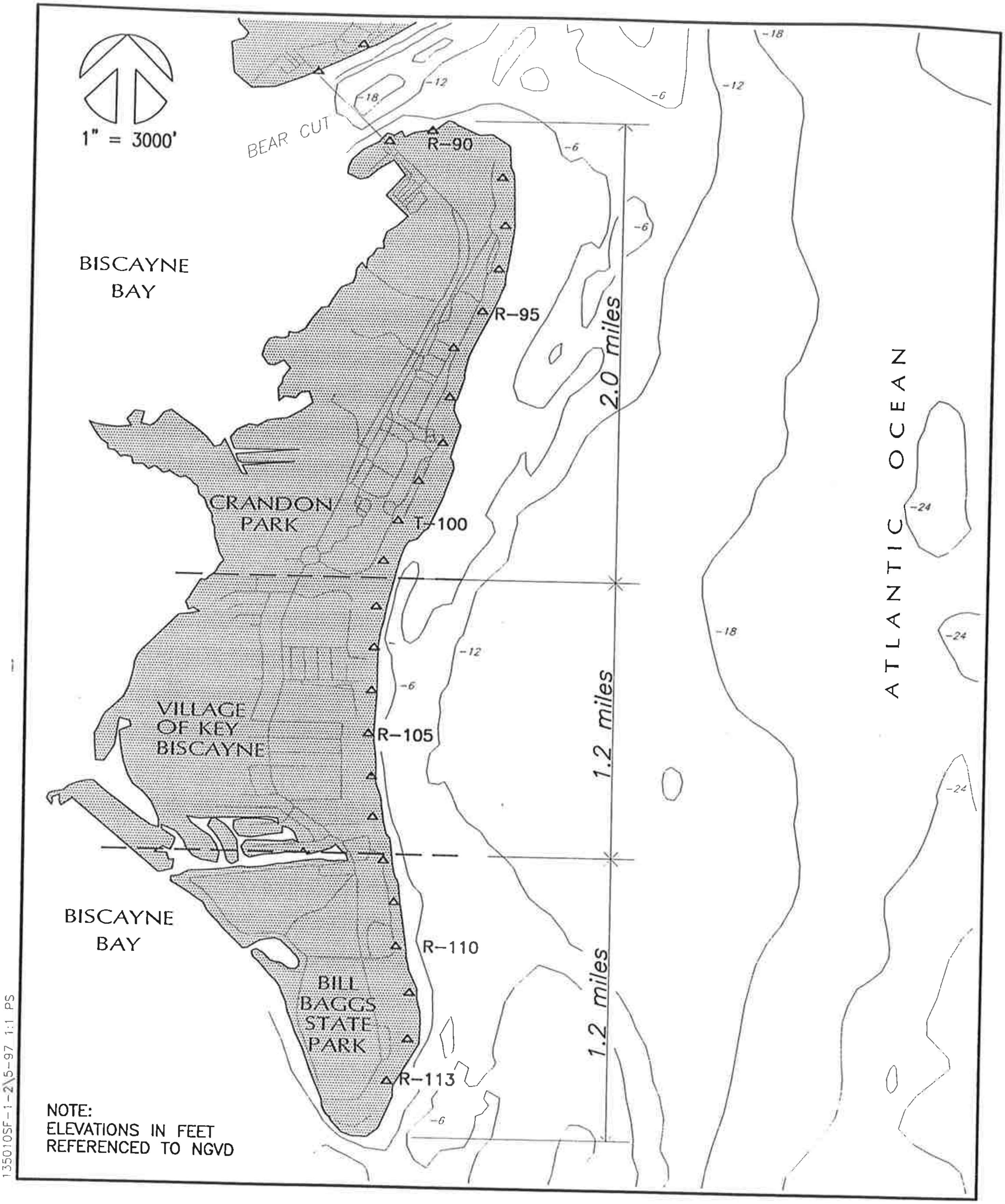
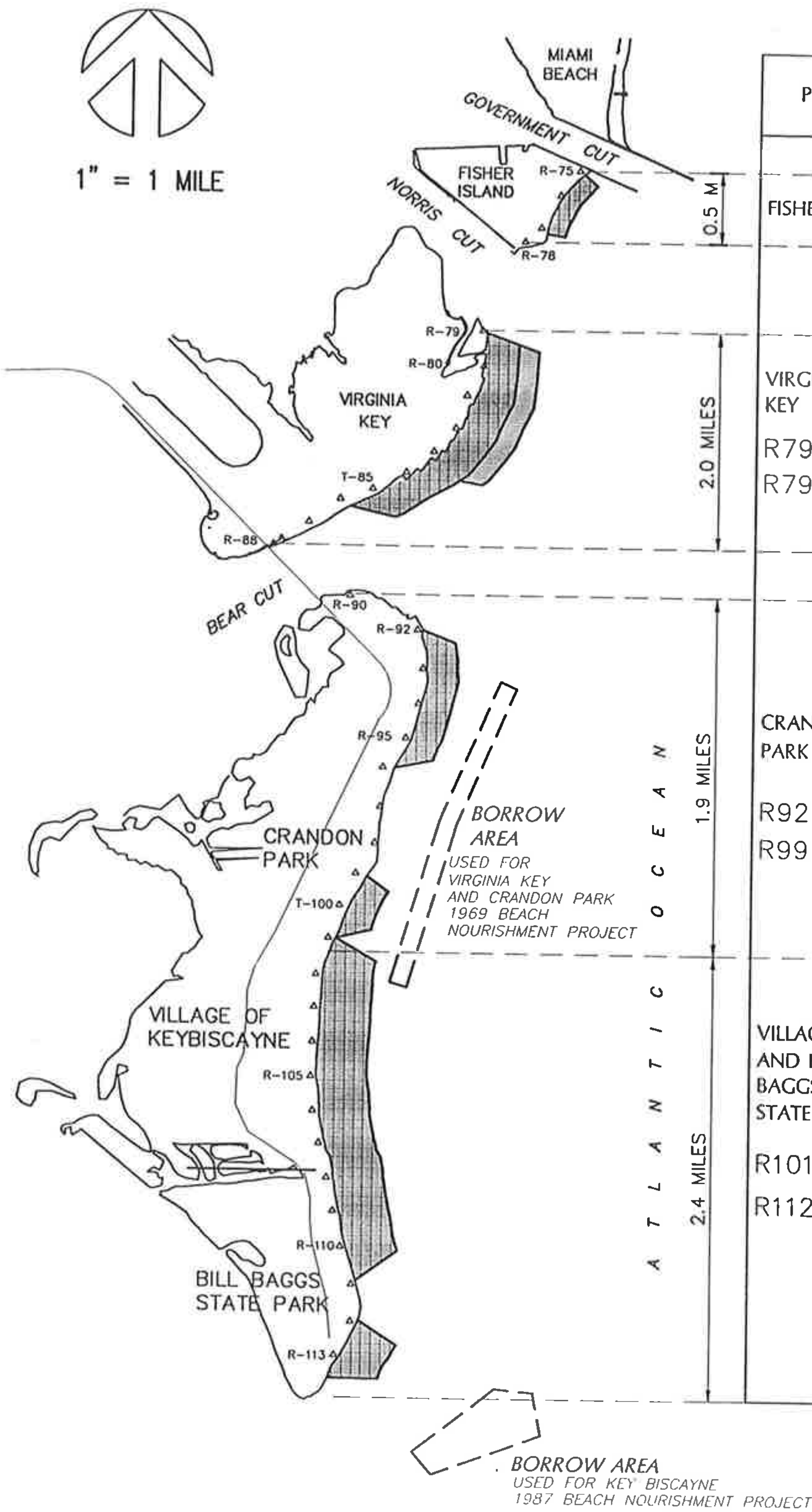


FIGURE 1.2

VICINITY MAP



PROJECT	YEAR	VOLUME (CU.YD.)
FISHER ISLAND	1991	25,000
VIRGINIA KEY		
R79 – R86	1969	176,800
R79 – R84	1974	110,000
CRANDON PARK		
R92 – R96 R99 – R101	1969	196,300
VILLAGE AND BILL BAGGS STATE PARK		
R101 – R111 R112 – R113	1987	420,000

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FIGURE 1.3
HISTORIC BEACH RENOURISHMENT

Key Biscayne (R-101 to R-108) and Bill Baggs State Park (R-108 to R-113) in combination with the reconstruction and extension of the terminal groin near the Cape Florida Lighthouse (USACE, 1996). This fill project was primarily in response to the long-term shoreline erosion occurring along the central and most developed part of the island, which in many locations had receded to the seawall/bulkhead (See Plate B1, Appendix B).

Fisher Island, to the north, was also nourished in April of 1991, as part of a privately funded restoration, with 25,000 cubic yards of aragonite sand from the Bahamas in combination with several enclosed groin systems along 2,060 feet of shoreline. These hard structures were specifically designed to preserve the beach fill under the predominant wave conditions (Olsen and Bodge, 1991).

1.4 Public Interest and Use

The re-establishment of the Village shoreline to a more natural condition through beach nourishment will provide many benefits supporting public interest and use. Some of the major benefits include:

Storm Protection: Beach nourishment can subvert or reduce significant structural damage to the adjacent upland coastal developments. Increased beach width and dune height can minimize damage from storm erosion including structural undermining of buildings and the associated scouring and impact loading from the onshore movement of waves. Increased storm protection benefits would contribute to property value appreciation. The potential economic savings associated with this reduction in storm damage is much more than the nourishment costs.

Recreational Benefit: Increased beach area will directly support an increased number of people and associated recreational activities. The beach related recreational activities may include sunbathing, swimming, walking, jogging, beach sports such as volleyball, and water sports such as sailing, snorkeling, etc.

Tourism: For the same recreational benefits listed above, the beach nourishment will help to support additional tourism to the area. This represents a potential increase in Village revenues as well as Federal, State and County tax revenues, as many tourists will be attracted to the hotels and resorts along the renourished beach. In addition, the Village shoreline is located between Crandon County Park to the north and Bill Baggs Cape Florida State Recreation Area to the south, both drawing a large number of tourists each year.

Environmental: Long-term beach erosion can produce substantial loss of habitat for sea turtle nesting. With the use of proper environmental constraints, nest relocation, and monitoring programs, periodic nourishments can help to maintain this nesting habitat. In addition, periodic nourishment can help to create and maintain a natural dune system that native plant species will be added back to the beach and dune system.

1.5 Scope

This report includes the following specific elements towards establishing a long range beach nourishment plan for the Village of Key Biscayne:

Physical Processes: The physical processes influencing the site are discussed in Chapter 2. This includes an investigation of the existing site characteristics, meteorological and oceanographic conditions, including wind, waves, tides, storm impacts, and downdrift influences from Government Cut. Potential for wave energy focusing along the shoreline is examined through the study of wave refraction and diffraction using the numerical model REFDIF (Dalrymple & Kirby, 1991). Shoreline and volumetric changes are investigated using USACE and DEP profile surveys and historical Mean High Water (MHW) surveys towards establishing the regional sediment movement.

Beach Design Alternative: Chapter 3 presents an engineering evaluation towards providing an effective beach nourishment design. Potential sand sources are investigated including offshore borrow sites, upland sand mines, and imported sources from the Bahamas and Turks and Caicos Islands. Environmental issues are addressed concerning the potential impact to seagrasses, sea turtle nesting, and other nearshore communities. Based on these analyses, a recommended plan is presented for maintaining a recreational beach along the Village of Key Biscayne.

Plan Implementation: The plan for implementing the recommended project is presented in Chapter 4. Permitting requirements are addressed as required by the Federal, State, and Local regulatory agencies. Construction, environmental monitoring, beach maintenance, and public education are included in this plan implementation. This plan also addresses potential sources for funding, eligibility, and the funding process. An economic analysis and schedule is presented for both short-term budgets and long-range management over a projected 50-year plan.

2.0 - PHYSICAL PROCESSES

2.1 General

This chapter examines the physical processes affecting the project shoreline at the Village of Key Biscayne. The general site characteristics and morphology of the region are reviewed, including the historical influence to the shorelines due to the construction of Government Cut. The available records and hindcast data for wind, waves, tides, currents, and hurricanes is reviewed towards evaluating their influence on the shoreline within the study area. The presence of wave focusing and potential "hot spots" is investigated through a wave refraction and diffraction analysis using the numerical model REFDIF. Shoreline and volumetric changes obtained from historic Mean High Water (MHW), DEP, and USACE profile surveys, combined with the results from the refraction and diffraction analysis, are used to investigate the regional sediment movement within the region.

2.2 Site Characteristics

2.2.1 Historic Formation

Key Biscayne is a low, sandy barrier island located at the end of the active littoral system along the Atlantic coastline. The barrier islands within this region, including Key Biscayne, Virginia Key, Fisher Island, and Miami Beach were formed by the gradual southerly migration of a sand spit over the last 4,000 years (Wanless, 1976). Sand composition in this area consists of both quartz and carbonate sediments overlying a coral limestone ridge (Key Largo Limestone Ridge) with the upper surface located 3 to 15 feet below MSL. This underlying bedrock ridge generally follows the seaward edge of the coastline but is absent along the central part of Key Biscayne. Examination of the bedrock and bathymetry contours in Figure 2.1, reveals that the presence of this underlying bedrock in combination with inlet effects, likely played a significant part in the formation of the upland and nearshore morphology of Key Biscayne. In particular, the apparent gap in the bedrock ledge immediately offshore of Key Biscayne coincides with the concave bay-shaped central shoreline and adjacent nearshore contours.

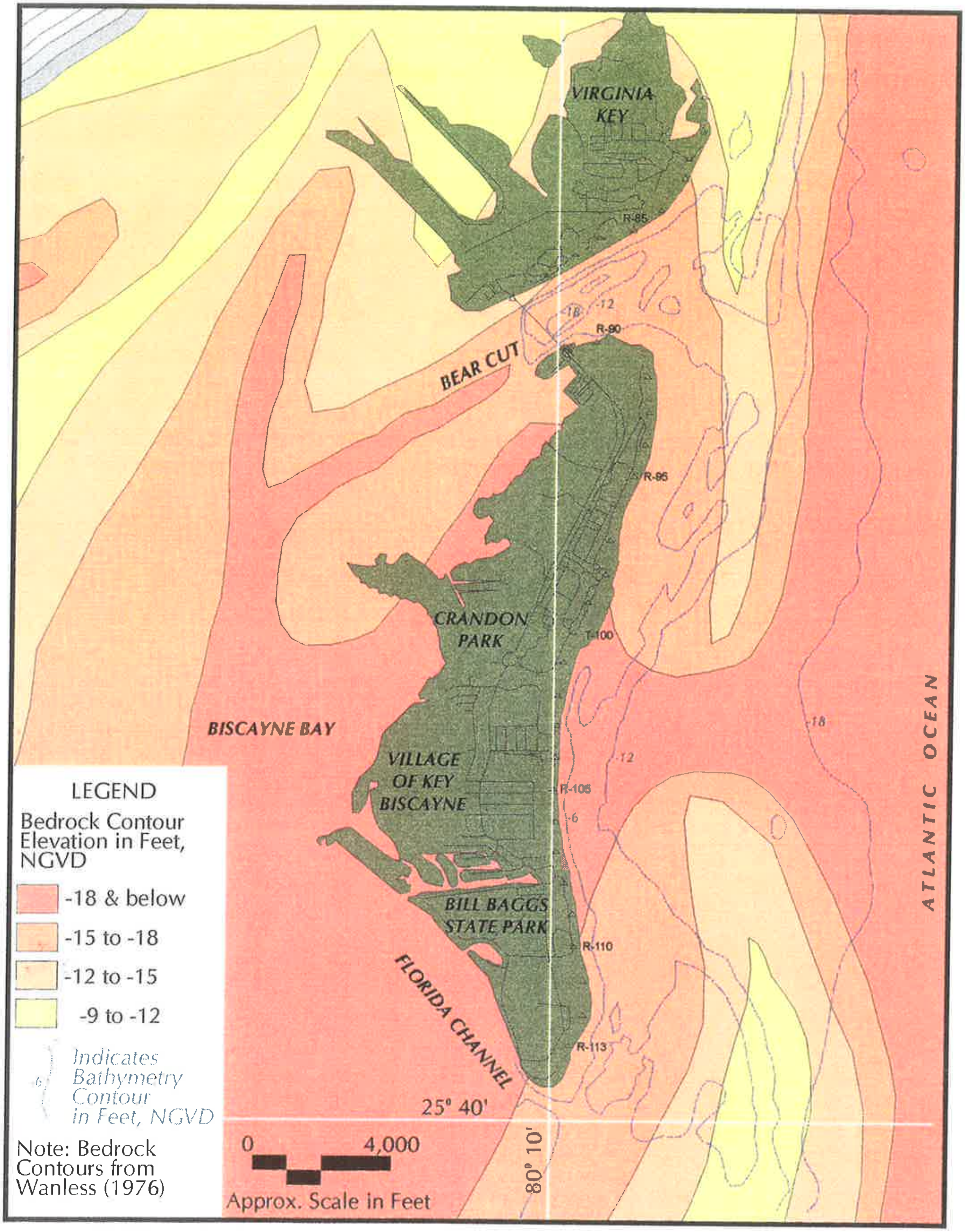

FIGURE 2.1

BEDROCK AND BATHYMETRY CONTOURS
KEY BISCAYNE AREA

In 1904, Government Cut was dredged through the southern extent of the barrier island (now known as South Miami Beach) forming Fisher Island to the south. Both Norris and Bear Cuts to the south represent naturally occurring tidal passes. Norris Cut is believed to have been formed as a storm wash-over during the Great Hurricane of 1835 (Chardon, 1976) while the existence of Bear Cut dates back at least to the early 1500's (see Site Photos B1-B4).

2.2.2 Nearshore/Offshore Conditions

Nearshore and offshore bathymetry features are illustrated in Figure 2.2 based on a merging of DEP profile survey data (Morgan & Eklund Surveyors, April 1996) in the nearshore region and NOAA Nautical chart contours and bathymetry offshore (NOAA Chart No. 11465, 1987). The nearshore areas consist of a wide, shallow littoral sand platform bordering the seaward shorelines out to approximately 5,000 feet offshore along the northern and southern portion of Key Biscayne and also along Virginia Key. This sand platform represents the extensive ebb shoal to the north and south of Key Biscayne associated with Bear Cut to the north and Cape Florida Channel (immediately south of Cape Florida State Park) to the south. Large beds of predominantly turtle and manatee seagrasses cover much of this nearshore sand platform transitioning to low-relief hardbottoms further offshore along the emergent bedrock. The extent of these nearshore/offshore hard bottom communities is delineated in Figure 2.3. The shallow nearshore sand platform is largely absent along the central portion of the island, causing the offshore contours to bend in close to the shoreline.

Along the north shoreline of Key Biscayne, the westward and southward movement of the Bear Cut ebb shoal has resulted in a significant sand spit within Crandon Park, that has been steadily building since about the 1940's, and is now a prominent and unique feature of the Key Biscayne shoreline (Site Photos A.7 - A.10). Further south within the Village, localized erosion at monument R-103 has created a distinct indentation in the shoreline (Site Photos A.11 - A.13). The beach width widens at R-104 with additional high erosion visible within the vicinity of R-105 (Site Photos A.14 - A.15). Between monuments R-107

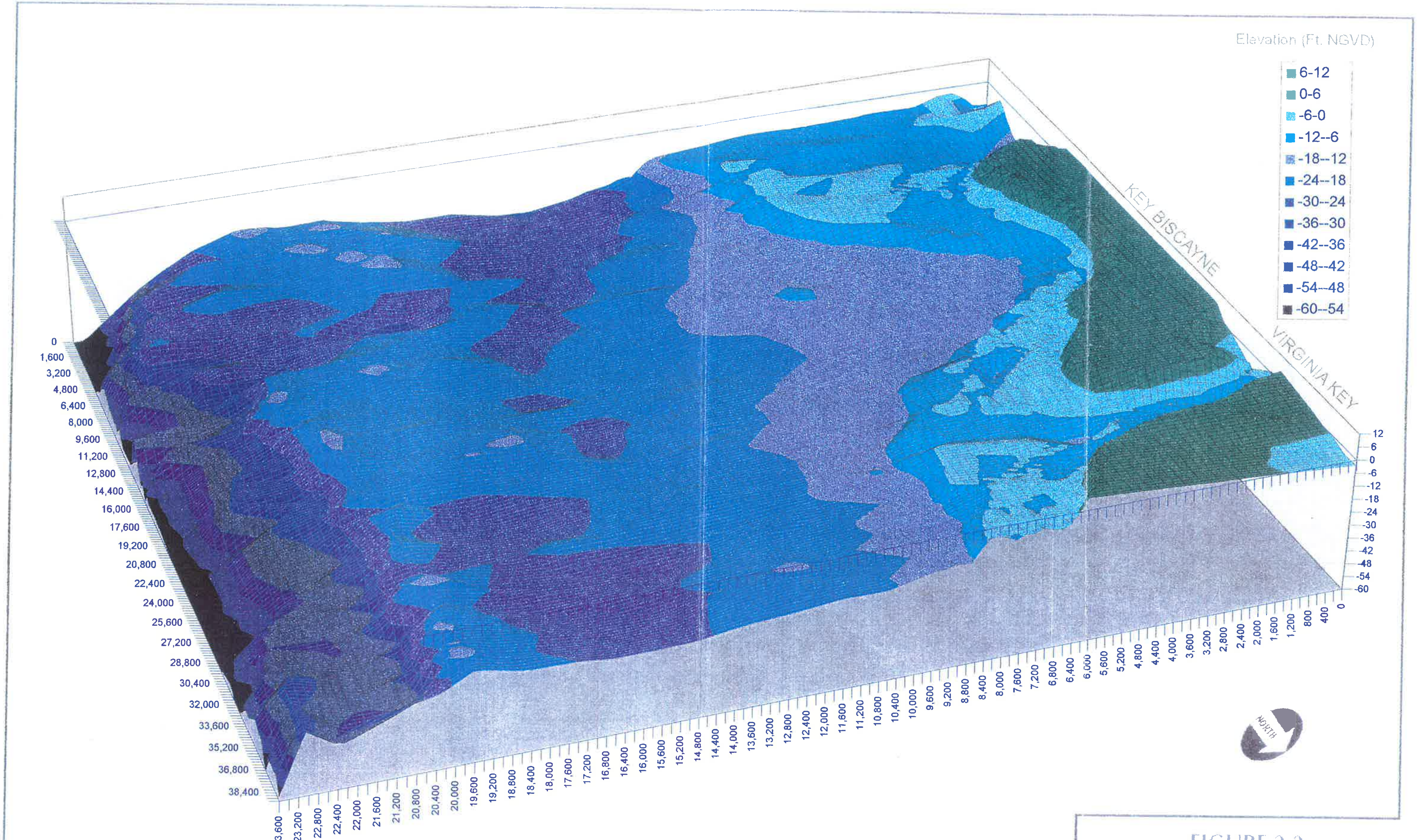

FIGURE 2.2
Nearshore and offshore bathymetry

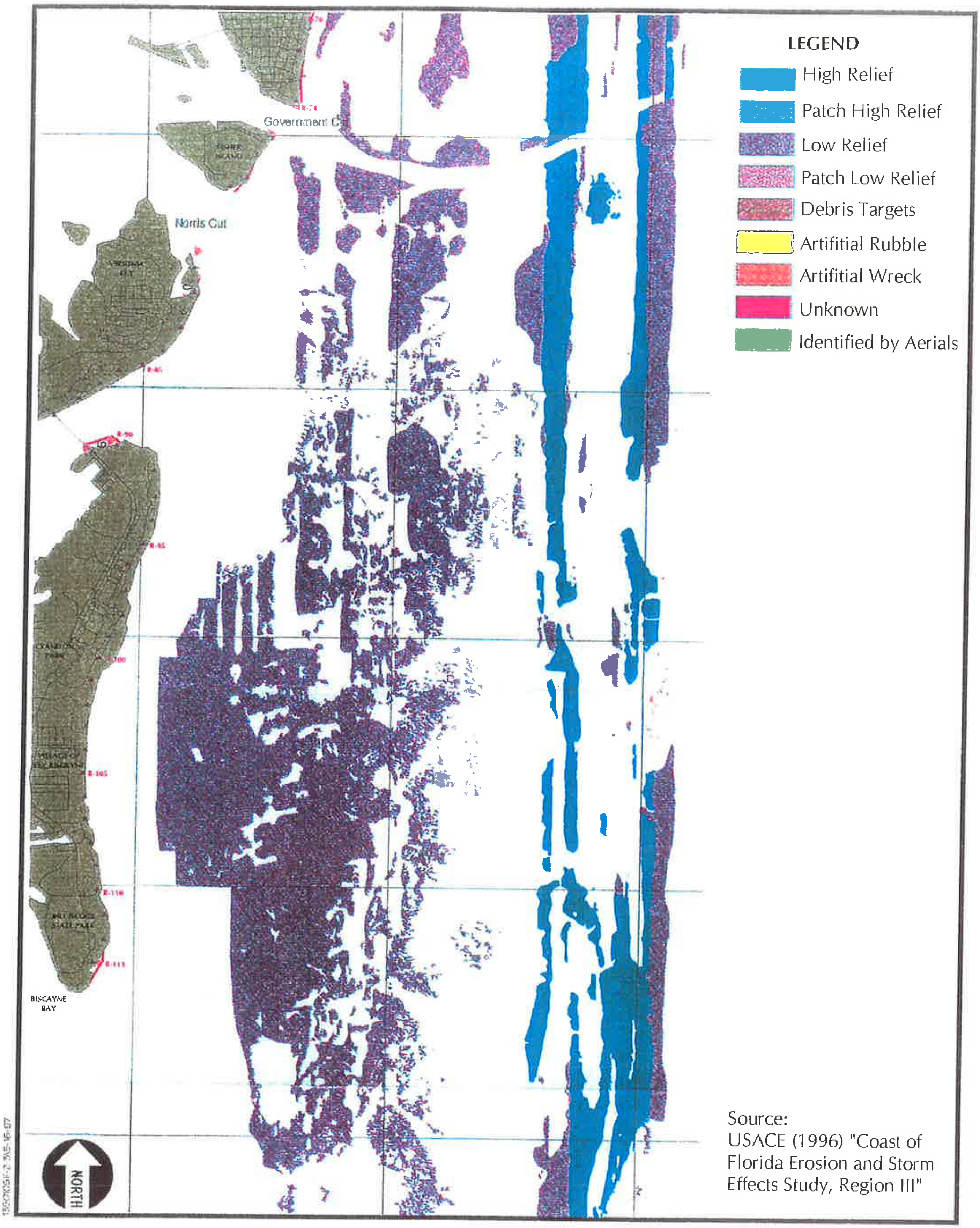

FIGURE 2.3
NEARSHORE AND OFFSHORE HARDBOTTOM COVERAGE

and R-108, a small sand spit may mark the spot where sand moves onshore from the south offshore ebb shoal (Site Photo A.16).

Offshore approximately 3.8 miles, lies an offshore reef line consisting of a high relief coral ridge approximately 16 to 30 feet below MSL. Beyond this ridge, water depths drop off quickly as observed by the bathymetry changes shown in Figure 2.2. Approximately 6.5 miles offshore, water depths reach 600 feet (100 fathoms) increasing to approximately 2,400 feet (400 fathoms) 30 miles offshore towards the island of Bimini (approximately 60 miles east of Key Biscayne).

2.2.3 Uplands

The uplands within Key Biscayne are relatively low with an average elevation of approximately +4 feet NGVD (USACE, 1996). Dune elevations are similarly low at +6 to +10 feet NGVD, indicative of the reduced nearshore wave climate which precludes the building of large dunes. Natural dunes and dune vegetation have been highly impacted within the Village due to the combination of nearshore upland development and a retreating shoreline. Natural dunes, however, are generally intact along the Bill Baggs State Park shoreline to the south and Crandon Park to the north.

Upland vegetation on Key Biscayne was drastically impacted by Hurricane Andrew in August 1992, which entirely destroyed the dense hammock of Australian Pine within Bill Baggs Park. The irradication of this non-native species allowed for recolonization of native vegetation through an extensive replanting program enacted by Dade County Resources Management (DERM) within Bill Baggs. Mangrove forests exist along the low-energy bay shoreline primarily within the undeveloped northwest corner of the island. A Wetland restoration, in progress, at Bill Baggs will add an additional mangrove habitat along the northwest shoreline of the Park south of the Village.

Upland development on Key Biscayne is primarily concentrated within the center portion of the island within the Village. Coastal development within the Village consists of hotels, resorts, and condominiums along the Atlantic shoreline, while businesses are located centrally, and residential communities towards the bay shoreline. Bill Baggs and Crandon Parks, for the most part, represent extensive undeveloped acreages.

2.2.4 Regional Influence of Government Cut

The most dramatic and rapid physical changes occurring to Key Biscayne, Virginia Key, and Fisher Island, in recent history, were due to the initial opening of Government Cut in 1904. The Atlantic shorelines of these barrier islands were significantly affected from this event as illustrated by the historic shoreline and contour changes shown in Figure 2.4. These changes are believed to have been due primarily to the abrupt deficit in the southward moving littoral supply, but may have also been influenced by a potential increase in the tidal prism within Biscayne Bay, causing increased current velocities through Bear and Norris Cuts.

Between the surveys of 1852 and 1919, the shoreline at Virginia Key receded by as much as 930 feet at some locations (DNR monument T-83) representing an estimated loss of over 1.5 million cubic yards of material. The shoreline along the newly created Fisher Island receded as much as 300 feet during this period until it was partially stabilized with the construction of a terminal groin near the south end of the island installed some time around 1927 (USACE, 1996). Key Biscayne, although less affected overall, showed a substantial recession of approximately 500 feet along the southern tip of the island. Additional shoreline erosion occurred along the central portion of the island with a loss of approximately 200 feet from R-100 to R-105 and approximately 100 feet from R-108 to R-110. These shoreline changes included adjacent accretional areas from approximately R-94 to R-99, R-106 to R-108 and R-110 to R-112.

After this initial shoreline recession, the coastline along Virginia Key showed a slower but continual erosion, particularly along the center portion of the coastline associated with the northeastern migration of Bear Cut (Figure 2.4). Due to the orientation of the southern coast of Virginia Key along this adjacent channel, the erosion along this 6,000 feet of southern shoreline is considered to be primarily current dominated. The shoreline retreats along the northern tip of Virginia Key is most likely a result of the littoral deficit

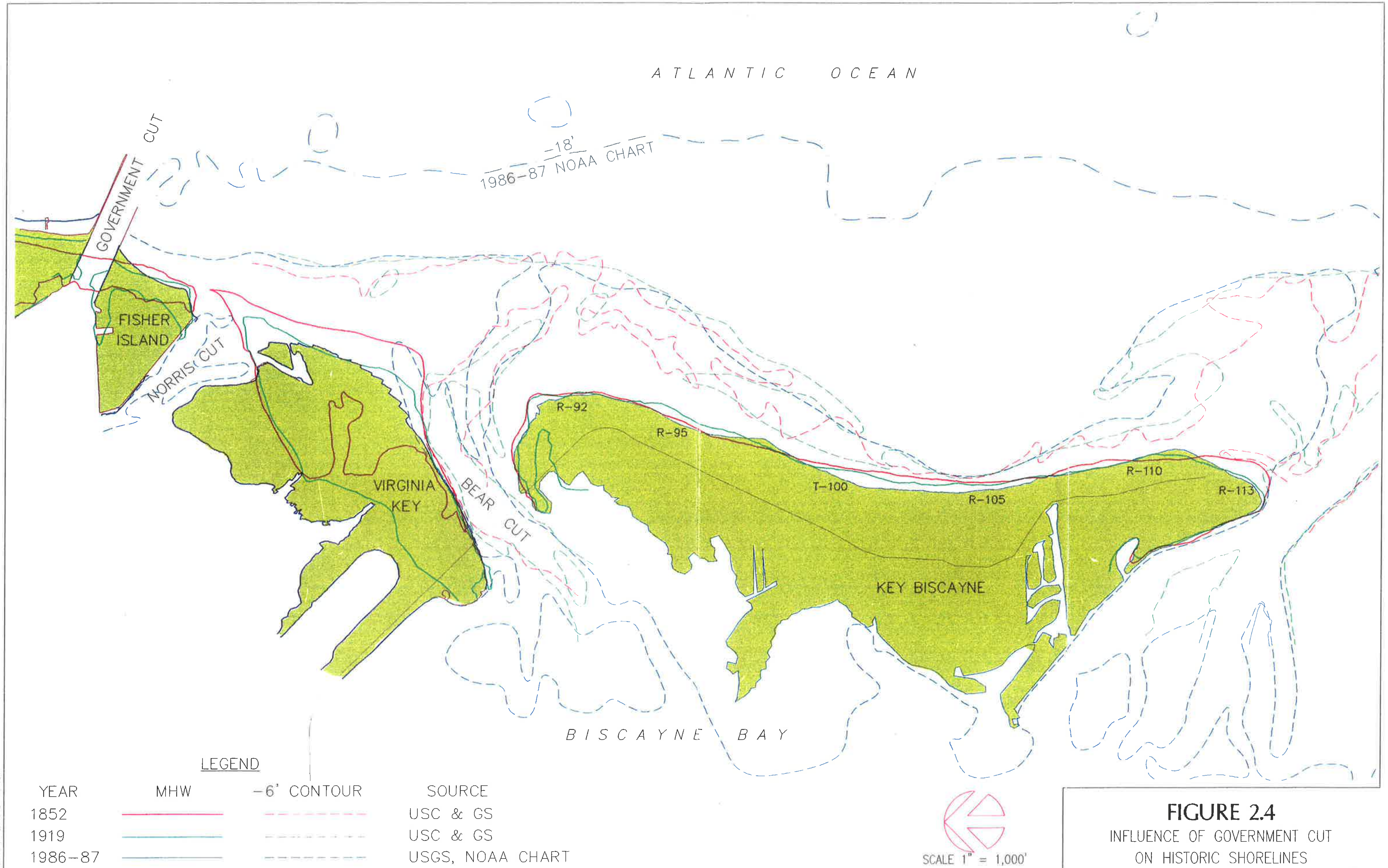

FIGURE 2.4
INFLUENCE OF GOVERNMENT CUT ON HISTORIC SHORELINES

due to Government Cut combined with the dominant northeastern waves and tidal currents through Norris Cut.

At Key Biscayne, the natural building of nearshore shoals along both the south and north shorelines and associated changes in the nearshore contours has resulted in a gradual reshaping of the coastline due to changes in wave refraction and sheltering effects. This reshaping has resulted in accretion along the north and south shorelines while the center portion of the island has shown a steady recession.

2.3 Meteorological & Oceanographic Conditions

2.3.1 Wind and Waves

The wave environment for this region is examined through the USACE Wave Information Study (WIS) hindcast data obtained at Station No. 8 (Lat: 25.8°, Long: 80.0°), located approximately 9 miles east of Virginia Key (Figure 2.5). This data is based on the results of an 18 year (1976-1993) hindcast study performed using a directional spectral wave hindcast model (WISWAVE 2.0, Hubertz, 1992). This eighteen years of meteorological information was compiled which, unlike previous hindcasts, includes tropical storms and hurricanes (Brooks, 1993).

The average hindcast wind and wave conditions at WIS Station No. 8 are presented in Figure 2.6 and Figure 2.7, respectively. The detailed wind and wave statistics are also presented in Tables 2.1 and 2.2 respectively. The winds at the project area blow predominately from the northeast to the southeast, occurring approximately 66 percent of the time with an average wind speed of 12.5 miles per hour. The easterly winds occur with a maximum percent of occurrence at 20.2% and at an average speed of 12.4 miles per hour.

The WIS data indicates that the long swell waves primarily occur from the northeast through north-northeast directions approximately 44 percent of the time, consistent with the movement of the predominant longshore transport to the south along Miami Beach. The expected significant wave heights from these directions generally range from 2.0 to 3.3 feet

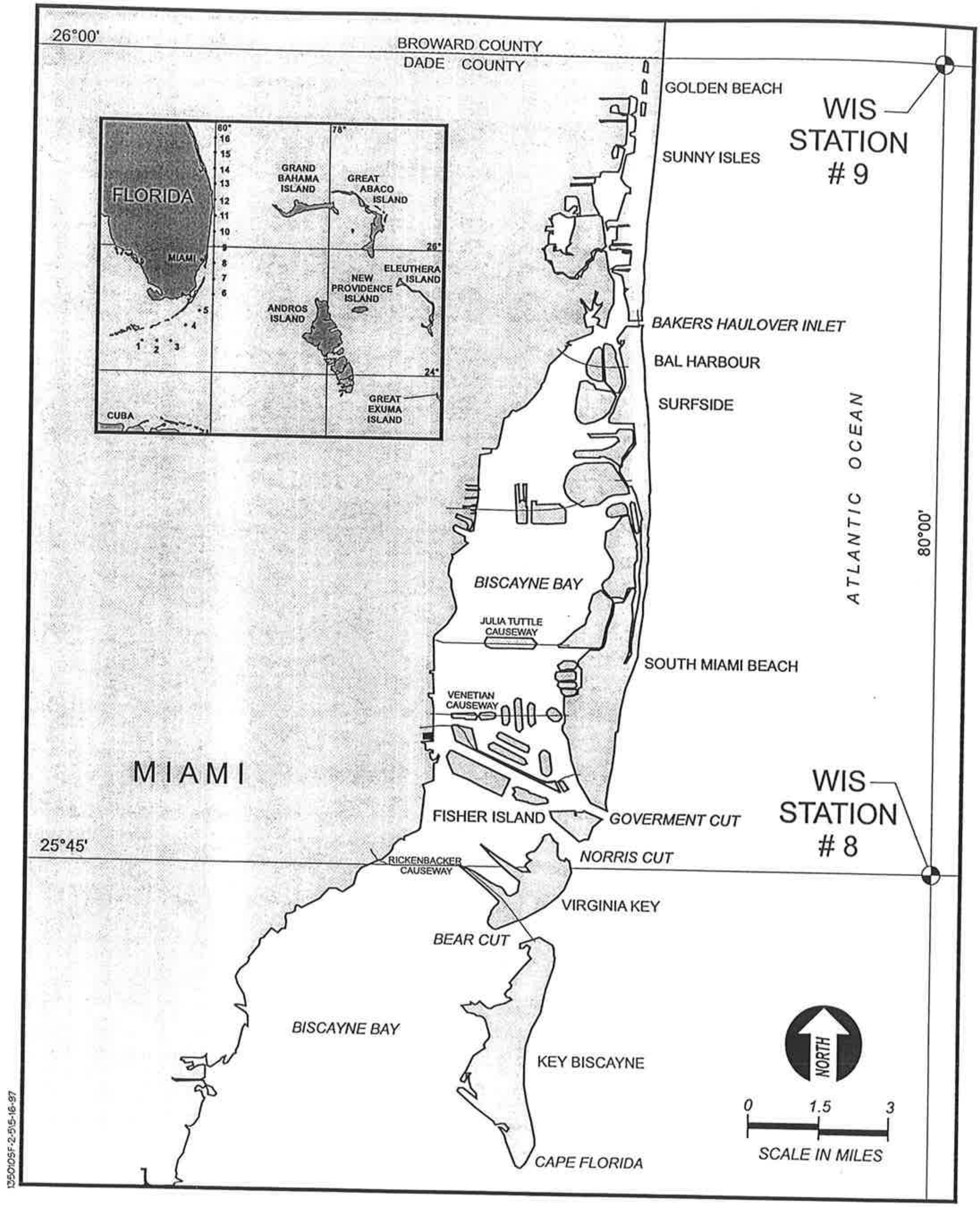

FIGURE 2.5

WIS ATLANTIC HINDCAST STATIONS OFFSHORE DADE COUNTY

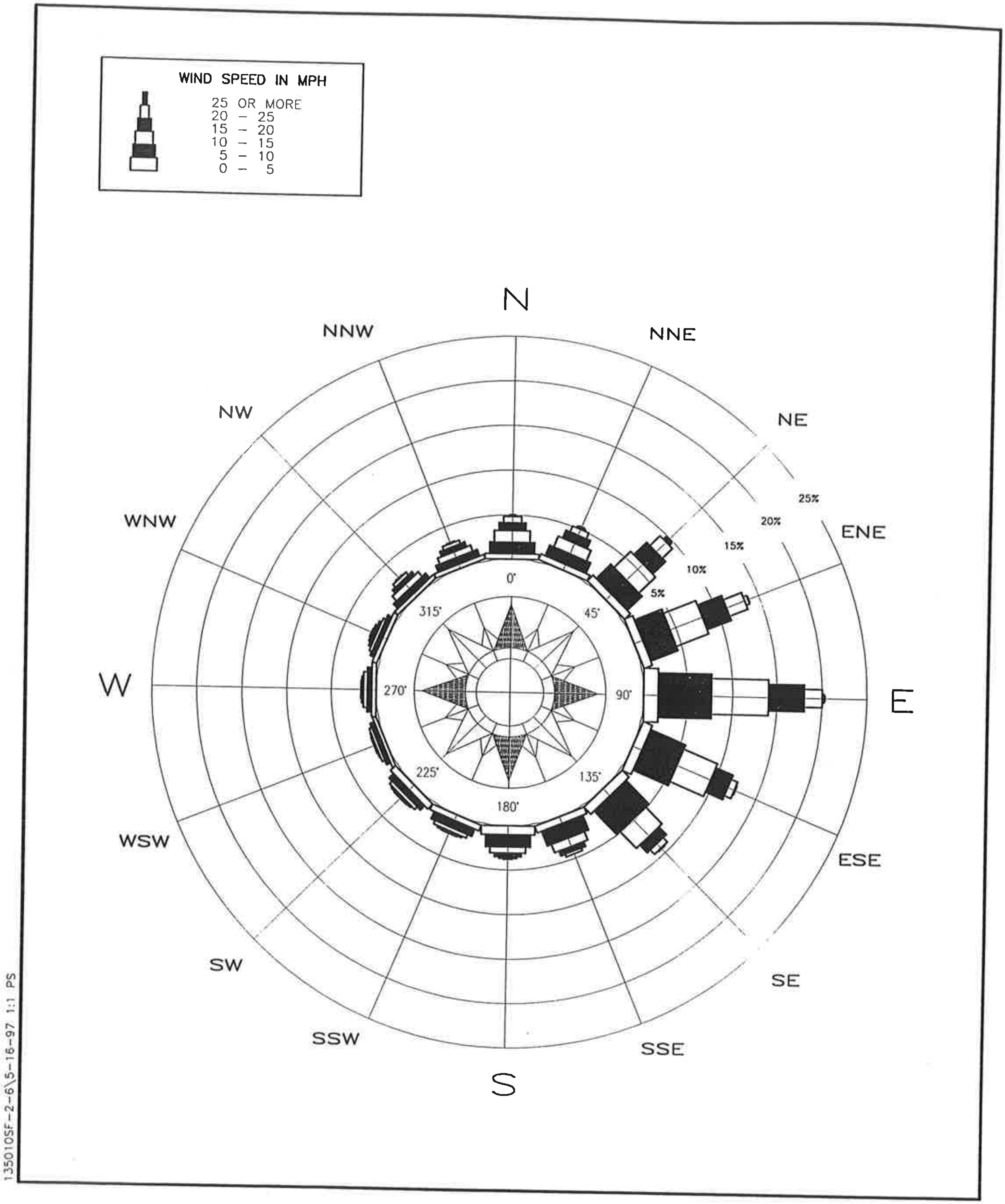

FIGURE 2.6

HINDCAST WIND CONDITIONS AT
WIS STATION No. 8 (1976–1993)

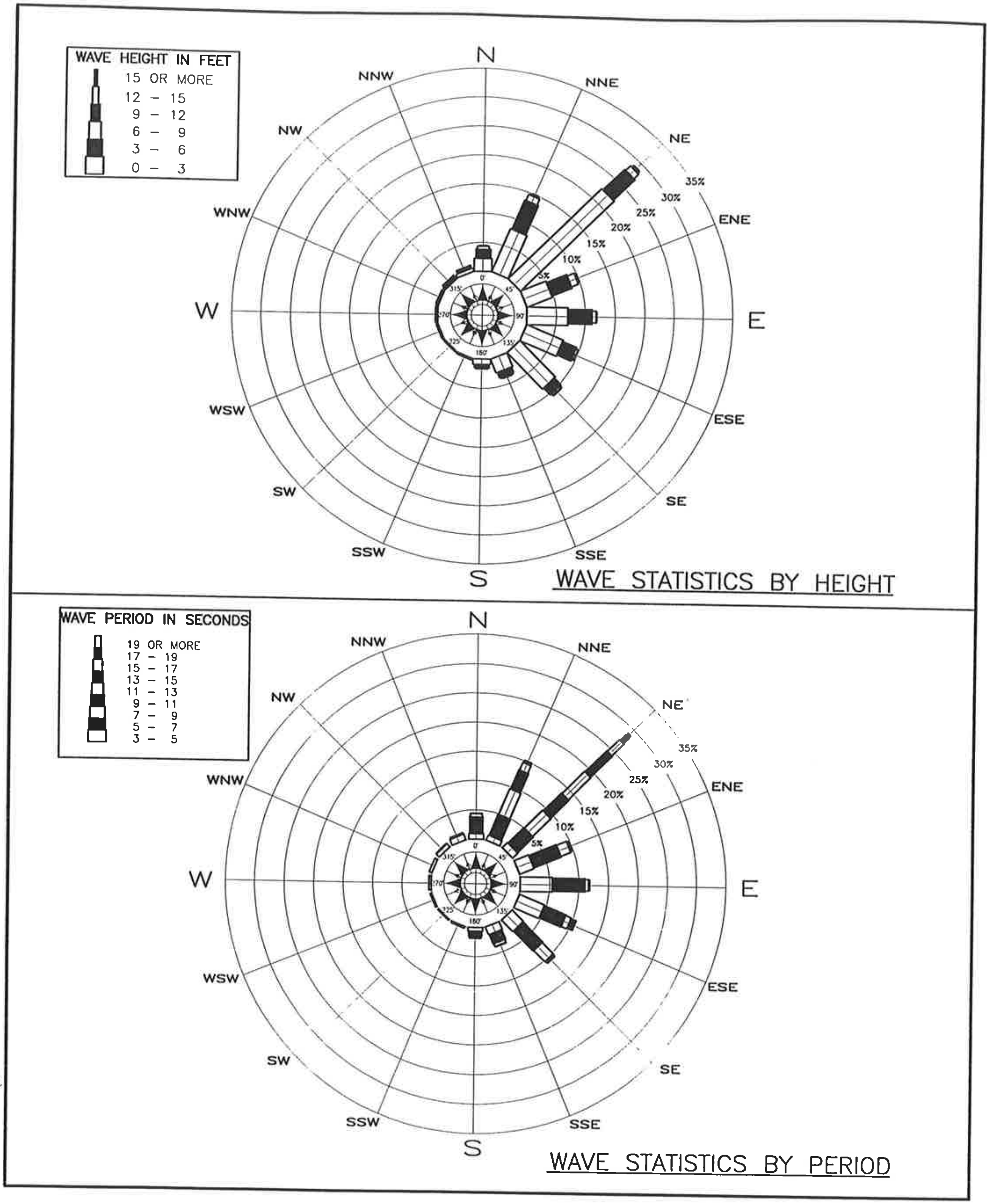

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FIGURE 2.7

HINDCAST WAVE CONDITIONS AT
WIS STATION No. 8 (1976–1993)

TABLE 2.1

AVERAGE WIND CONDITIONS

WIS STATION NO. 8

DIRECTION	WIND SPEED (mph)	PERCENT OF OCCURRENCE (%)
N	13.1	5.1
N-NE	13.0	5.2
NE	13.8	9.8
E-NE	13.6	13.7
E	12.4	20.2
E-SE	11.5	12.6
SE	11.0	9.5
S-SE	10.3	4.5
S	9.6	3.8
S-SW	9.0	2.3
SW	8.7	2.2
W-SW	9.3	1.5
W	9.7	1.8
W-NW	11.3	1.9
NW	12.3	2.9
N-NW	12.6	3.2

TABLE 2.2

HINDCAST WAVE CONDITIONS

WIS STATION NO. 8

DIRECTION	SIGNIFICANT WAVE HEIGHT, Hs (ft)	WAVE PERIOD, T (sec)	PERCENT OF OCCURRENCE (%)
N	3.9	5.5	4.5
N-NE	3.5	7.8	15.0
NE	2.6	10.7	29.0
E-NE	3.8	5.5	9.9
E	3.2	4.7	11.8
E-SE	2.8	4.8	9.7
SE	2.2	5.8	10.7
S-SE	3.0	5.3	3.9
S	3.6	5.2	1.8
S-SW	3.2	4.4	0.4
SW	2.9	3.9	0.2
W-SW	2.5	3.6	0.3
W	2.3	3.4	0.4
W-NW	2.9	3.7	0.5
NW	3.1	4.0	0.8
N-NW	3.2	4.1	1.2

with dominant periods from 6 to 12 seconds. Inspection of Figure 2.7 reveals that the northeast sector is affected by a broad range of wave conditions with wave energy distributed over a relatively large frequency range with wave periods from 5 to 17 seconds. Long period swells generated by distant storms or open ocean prevailing winds, are limited by the presence of the Bahama Banks and Cuba. Large swells generated by Northeasters reach the shoreline of Dade County generally from the north-northeast, through a narrow window located between West Palm Beach and the Western edge of the Bahama Banks.

2.3.2 Tides and Currents

Tides at this region are semidiurnal with a mean range of 2.5 feet and spring range of 3.0 feet. Tidal currents at Government Cut as reported by NOAA (1996) are 3.5 feet per second during flood tide and 3.0 feet per second during ebb. Maximum tidal currents at Norris Cut and Bear Cut are reported at 2.2 feet per second and 4.0 feet per second, respectively (USACE, 1972).

The most significant offshore current in this region is the Florida Current which is a portion of the Gulf Stream flowing through the Florida Straits. The Florida Current flows northward approximately one mile offshore with only intermittent reversals due to eddies that may spin off the western edge of the current. Its velocity varies from a low of 17 miles per day (1 foot per second) in November, to a high of 37 miles per day (2.3 feet per second) during the month of July.

Nearshore wave and wind generated currents vary depending on the shoreline alignment, nearshore bathymetry and the wave and wind climate at the time. These currents have a very significant influence on the erosion and accretion patterns along the shoreline since they ultimately drive the transport of sediment along the beach.

2.3.3 Hurricanes

A Hurricane is defined as a severe tropical, cyclonic storm with maximum sustained 1 minute mean surface winds of at least 64 knots (74 mph) and low barometric pressure that results in the rise of water levels (storm surge) and the development of large storm waves that can cause severe damage to coastal communities. Hurricanes generally originate in the tropical and subtropical latitudes of the Atlantic Ocean in the warm waters north of the equator. Characteristics of hurricanes are low barometric pressure, sustained surface winds over 64 knots (74 mph), heavy rainfall, large waves and storm surges. The classification of hurricanes by storm intensity (Saffir and Simpson, 1974) is shown in Table 2.3.

Hurricanes impacting the U.S. East Coast and Caribbean Islands primarily occur from June to late October. The strongest hurricanes typically develop in the Atlantic Ocean during the months of August and September. These storms generally follow a westward path with an eventual recurvature towards the north. Depending on the path of this recurvature, these late summer hurricanes can potentially impact a large area including the Caribbean Islands, the eastern seaboard ranging from Florida to Maine, and the coastal states along the Gulf of Mexico.

Historical records compiled over the past 123 years indicate that there have been approximately 30 hurricanes of Category 1 strength or greater (sustained winds greater than 74 mph) that have passed within a 50 nautical mile radius of Government Cut (Figure 2.8). Based on this history, we can expect a hurricane of Category 1 strength or greater to occur, on average, every 4.1 years passing within this 50 nautical mile radius.

Storm surges associated with the passage of hurricanes are a combined result of wind, barometric pressure, waves and normal astronomical tides. The hurricane of 1926 (September 18), passing approximately 15 miles south of Key Biscayne, produced a storm surge reported at 9.1 feet MLW (8.1 feet NGVD) at Key Biscayne and 7.1 feet MLW (6.1 feet NGVD) along Miami Beach (USACE, 1962). During Hurricane Andrew (August 23, 1992), storm surges were reported as high as 10 feet NGVD along the Atlantic shoreline of Southern Dade County and 14 to 17 feet NGVD along the shoreline in Biscayne Bay (Hurricane Andrew Storm Summary, USACE, 1993). Storm surge from Andrew measured from high water marks at Key Biscayne ranged from 8.8 feet NGVD along the northern

TABLE 2.3

Classification of Hurricane Intensity
Saffir-Simpson Scale (Saffir and Simpson, 1974)

CATEGORY	WINDS (knots)	WINDS (mph)	PRESSURE (millibars)	PRESSURE (inches)	STORM SURGE ELEVATION (ft, MSL)	DAMAGE
1	64 - 83	74 - 95	> 980	> 28.9	4 - 5	Minimal
2	83 - 95	96 - 110	965 - 979	28.5 - 28.9	6 - 8	Moderate
3	96 - 113	111 - 130	945 - 964	27.9 - 28.5	9 - 12	Extensive
4	114 - 135	131 - 155	920 - 944	27.2 - 27.9	13 - 18	Extreme
5	> 135	> 155	< 920	< 27.2	18	Catastrophic

Damage Characteristics

Category

ONE — **Minimal:** No real damage to building structures. Damage primarily to unanchored mobile homes, trees and foliage. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.

TWO — **Moderate:** Considerable damage to shrubbery and tree foliage: some trees blown down; some roofing material, door and window damage to buildings. Considerable damage to vegetation, mobile homes and piers. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Marinas flooded. Small craft in unprotected anchorages torn from moorings.

THREE — **Extensive:** Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures. Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Mobile homes are destroyed. Some damage to roofing materials of buildings; some window and door damage . Some structural damage to small buildings. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain continuously lower than 5 feet MSL may be flooded inland 8 miles or more.

FOUR — **Extreme:** More extensive curtain wall failures with some complete roof structure failure on small residences. Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Major erosion of beach areas. Major damage to lower floors of structures near the shore. Terrain continuously lower than 10 feet MSL may be flooded, requiring massive evacuation of residential areas inland as far as 6 miles.

FIVE — **Catastrophic:** Complete roof failure on may residences and industrial buildings. Shrubs and trees blown down. Very severe and extensive damage to windows and doors. Some complete building failures with small utility buildings overturned and blown over or away. Major damage to lower floors of all structures located less than 15 feet MSL and within 500 yards of the shore line. Massive evacuation of residential areas on low ground within 5 to 10 miles of the shoreline may be required.

SOURCES: Doehring, et al. 1994; Neuman, et al. 1993

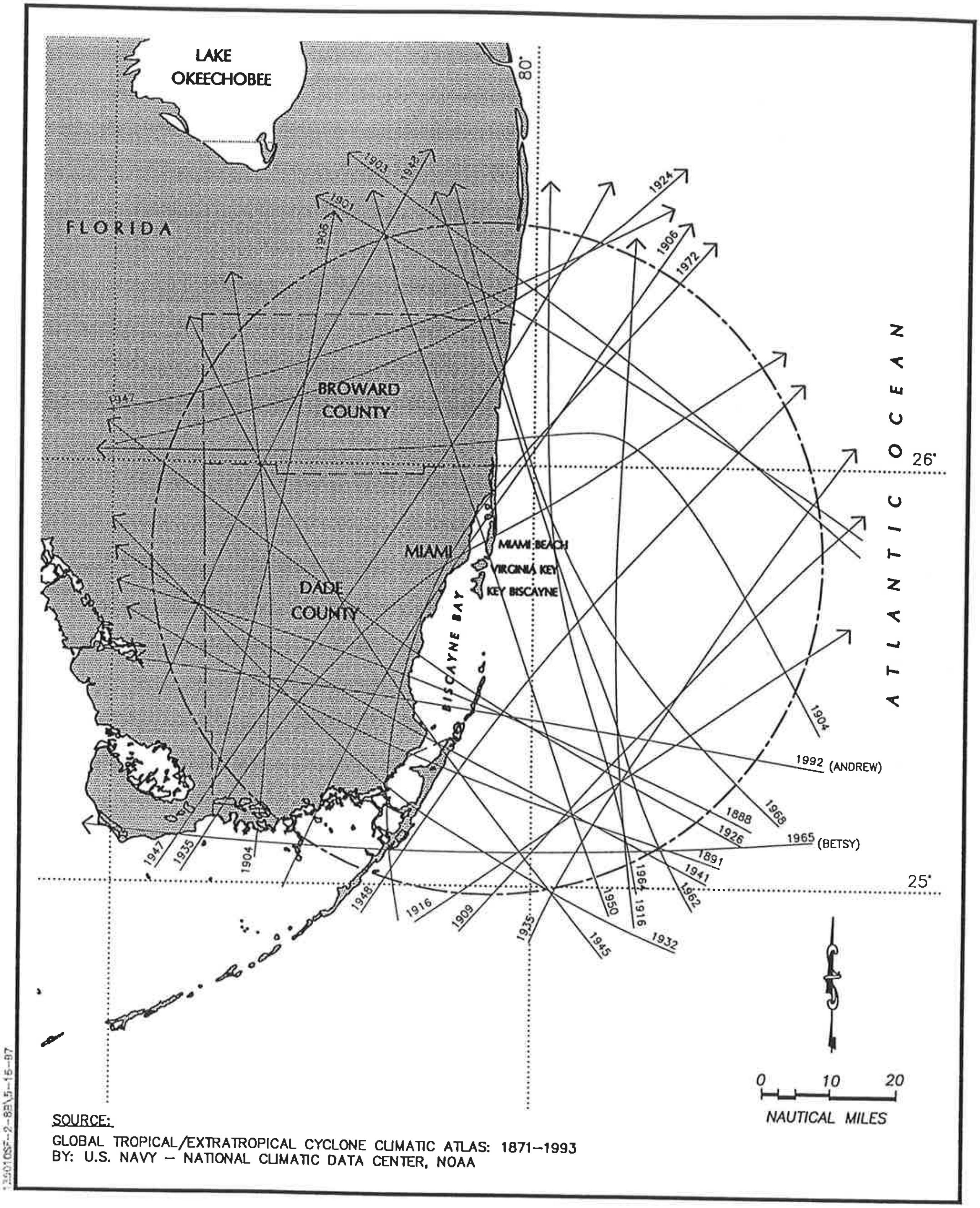

FIGURE 2.8

HISTORIC HURRICANE PATHS
WITHIN 50–NAUTICAL MILE RADIUS

part of the island to 9.3 feet NGVD along the southern part (USACE, 1992). Hurricane Betsy in 1965 (September 8), passing approximately 36 miles south of Key Biscayne, caused severe beach erosion and undermined the exposed seawall along the Key Biscayne Beach (Warzeski, 1976). Passing through South Florida, Betsy covered an area of 600 miles in diameter with a maximum wind speed at 110 knots (127 mph).

For coastal construction permitting, Florida DEP currently uses a storm surge elevation of +14 feet NGVD at Key Biscayne associated with a 100-year storm (Category 3 Hurricane) established by Dean and Chiu (1981). The current 100-year storm hydrograph used by DEP for wave impact and erosion analysis is shown in Figure 2.9.

2.4 Wave Refraction & Diffraction

2.4.1 Wave Transformation Processes

Waves propagating from deep ocean waters to the shallow coastal areas will undergo many transformational processes dependent on the nearshore bathymetry and the characteristics of the incident waves. These processes include refraction, diffraction, shoaling, and energy dissipation (wave breaking and turbulent losses). Of these, refraction and diffraction effects induced by shoals and other shallow bathymetric features may cause considerable focusing of wave energy at the shoreline.

Wave refraction is the process that causes the bending of the wave fronts or crests as they move obliquely into shallow water. Since the speed of the wave is determined by the depth in shallow water, the part of the wave moving into increasingly shallower water will tend to bend so that the wave crests become aligned nearly parallel to the depth contours. This process is responsible for the fact that waves tend to break more or less parallel to the coastline.

Wave diffraction involves the bending of wave crest around the backside or lee of an object or obstruction. Common examples include the diffraction of waves around a breakwater, island, or moored floating object such as a ship or barge. Wave diffraction,

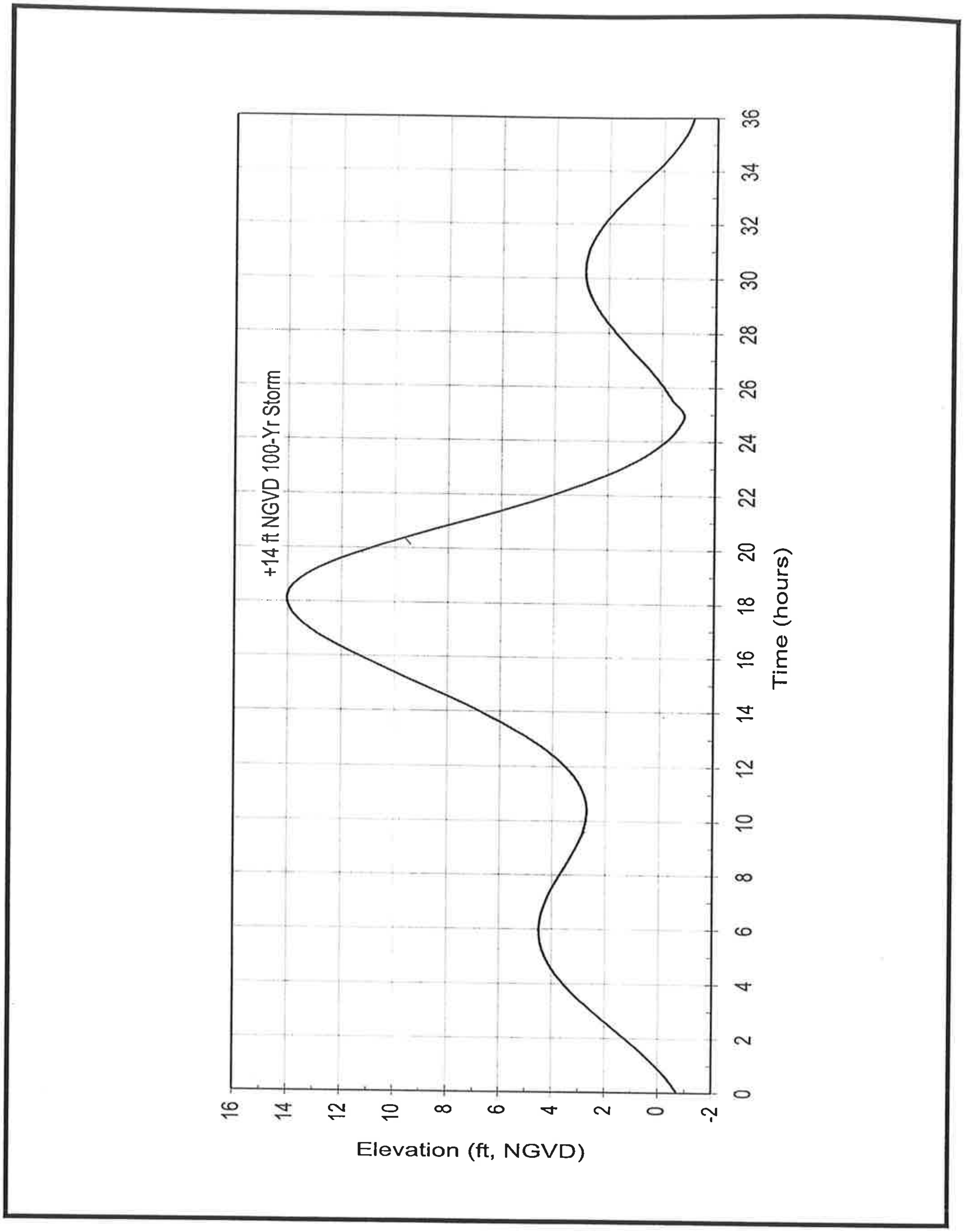

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FIGURE 2.9
PREDICTED STORM SURGE HYDROGRAPH

however, can also occur around submerged objects or bathymetric features such as underwater ridges or reef heads such as occurs in the present analysis.

2.4.2 *REFDIF Numerical Model*

The investigation of wave transformation and wave energy focusing was conducted using the weakly nonlinear refraction/diffraction model REFDIF developed by Dalrymple and Kirby (1991). This model incorporates all of the transformational processes that were described in the preceding section.

The wave model utilized by REFDIF includes a weakly nonlinear Stokes expansion for waves in deep and intermediate water depth. In the shallower regions of the bathymetry where the Stokes model is not valid, REFDIF uses a heuristic wave model developed by Hedges (1976) which approaches solitary wave theory in very shallow water. Energy dissipation is incorporated through frictional losses along the bottom from rough, porous or viscous surfaces, and also from wave breaking and surface films. REFDIF is typically used with monochromatic (regular) waves traveling along a given direction representing a statistical average of the oceanographic conditions over a certain time period or directional sector.

2.4.3 *Methodology*

As input, the model requires a rectangular matrix of water depths describing the nearshore/offshore bathymetry of the site. Figure 2.10 shows the extent of the computational grid established for the region encompassing Key Biscayne which spans 23,400 feet (4.4 miles) east-west by 39,000 feet (7.4 miles) north-south. The large grid size was necessary to extend the computational domain to relatively deep water (≈60 feet) and to incorporate the bathymetry effects both to the north and south of Key Biscayne under Northeast and Southeast wave conditions. Water depths at each grid point were obtained through an interpolation of digitized bathymetry and survey data using the AutoDesk SOFTDESK program. This is the same bathymetry data shown previously in

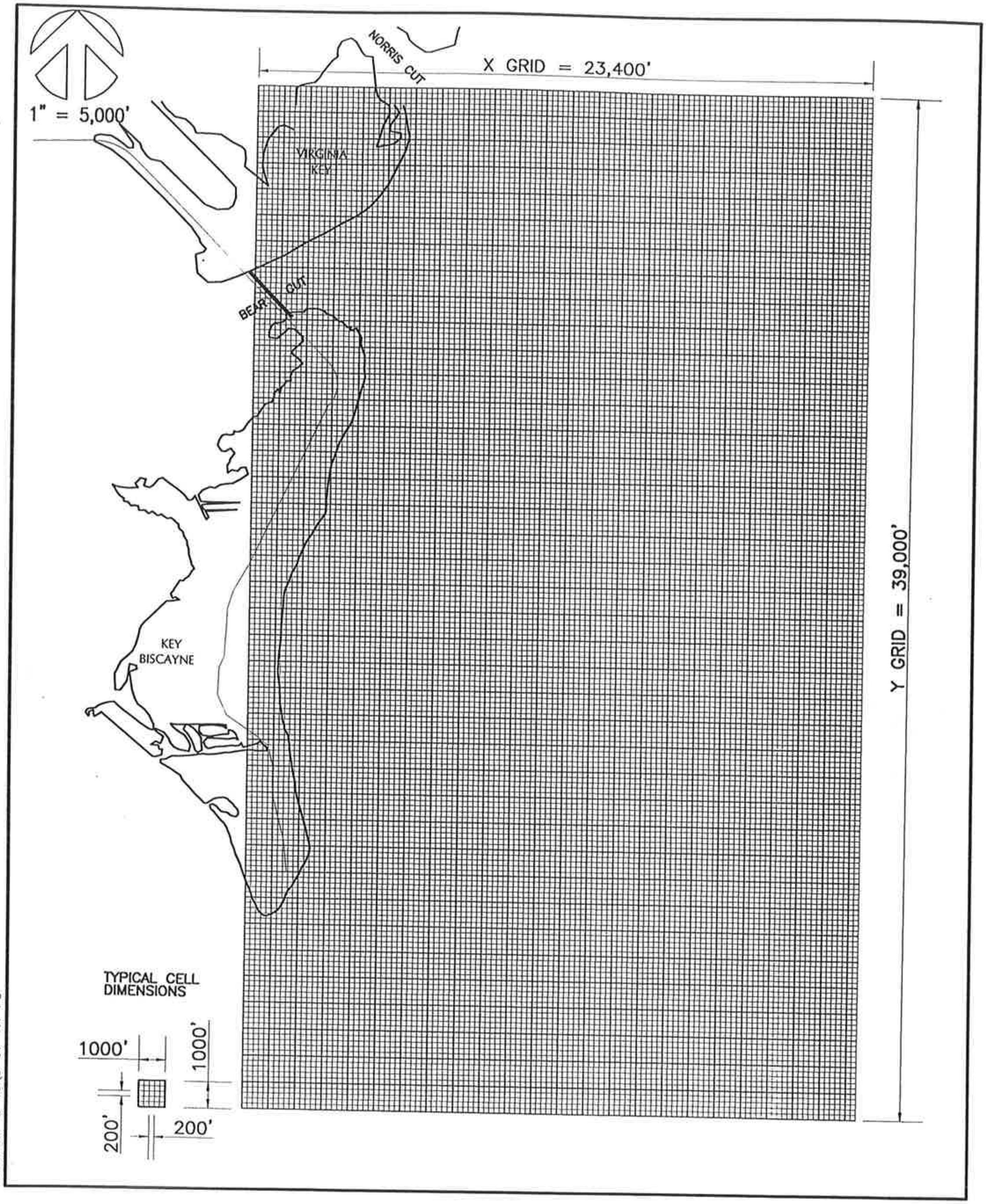


FIGURE 2.10

REFDIF COMPUTATIONAL GRID

Figure 2.2 and described in Section 2.2.2. Grid points were interpolated at every 200 feet in both the x and y directions, giving a total of 23,128 points for the total computational grid.

The input wave conditions for REFDIF were obtained from the WIS data at Station No. 8 initially refracted to the seaward grid boundary of the model. The required input wave parameters at the seaward grid boundary include wave period, amplitude, and direction. The model subsequently calculates a new amplitude and direction at each grid point proceeding in the x-direction. The selected input wave cases chosen for this study are shown in Table 2.4. The WIS data in this case has been recompiled over larger 45 degree sectors where the predominant wave energy occurs from the Northeast, East, and Southeast directions.

2.4.4 Results

The results of this model study are presented in Figures 2.11 through 2.13 showing wave directions (arrows) and wave height amplification or focusing (colors) superimposed over the bathymetry. The most striking feature of these results is the fact that the nearshore wave focusing is influenced by submerged features several miles offshore. In particular, the shallow high-relief hard-bottom areas just west of the 30 feet contour (below NGVD) appear to induce considerable wave focusing. The specific results from this analysis are discussed below using one representative case for each of the three predominant directional sectors:

Northeast Waves: During the winter time, the Key Biscayne beach is subject to predominantly northeast waves. Figure 2.11 shows the results for the highest representative wave period (T = 8 secs) occurring from the northeast direction with a deep water significant wave height of 3.8 feet. This case represents 9.7% of the total wave activity occurring at WIS Station No. 8 (Table 2.4). In general, these northeasterly waves induce considerable wave focusing on the north shoal offshore of Crandon Park, the south shoal offshore Bill Baggs State Park, and within the Village. This particular case produces increased waves focusing from R-103 to R-105 at the Village and from R-108 to R-110 at

TABLE 2.4

Hindcast Wave Conditions for REFDIF Analysis
WIS Station No. 8

Direction	Period (T in seconds) between										Totals/ Averages
	3-5	5-7	7-9	9-11	11-13	13-15	15-17	17-19	19-21	> 21	
	% of Occurrence										Total (%):
N	1.87	4.76	1.09	0.45	0.14	< 0.01	-	-	-	-	8.3
NE	2.52	8.19	9.71	7.83	6.75	5.64	2.90	1.30	0.52	0.06	45.4
E	9.43	10.32	1.50	0.37	0.06	-	-	-	-	-	21.7
SE	5.75	7.82	3.63	0.49	0.10	0.06	0.04	0.02	< 0.01	-	17.9
S	1.32	1.70	0.57	0.09	-	-	-	-	-	-	3.7
SW	0.45	0.06	< 0.01	-	-	-	-	-	-	-	0.5
W	0.77	0.02	-	-	-	-	-	-	-	-	0.8
NW	1.43	0.26	-	-	-	-	-	-	-	-	1.7
	Average Significant Wave Height (ft)										Average (ft):
N	2.2	3.5	6.7	7.0	5.3	22.6	-	-	-	-	3.9
NE	2.1	3.3	3.8	3.0	2.2	2.4	2.6	2.7	3.2	2.9	2.9
E	2.1	4.2	3.2	3.0	1.0	-	-	-	-	-	3.2
SE	1.8	2.8	2.6	2.9	1.6	1.4	1.2	1.7	2.0	-	2.4
S	1.8	3.5	5.8	10.3	-	-	-	-	-	-	3.4
SW	2.4	4.7	4.9	-	-	-	-	-	-	-	2.7
W	2.4	4.8	-	-	-	-	-	-	-	-	2.4
NW	2.8	5.0	-	-	-	-	-	-	-	-	3.1

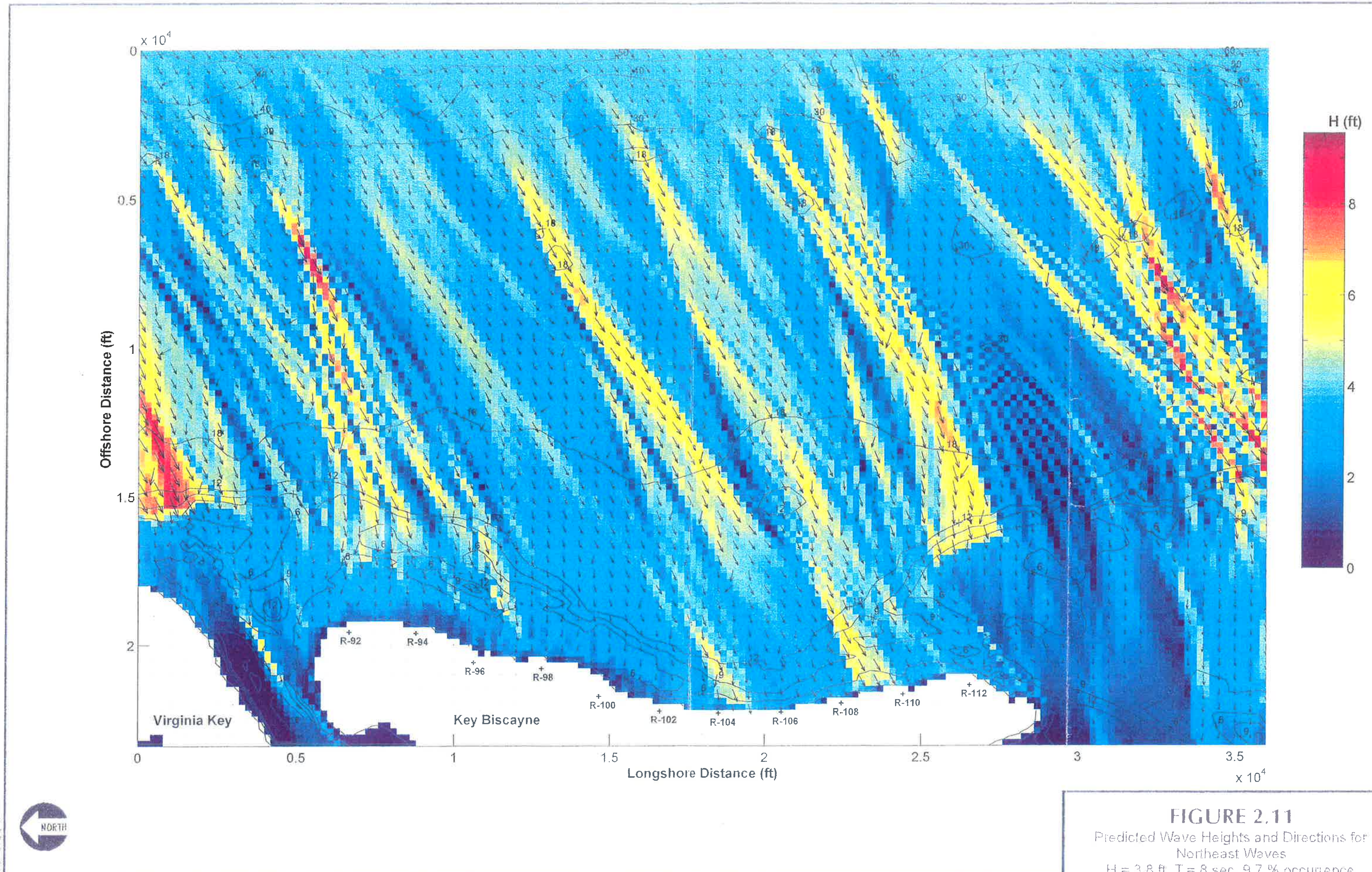


FIGURE 2.11

Predicted Wave Heights and Directions for Northeast Waves

H_s = 3.8 ft, T = 8 sec, 9.7 % occurrence

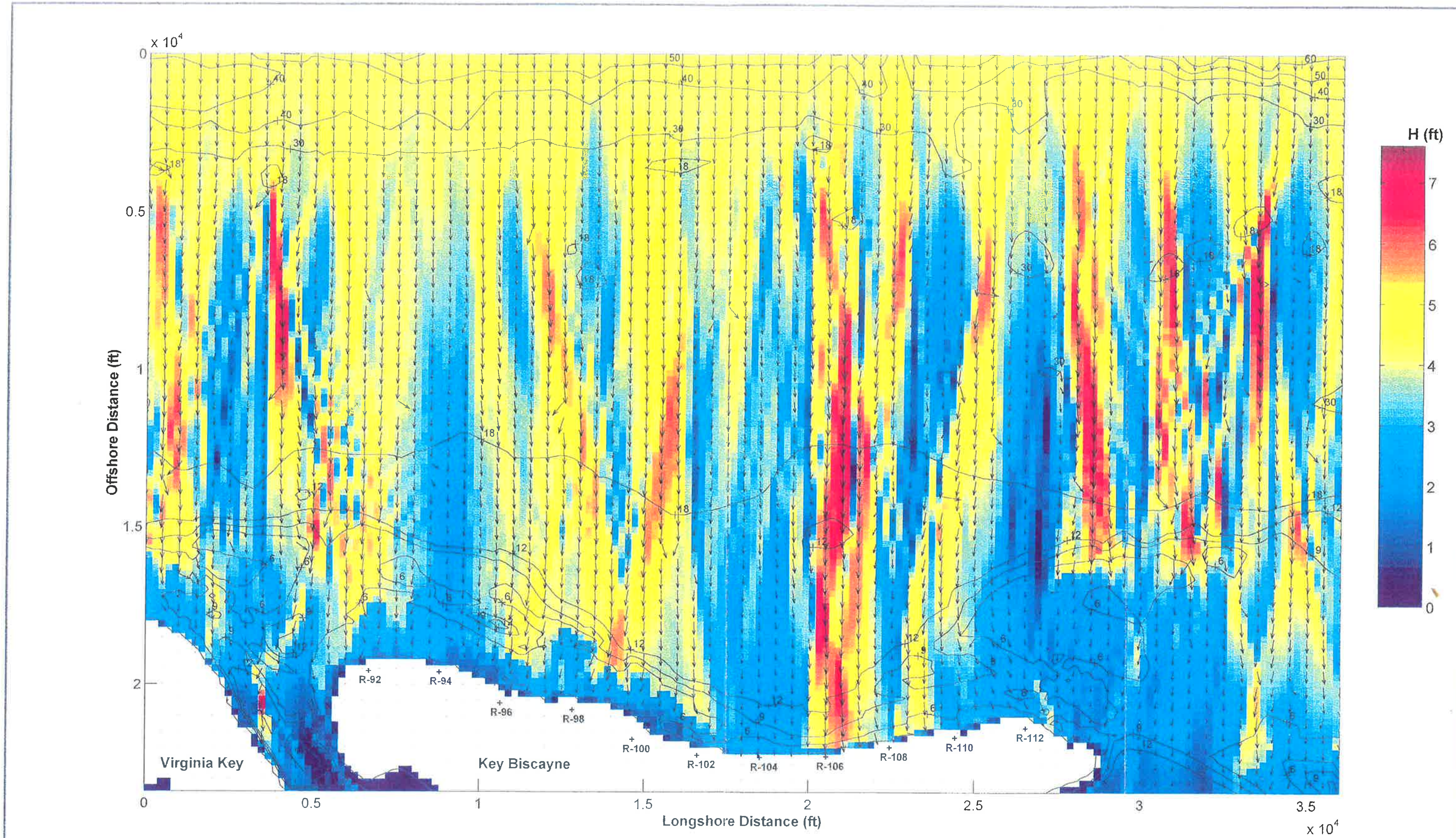


FIGURE 2.12
Predicted Wave Heights and Directions for East Waves
H_s = 4.2 ft, T = 6 sec, 10.3 % occurrence

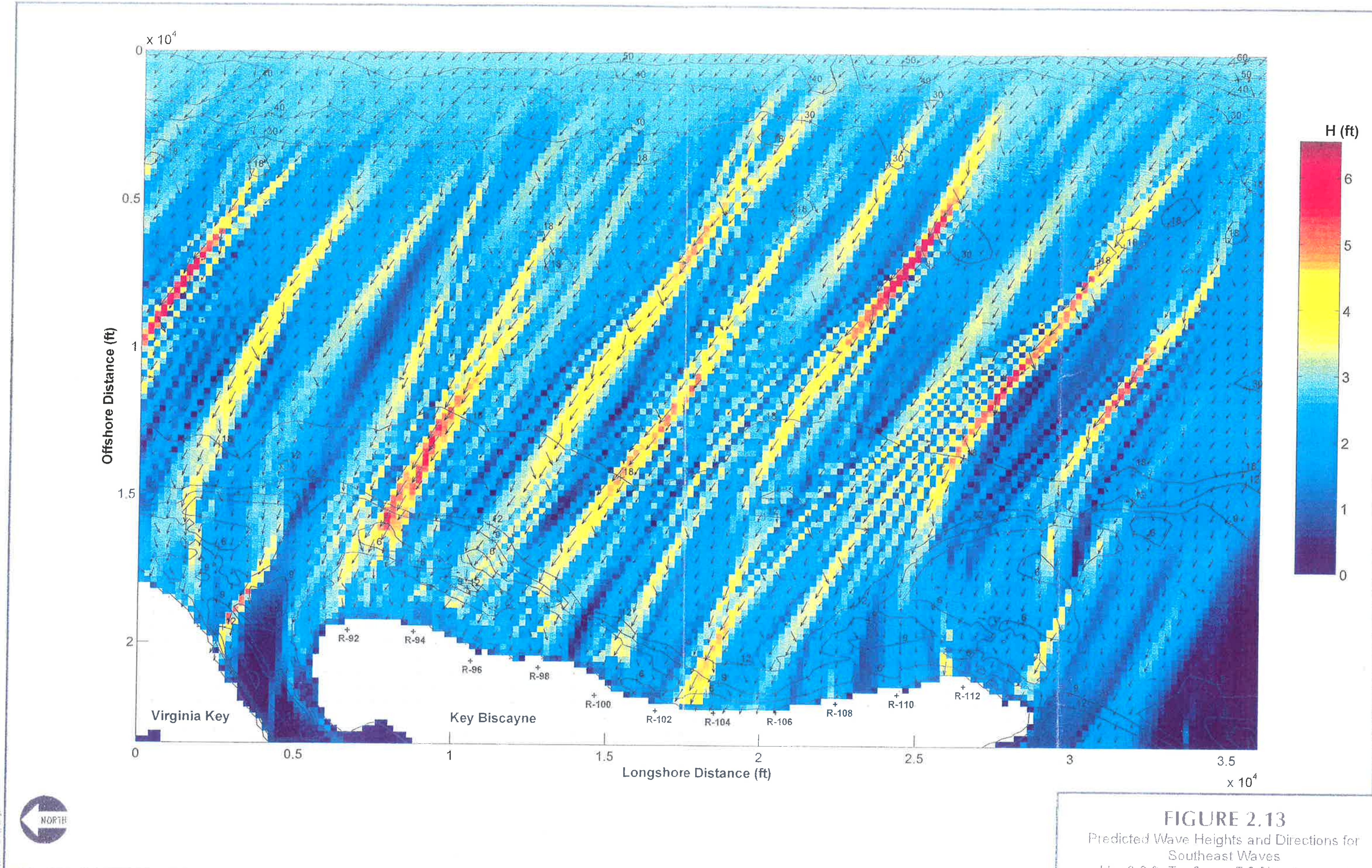


FIGURE 2.13
Predicted Wave Heights and Directions for Southeast Waves
H_s = 2.8 ft, T = 6 sec, 7.8 % occurrence

Bill Baggs. As illustrated in this figure, significant wave energy is dissipated through wave breaking at both the north and south shoals before reaching the shoreline. Wave energy however, impacts the shoreline directly along the Village and north Bill Baggs due to the deeper contours along this area.

East Waves: Figure 2.12 presents the results for east waves with a wave period of 6 seconds and deep water significant wave height of 4.2 feet representing 10.3% of the total wave activity at WIS Station No. 8. These direct easterly waves produce an area of wave energy focusing between approximately R-105 and R-107 within the Village. Here again, wave focusing/shoaling along the north and south shoals results in wave breaking at approximately the 5 foot depth contour.

Southeast Waves: A representative case for southeast waves, predominantly occurring during the summer time, is shown in Figure 2.13 for a wave period of 6 seconds and deep water significant wave height of 2.8 feet. This case accounts for 7.8% of the total wave activity occurring at WIS Station No. 8. Wave energy focusing along the Village primarily occurs along the R-102 to R-104 area for this representative wave condition. Wave focusing along the north shoal area is dissipated generally along the 5 foot depth contour before reaching the Crandon Park shoreline.

2.5 Regional Sediment Movement

2.5.1 Shoreline and Volumetric Changes

Historic MHW Shorelines: The regional littoral processes effecting the shoreline within the Village of Key Biscayne are first examined through the changes occurring in the historic shoreline positions. Shoreline positions obtained from MHW and profile surveys at each DEP monument are evaluated from 1913 to 1992 using the 1851 shoreline as a base for comparison. This data is presented in Figures 2.14 and 2.15 covering two different historical periods from 1913 to 1945, and 1945 to 1992. The raw MHW shoreline data for 1851 to 1986 and their sources are summarized in Appendix D. The 1992 MHW data was obtained from 1992 Dade County aerial photographs of the Coastal Construction Control Line (CCCL).

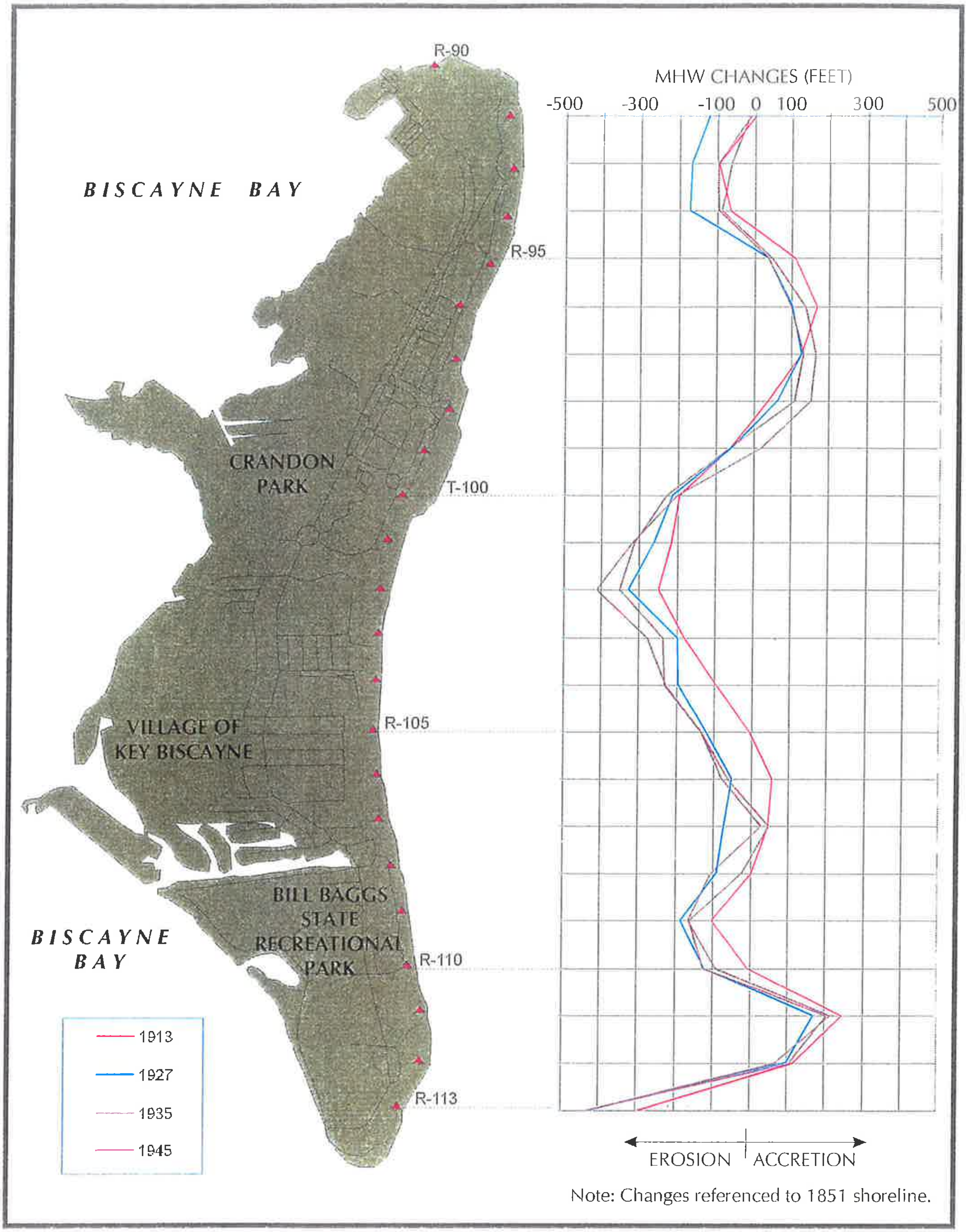


FIGURE 2.14
HISTORICAL MHW CHANGES, 1913 - 1945

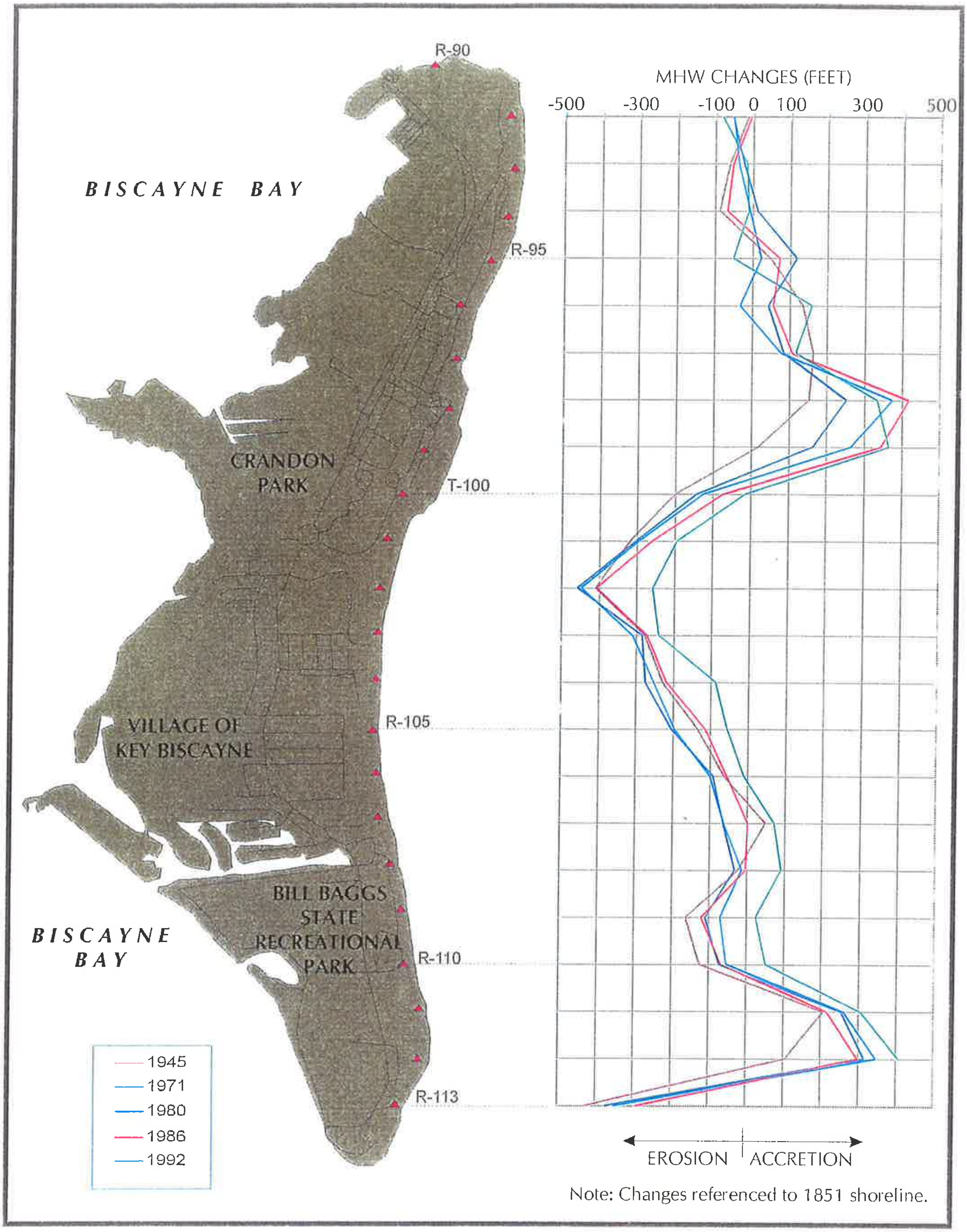


FIGURE 2.15

HISTORICAL MHW CHANGES, 1945 - 1992

As examined previously in Section 2.2.4, the most dramatic changes along the Key Biscayne shoreline occurred after the initial opening of Government Cut in 1904 as displayed from the 1913 MHW positions. Changes from this event mark the known beginning of the long-term historical trend of accretion along the north and south shoal areas and erosion along the central shoreline of the Village. The most significant long-term shoreline recession occurred in the vicinity of R-102 within the Village and R-113 near the southern tip of the island with both locations eroding more than 400 feet by 1945.

Accretional areas initially occurred within Crandon Park from R-94 to R-99 and at Bill Baggs from R-110 to R-112. Since the 1945 survey, the north shoreline has shown the additional accretion of a sand spit from approximately R-97 to R-100 (Figure 2.15) as described previously in Section 2.2.2. In some places this spit has seen dramatic growth of up to +12.9 feet per year (at R-99 between 1971 and 1986). More recent April 1996 profile surveys have continued to show a high growth rate of approximately 10 feet per year at R-99 combined with a southern migration of the spit.

The beach fill project of 1969 is visible in the spike in the 1971 MHW line in the vicinity of R-94 to R-96. The difference between the 1986 and 1992 MHW lines at R-100 through R-112 is indicative of the 1987 beach fill project.

1987 Beach Fill Performance: The spring, 1987 USACE beach fill project at Key Biscayne placed a reported 420,000 cubic yards of fill material from approximately R-101 to R-113 excluding an accretionary 1,600-foot section of shoreline within Bill Baggs in the vicinity of R-111 and R-112 (USACE, 1996).

Based on the USACE final construction plans for this 1987 beach fill, the volumetric difference between the pre-construction survey of April 1986 and the 1987 construction template, was computed at approximately 375,000 cubic yards. Out of this 375,000 cubic yards, approximately 278,000 cubic yards resides in the construction template within the limits of the Village of Key Biscayne.

The distribution of the 1987 construction template volume is shown in Figure 2.16 compared to the actual fill volume as surveyed in January 1988 (profile comparisons are shown in Appendix E). According to this 1988 survey, approximately 500,000 cubic yards of material was placed within the entire project area with approximately 353,000 cubic yards of that total volume placed within the Village. This large surveyed volume is approximately 125,000 cubic yards more than the 1987 construction template or 80,000 cubic yards more than the reported 420,000 cubic yards placed. Within the limits of the Village, this represents approximately 75,000 cubic yards over the construction template of 278,000 cubic yards.

These results suggest that a large volume of material was placed in the Village beyond that which was specified in the 1987 construction template (approximately 27% more). Factors that may account for this additional material include an overfill volume (although no overfill was specified in the May 1984 Project Report and EIA (USACE, 1984)) or inaccuracies in the computed/measured pumping rate. For the purposes of this report, the January 1988 survey is assumed generally to be the same as an "as-built" survey providing the most accurate indicator of the actual quantity of material placed.

After this January 1988 post-construction survey, three more monitoring surveys were completed in April 1989, February 1990, and May 1991 (profiles shown in Appendix E). The surveys of 1988 and 1991 are compared in Figure 2.17, showing an overall erosion of approximately 27,000 cubic yards over the entire project area and 22,000 cubic yards within the Village. This equates to a post-construction erosion rate of approximately 9,000 cubic yards per year over the project area or 7,000 cubic yards per year within the Village.

The corresponding shoreline changes from these monitoring surveys are shown in Figure 2.18, based on the 1988 post-construction survey. It is interesting to note, that these volumetric and shoreline changes occurring after the 1987 beach fill show the same erosional and accretional patterns that is observed in the historical MHW changes

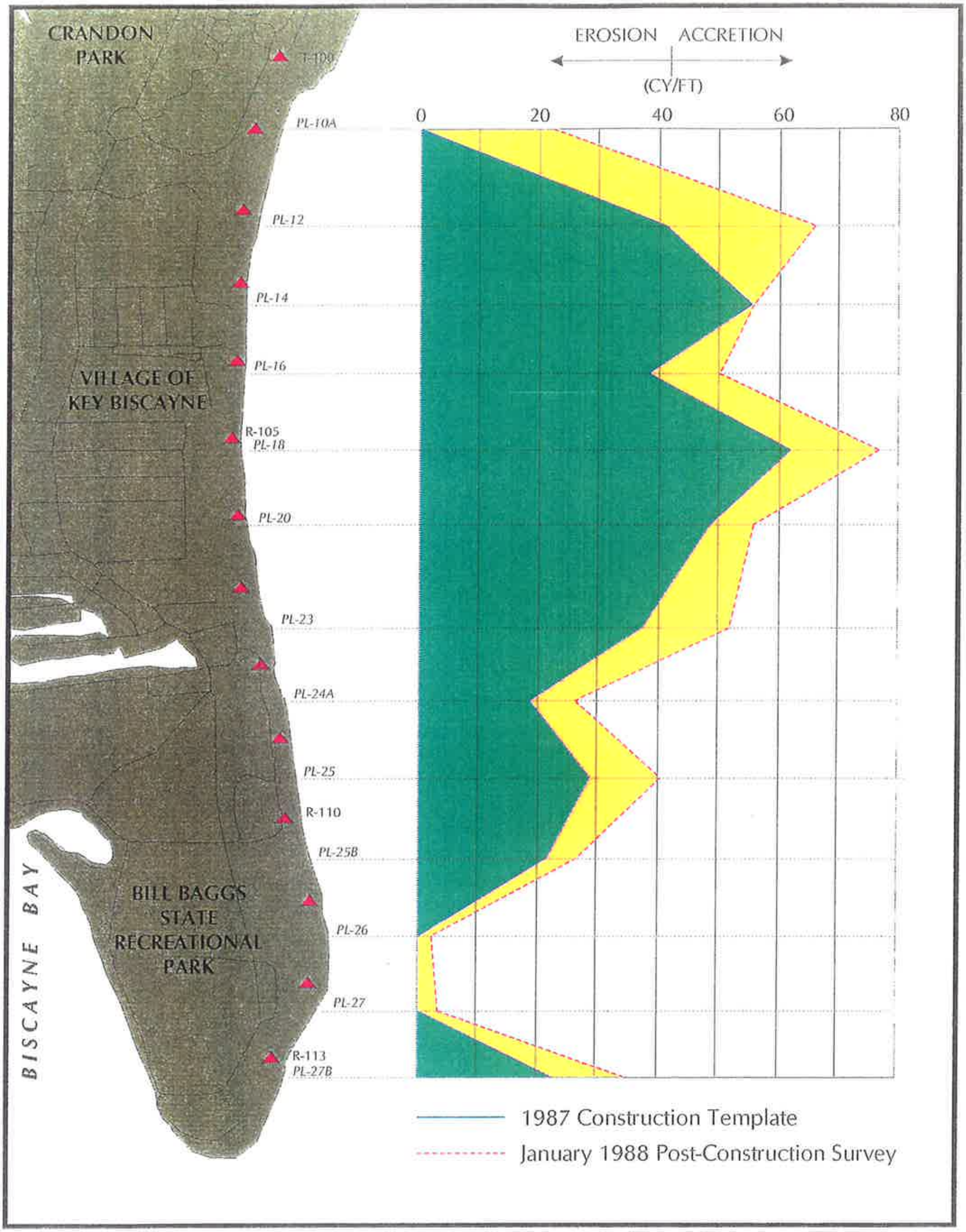


FIGURE 2.16

1987 Beach Fill Construction Template vs. Actual Placed Volume

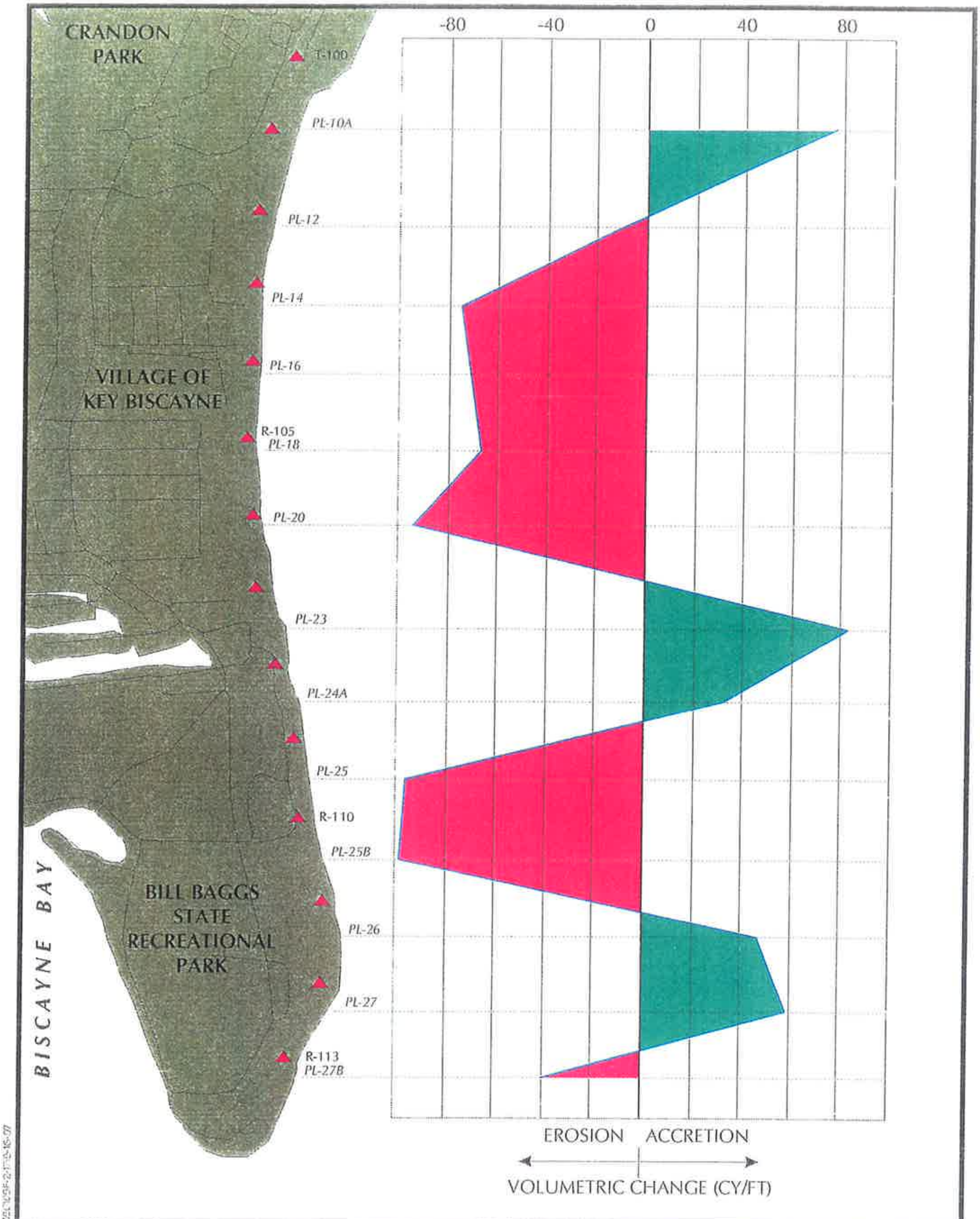


FIGURE 2.17

Volumetric Changes at 47 months (May 1991) USACE Monitoring Survey

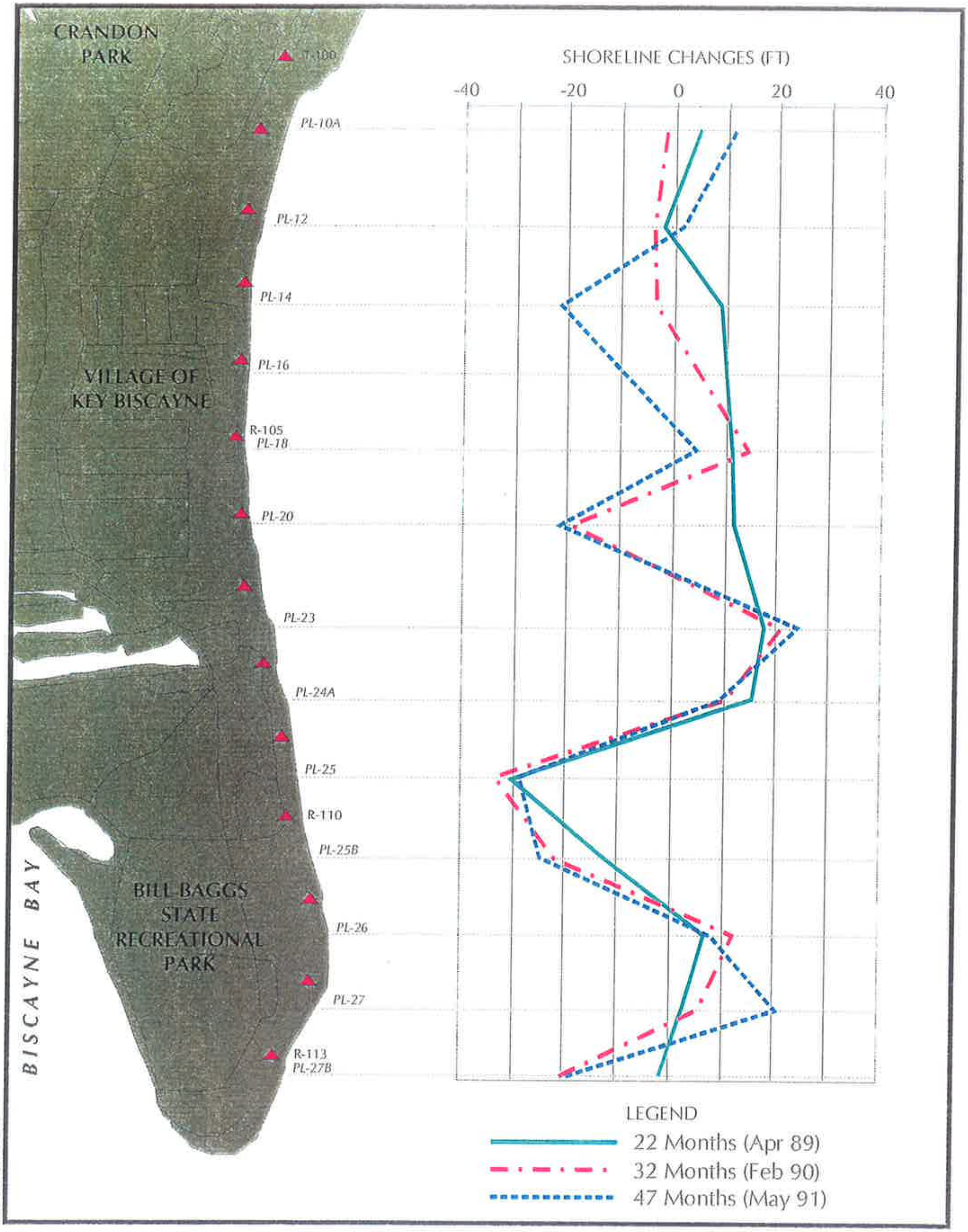


FIGURE 2.18

Shoreline Changes from USACE Post-Construction Surveys

(Figures 2.14 and 2.15). Namely, erosion occurred from approximately R-102 to R-106 and R-109 to R-111 while accretion was observed at approximately R-107 to R-108 and again at R-111 to R-113.

Comparisons between the recent April 1996 Morgan & Eklund survey (conducted at DEP monuments) and the USACE post-construction surveys (conducted at USACE profile lines) cannot be made directly due to the different location of the transects. However, by overlaying the plan view of the USACE 1987 beach fill construction template with the DEP monument transects, a volumetric deficit of 32,000 cubic yards is obtained within the Village. With the overfill volume of 75,000 cubic yards within the Village established previously (based on the difference in the construction template and 1988 post-construction survey) the total fill lost, as of April 1996, is approximately 107,000 cubic yards. Thus, out of the total estimated 353,000 cubic yards placed within the Village in June 1987, approximately 246,000 cubic yards remains (as of April 1996) or 69% of the initial fill volume. This lost volume depicted in Figure 2.19, generally represents an average erosion rate for the 1987 fill of approximately 12,000 cubic yards per year along the Village shoreline.

2.5.2 Littoral Movement

The movement of sand along the Key Biscayne coastline is examined using the REFDIF results of wave focusing and wave breaking presented in Section 2.4. With the provided conditions of wave breaking along the shoreline and shoal areas of Key Biscayne, longshore transport rates were computed using the energy flux method as presented in the Shore Protection Manual (USACE, 1984). In general, this method assumes that the longshore transport of sediments is driven by the longshore component of wave energy within the surf zone. The dissipation of wave energy through shallow-water breaking represents the point at which the maximum energy is transferred to the seabed in the longshore direction.

The parameters used to calculate the longshore transport rate, provided from REFDIF, include the breaking wave height and location, water depth at breaking, and wave angle

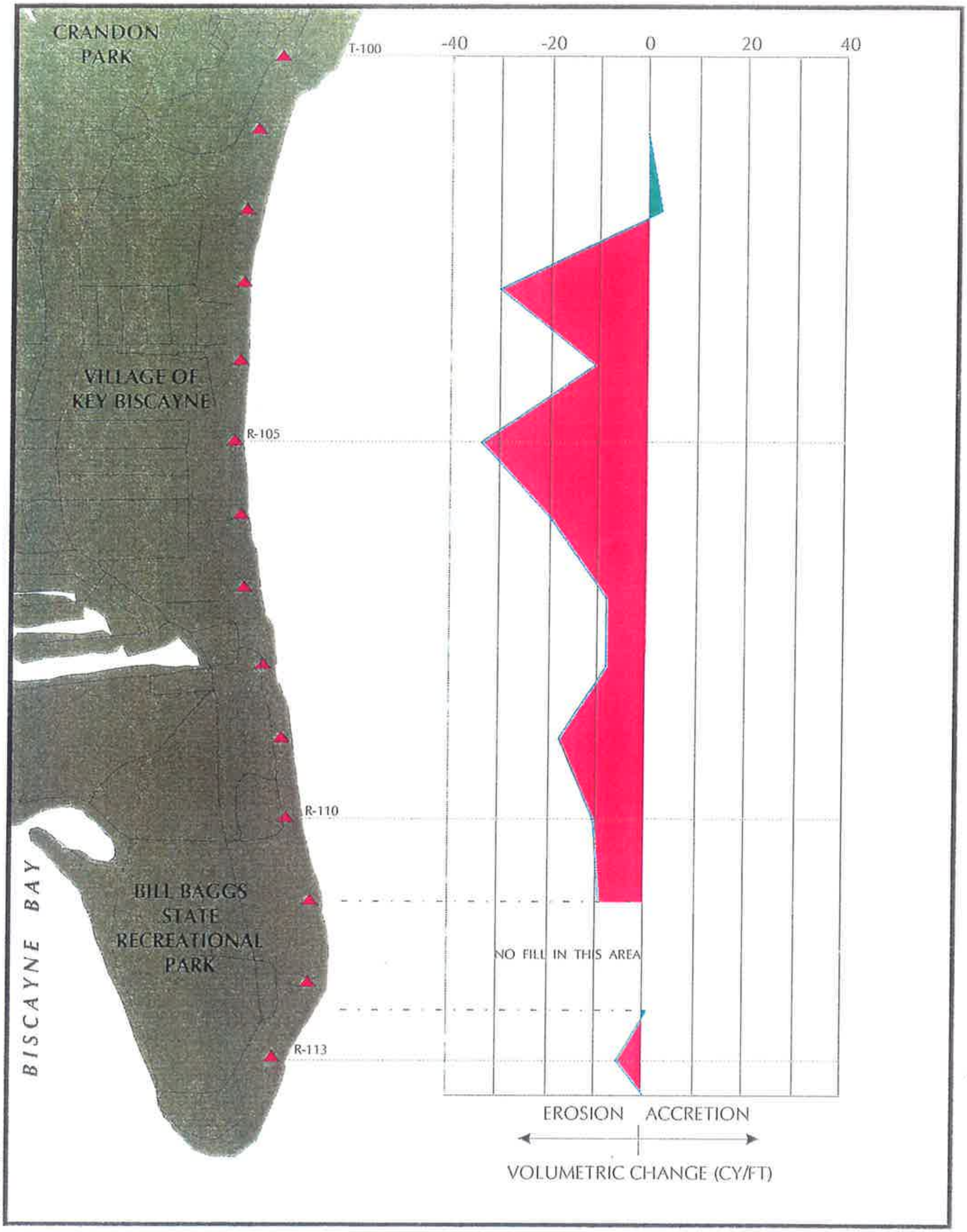


FIGURE 2.19

Volumetric Erosion of 1987 Fill as of April 1996 at breaking. Other parameters used in the calculation include the fluid and sediment particle densities, sediment porosity, and a dimensionless coefficient *K* relating the ratio of longshore sediment transport to the dimensionless longshore energy flux per unit length of shoreline (Komar & Inman, 1970).

Due to the extensive coverage of seagrass within the nearshore littoral platform, potential transport rates will be significantly less than compared to areas with mobile sediment and no seagrass. To accommodate for this reduction in transport, the dimensionless coefficient *K* was calibrated based on the historical estimates of gross transport rates along Key Biscayne. The results of this calibration are intended to provide only general estimates on the transport rates and overall qualitative trends.

Results of longshore transport rates are presented for three different cases corresponding to the wave conditions modeled by REFDIF shown previously in Figures 2.11 through 2.13 (Section 2.4). These cases represent the predominant wave period bands occurring within the northeast, east, and southeast sectors and account for 9.7%, 10.3%, and 7.8% of the total wave activity, respectively, at WIS Station No. 8.

Northeast Waves: Under this particular northeast representative condition shown in Figure 2.20, sand transport occurs predominantly towards the south. A strong southward gradient dominates the north shoal area with localized rates up to 38,000 cubic yards per year corresponding to the significant wave focusing in this area. This strong south transport immediately adjacent to a low transport area to the south, may explain the accretional trend of the large sand spit within Crandon Park and the adjacent south shoals (immediately offshore R-102). Further south, wave focusing creates localized transport rates of approximately 15,000 cubic yards per year southward in the vicinity of R-104 to R-105 and again from R-108 to R-110. Significant wave breaking along the 5-foot contour of the south shoal (directly offshore R-112) produces a northward transport with localized rates up to approximately 20,000 cubic yards per year. It is expected that similar transport patterns exist for the entire statistical occurrence of northeast waves (45%).

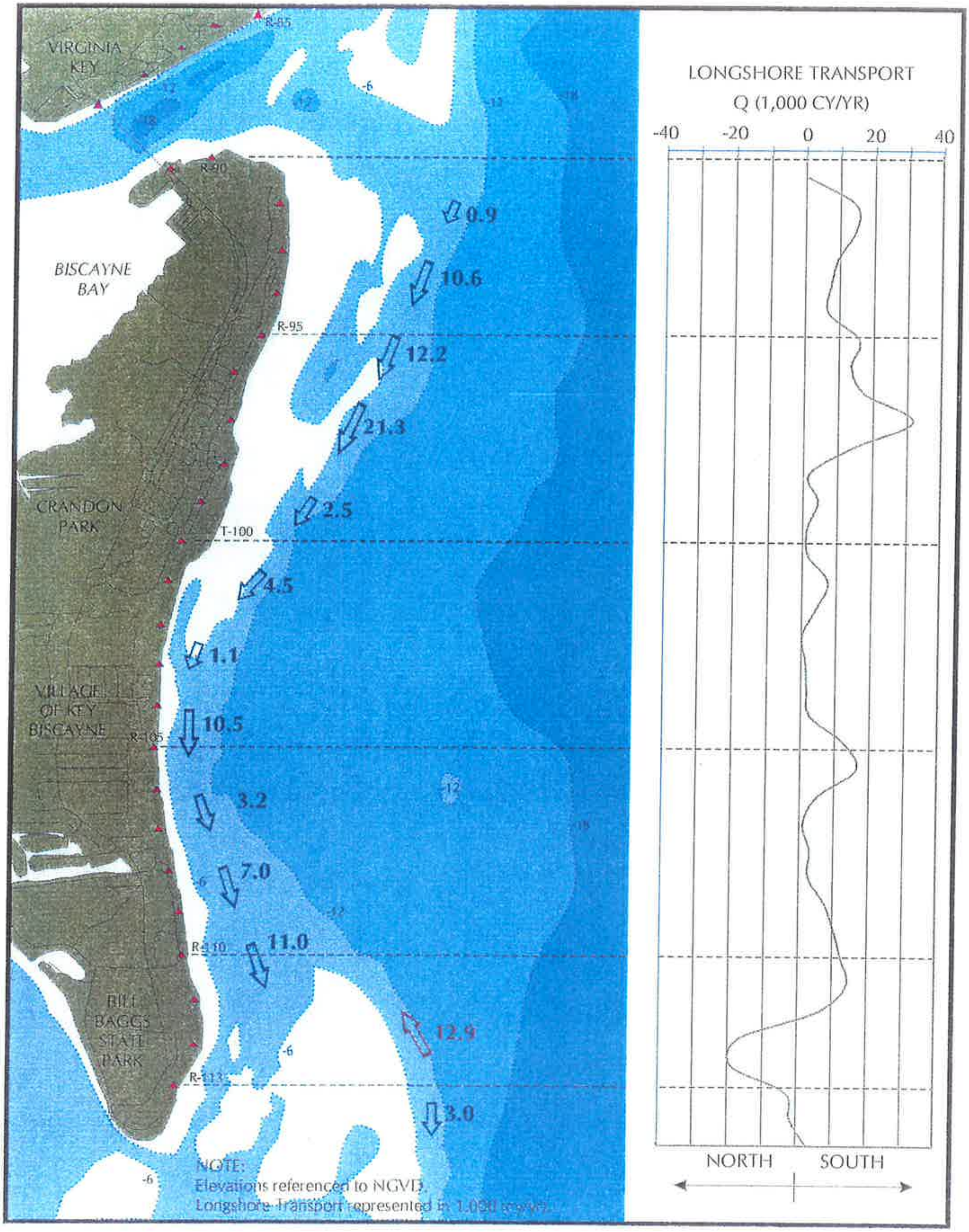


FIGURE 2.20

LITTORAL TRANSPORT PATTERNS UNDER NORTHEAST WAVES

H_s= 3.8 Ft, T= 8 Sec, 9.7 % Occurrence

East Waves: Longshore transport under east wave conditions is illustrated in Figure 2.21, displaying a predominant southward movement. Similar to the northeast wave conditions, strong southward transport occurs along the north shoal area (offshore R-96 to R-100) producing peak localized transport rates of up to approximately 14,000 cubic yards per year. Although significant wave energy focusing occurs in the vicinity of R-106, the near-perpendicular wave approach limits the potential longshore transport for this case. Within Bill Baggs State Park, transport reversals occur with a north transport from approximately R-108 to R-110 and south transport from R-112 to R-113. Strong wave breaking along the offshore shoal produces a north transport (similar to northeast case) with a peak rate of approximately 20,000 cubic yards per year.

Southeast Waves: Under this lower wave energy southeast direction, representing typical summertime conditions, longshore transport is predominantly towards the north (Figure 2.22). The highest transport rate occurs along the north shoal with a very localized rate of approximately 18,000 cubic yards per year to the north corresponding to an area of significant wave energy focusing. Transport along the remainder of the shoreline is relatively mild except at R-103 where localized wave focusing produces a rate of approximately 9,000 cubic yards per year to the north.

Overall: Although this modeling examined only a limited number of representative cases, the dominance of the southward littoral movement associated with the more frequent northeast and east wave conditions suggest that the resultant annual drift is predominately towards the south. This is in agreement with Wanless (1974) and the well established fact that southward littoral drift dominates along the beaches to the north of Government Cut.

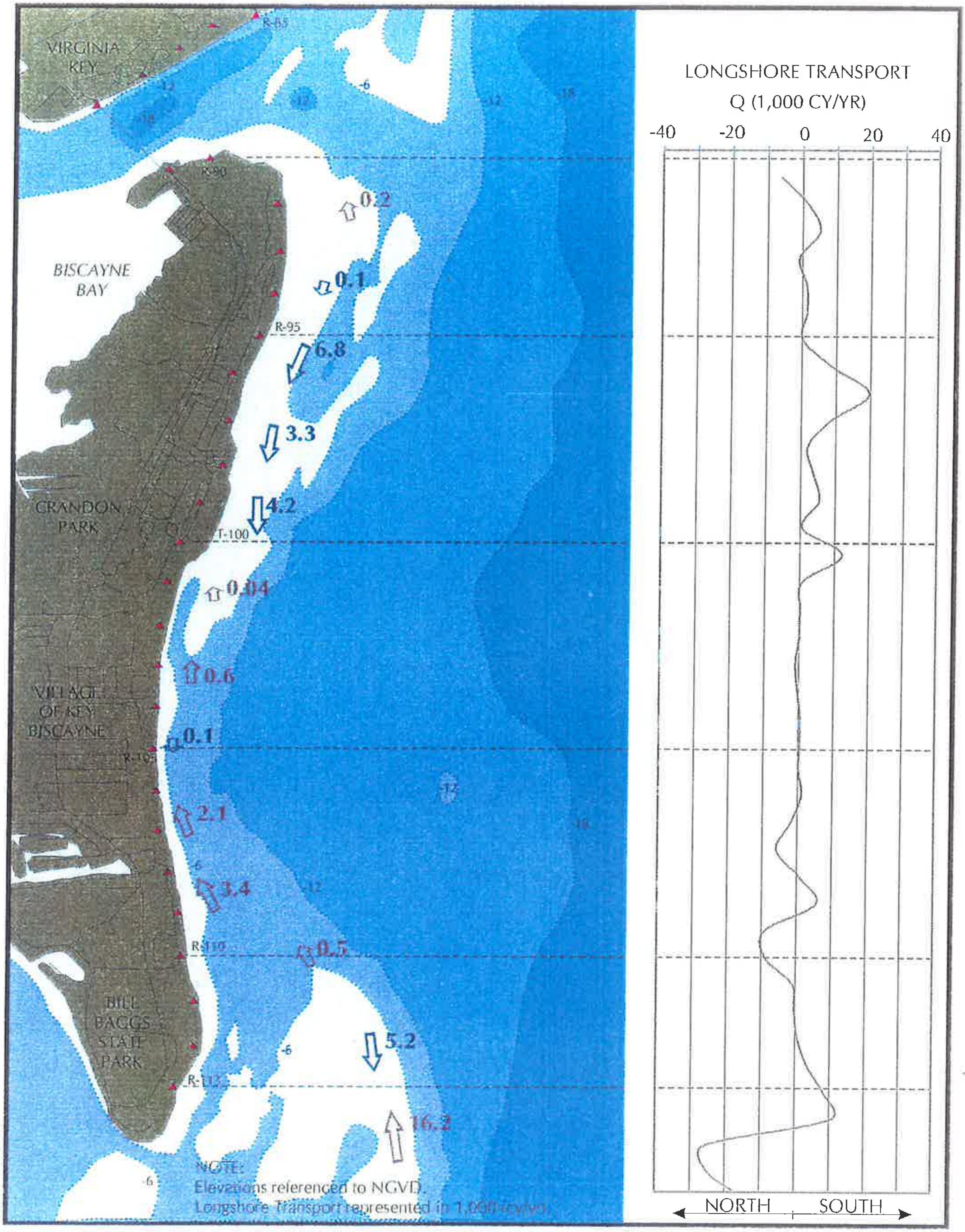


FIGURE 2.21

LITTORAL TRANSPORT PATTERNS UNDER EAST WAVES

H_s= 4.2 Ft, T= 6 Sec, 10.3 % Occurrence

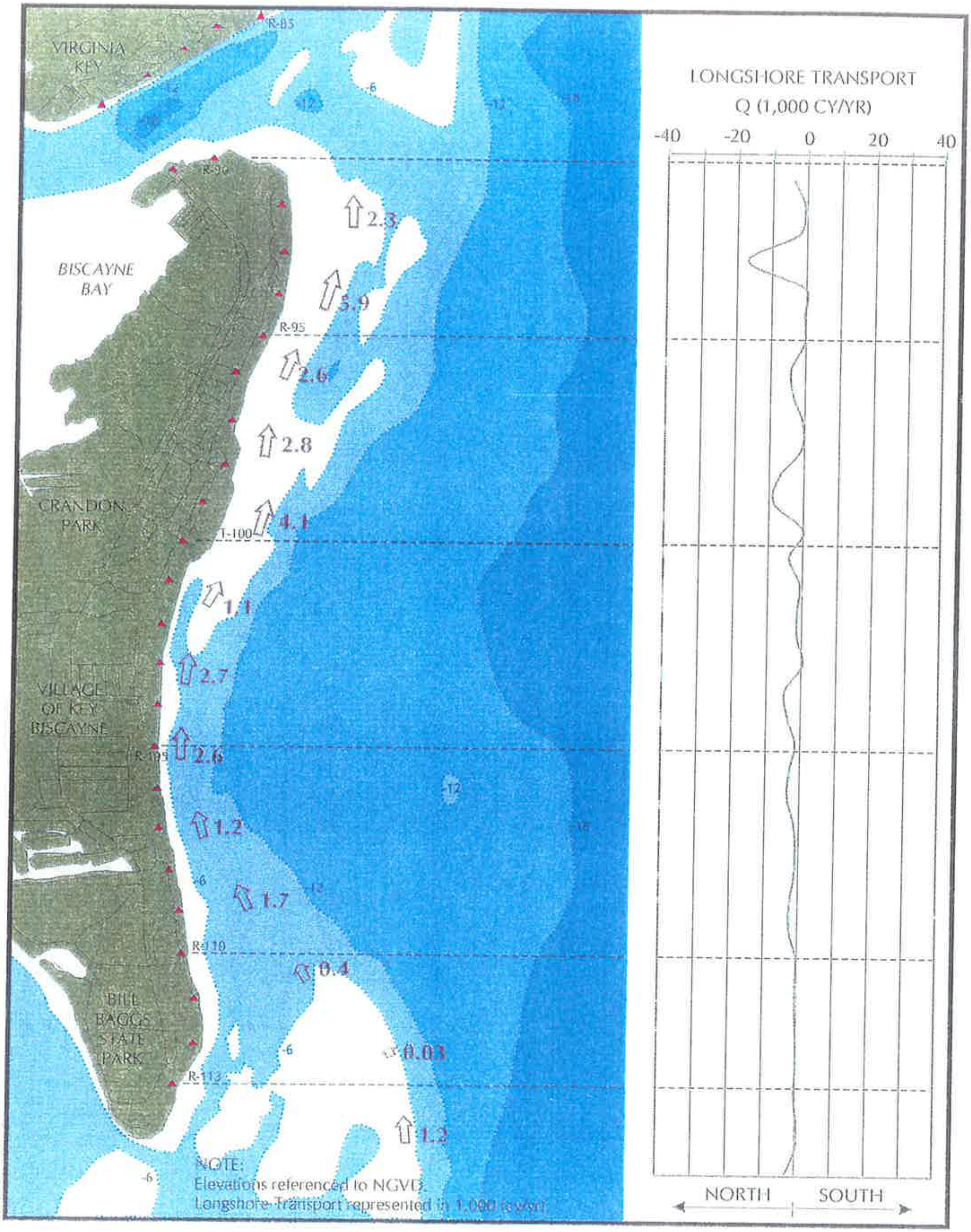


FIGURE 2.22

LITTORAL TRANSPORT PATTERNS UNDER SOUTHEAST WAVES

H_s = 2.8 Ft, T= 6 Sec, 7.8 % Occurrence

3.0 - BEACH DESIGN ALTERNATIVES

3.1 General

This chapter presents the proposed beach nourishment design for the Village of Key Biscayne with the associated engineering and environmental considerations. In general, the proposed design seeks to restore the Village shoreline to the same footprint as specified in the USACE 1987 construction template. The engineering evaluation includes the examination of potential benefit from increased storm protection of upland structures and properties.

Of particular importance is the identification of a high-quality sand source for both the immediate and long-term nourishment needs. Numerous alternatives are investigated including offshore borrows, upland sites, and imported sources from the Caribbean. Environmental concerns are addressed including potential impact to seagrass beds and hardbottom communities. Consideration of sea turtles and the nesting season which runs from May 1 through October 31 is also included.

3.2 Engineering Evaluation

3.2.1 Design Criteria

Criteria for the proposed design were developed based on the historical erosion rates, critical areas of erosion, limit of nearshore seagrasses, permitting considerations, and the projected nourishment interval. It is evident, historically, that the Village shoreline represents an area of moderate erosion as was observed in Section 2.5. Based on the performance of the 1987 beach fill, an erosion rate of 12,000 cubic yards per year was determined occurring over approximately a 9-year period. This represents an associated deficit of approximately 107,000 cubic yards established between the 1987 beach fill and April 1996 survey.

It was determined that a beach fill based on this USACE 1987 construction footprint would address the critically eroded areas in the vicinity of R-103 and R-105 while providing increased storm protection for the Village. A project life of approximately 8 to

10 years is anticipated based on the past performance of the 1987 fill. Impact to existing seagrasses should be minimal based on the Dade County DERM (Department of Environmental Resource Management) investigation of seagrass limits in February 1997.

The process of obtaining permits is expected to be simplified since this design essentially represents a restoration of the beach and dune to the pre-existing footprint accurately specified by the USACE 1987 design.

3.2.2 Beach Fill Design

Fill Template: The extent of the proposed beach fill template is shown in Figure 3.1. The fill design is located completely within the Village spanning from approximately 350 feet south of R-101 to approximately 500 feet south of R-107 for a total project length of approximately 5,600 feet. The beach fill design profiles along the six DEP monument profile lines (R-102 to R-107) are shown in Figures 3.2 through 3.4.

The berm height of the nourishment profile is +9.0 feet NGVD with a construction foreshore slope of 1:14 extending offshore to the toe of the fill. After placement of the construction fill, the profile is expected to adjust towards an equilibrium profile which is approximated by a 1V:10H foreshore slope and 1V:25H nearshore slope extending to the equilibrium toe.

Fill Volumes: Based on the April, 1996 survey, total construction fill for this project is estimated at 107,000 cubic yards including an overfill volume. In 1997, approximately 120,000 cubic yards, including an average annual erosion rate at 12,000 cubic yards of fill volume is necessary to restore the beach to the approximate conditions of the post 1987 beach fill. This fill volume is expected to last approximately 10 years at which time the beach would have eroded back near to its present state and another nourishment would be required. In the event of severe erosion as a result of a storm or a series of storms, the beach nourishment may occur sooner.

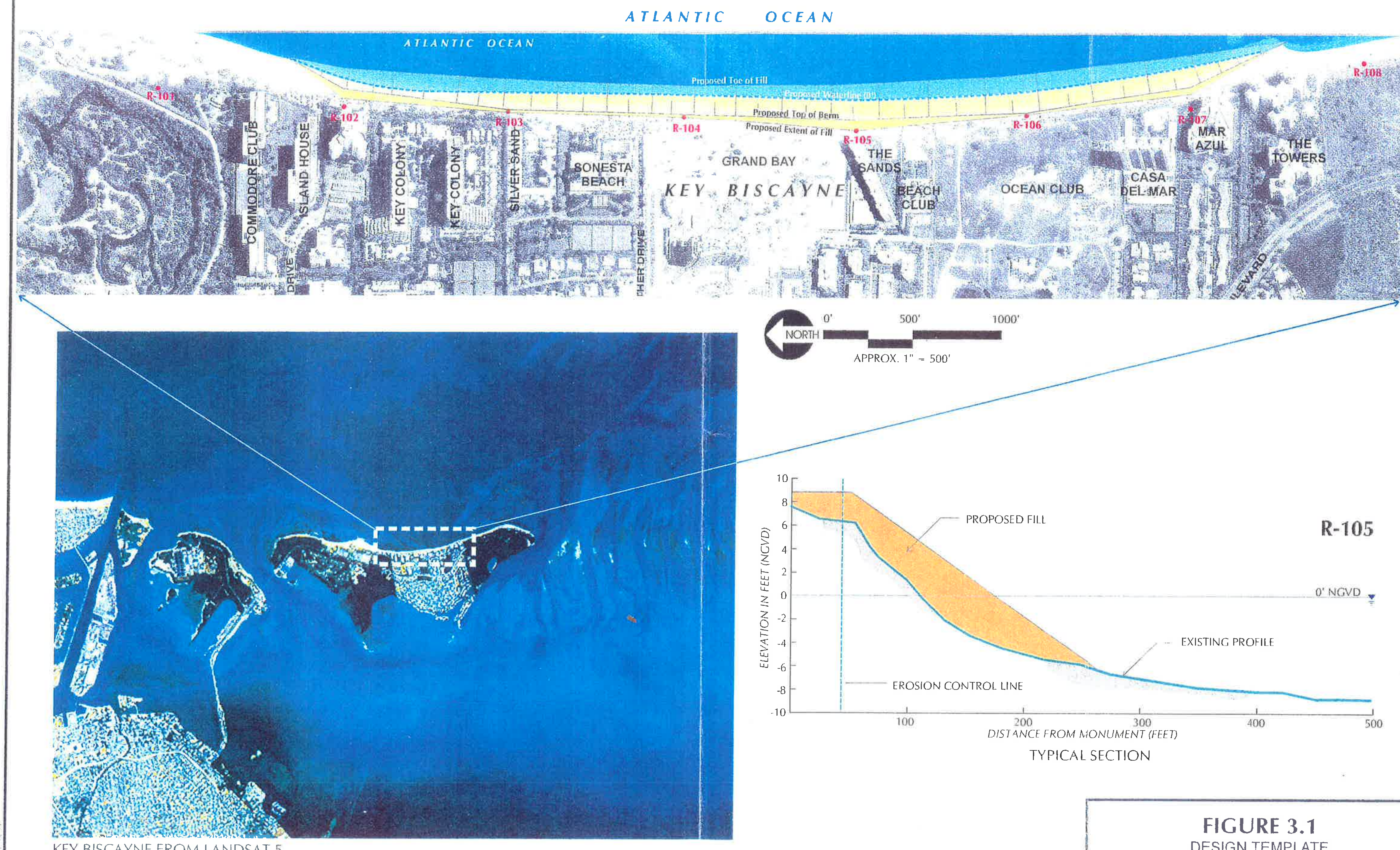
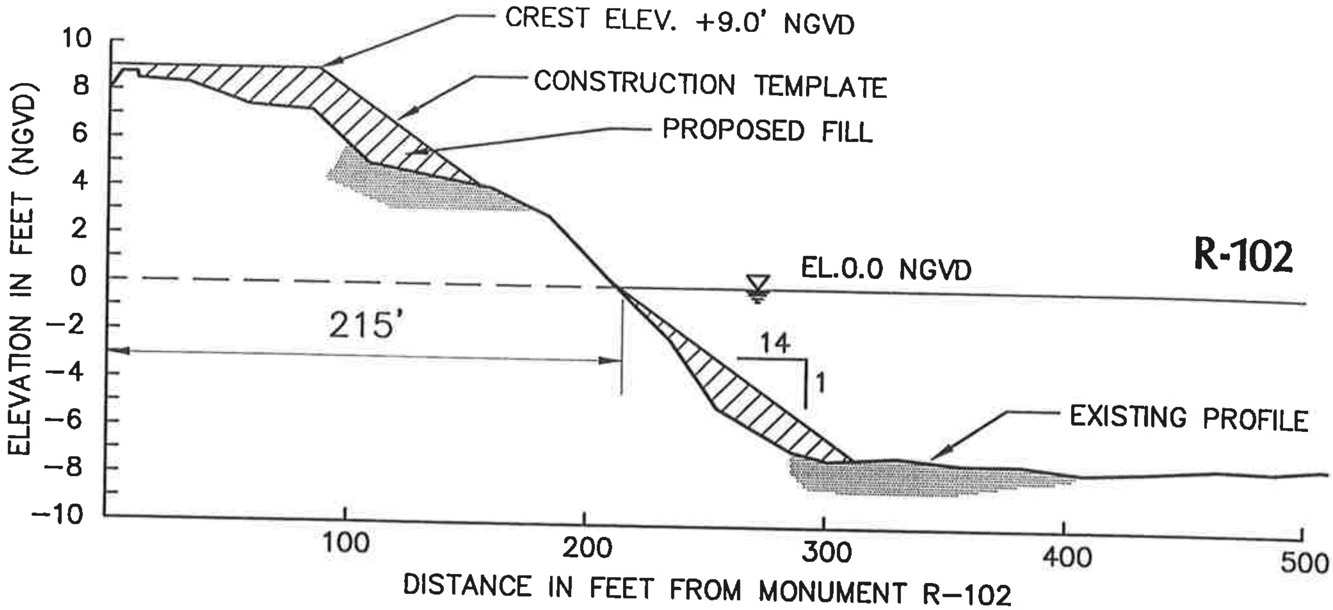
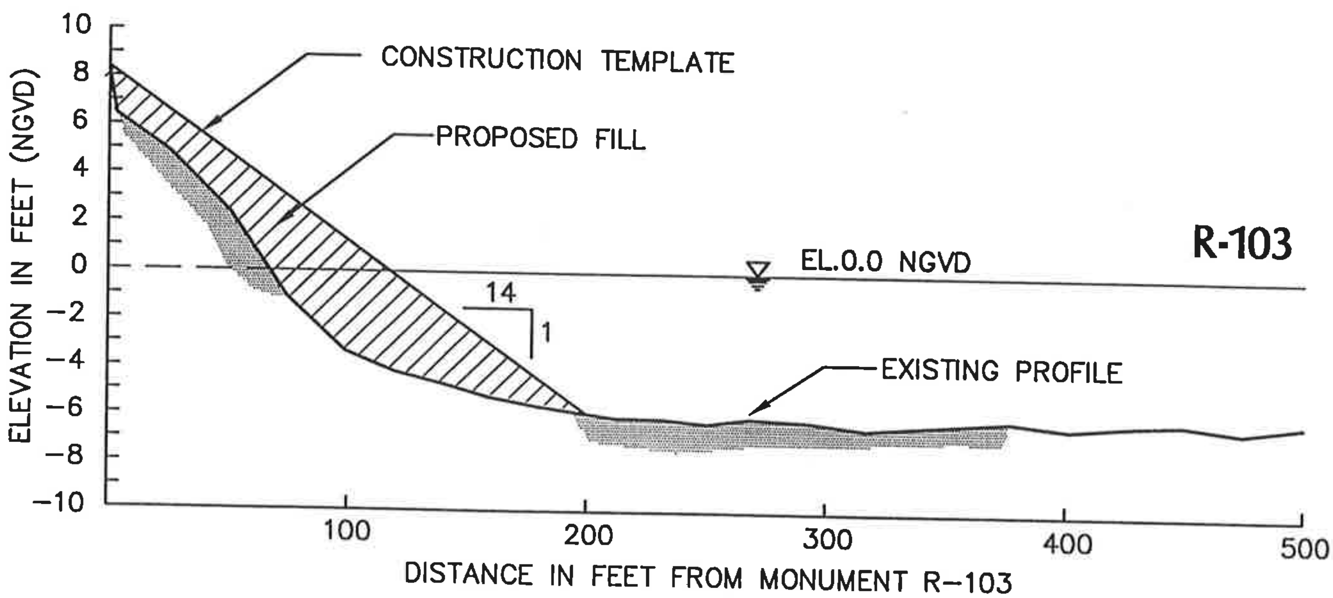


FIGURE 3.1
DESIGN TEMPLATE
VILLAGE OF KEY BISCAYNE





NOTE:

THE FILL TEMPLATE CONCIDES WITH THE PERMITTED CONSTRUCTION FOOTPRINT OF 1987 BEACH NOURISHMENT PROJECT BY U.S. ARMY CORPS OF ENGINEERS.

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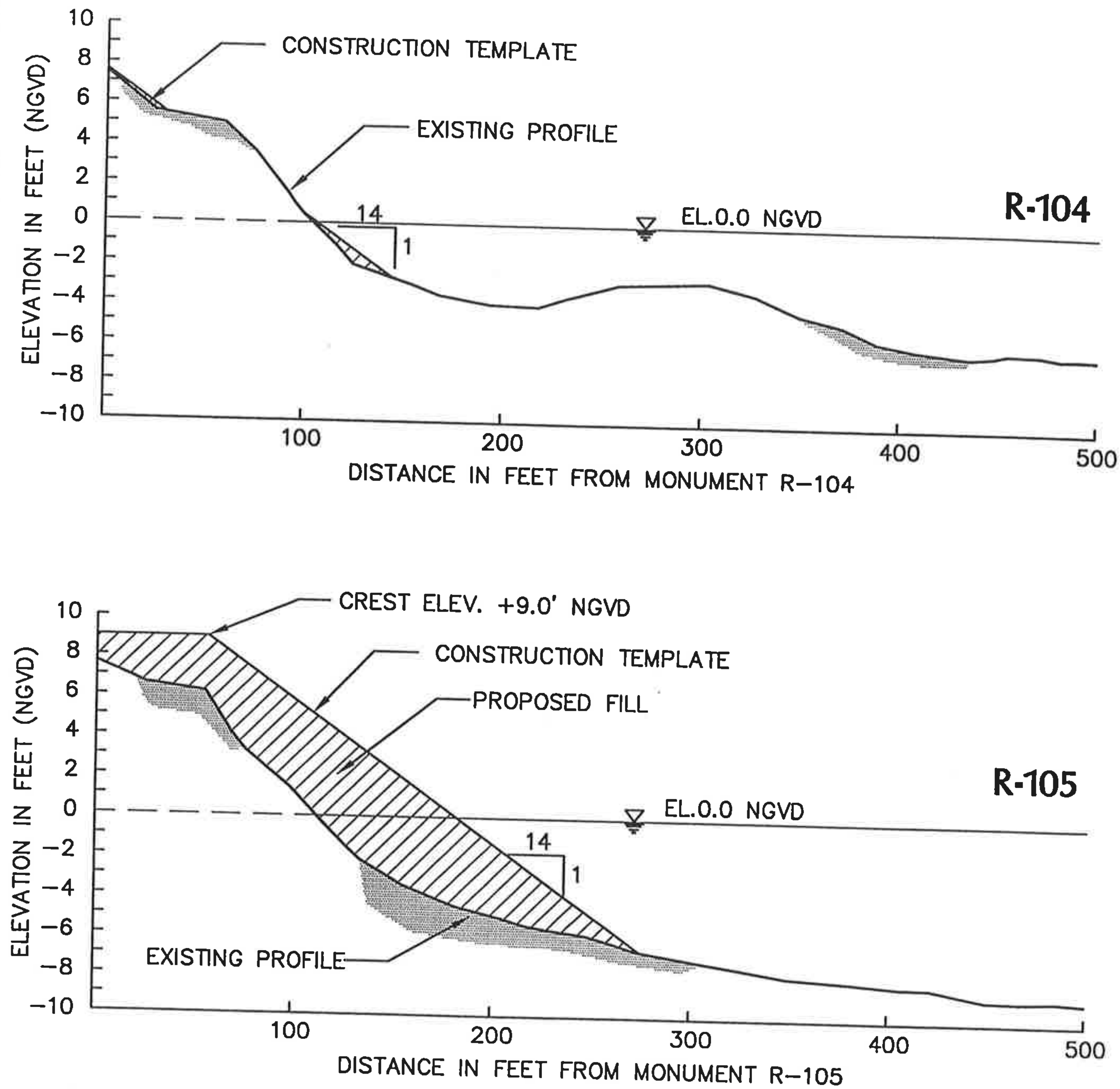
FIGURE 3.2

DESIGN CROSS-SECTIONS

DNR MONUMETS 102 & 103



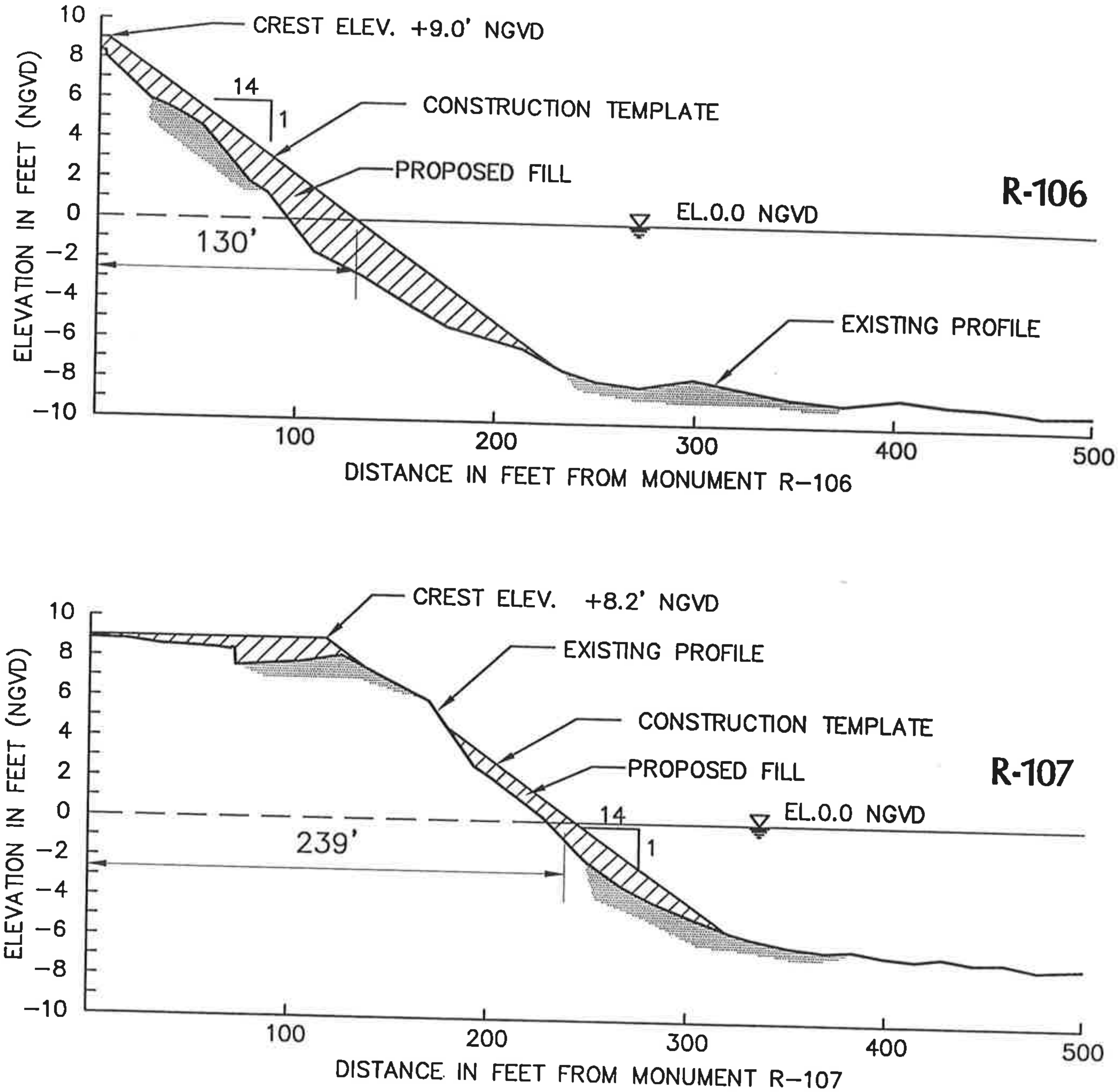
NOTE:

THE FILL TEMPLATE CONCIDES WITH THE PERMITTED CONSTRUCTION FOOTPRINT OF 1987 BEACH NOURISHMENT PROJECT BY U.S. ARMY CORPS OF ENGINEERS.

FIGURE 3.3

DESIGN CROSS-SECTIONS

DNR MONUMETS 104 & 105



NOTE:

THE FILL TEMPLATE CONCIDES WITH THE PERMITTED CONSTRUCTION FOOTPRINT OF 1987 BEACH NOURISHMENT PROJECT BY U.S. ARMY CORPS OF ENGINEERS.

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FIGURE 3.4

DESIGN CROSS–SECTIONS

DNR MONUMETS 106 & 107

The overfill volume is the additional material needed to offset the losses due to dissimilarities between the grain-size characteristics of the native beach sand and the proposed fill source(s). In general, fill sands with the same or coarser sized grains as the native sand will tend to be more stable than finer-grained fill sands. Since in this case, the total construction fill is limited by the 1987 beach fill footprint, the overfill volume will form a portion of the total proposed 120,000 cubic yards. The overfill volume is usually only applied to the amount of nourishment material that will be exposed directly to wave or current action over the nourishment interval. Because, the nourishment volume in this case is expected to completely erode over the 10 year nourishment interval (and thus the total volume exposed to wave/current action), an overfill factor is applied for the entire nourishment volume. The potential sand sources examined for this project have overfill ratios generally ranging from 1.0 to 1.5 primarily depending on their median grain sizes. Based on an average overfill factor of 1.22, an average overfill quantity is estimated at approximately 18,000 cubic yards using the modified method as presented in the Shore Protection Manual (USACE, 1984).

3.2.3 Storm Protection

To investigate the potential for increased storm protection from the placement of the proposed fill, the bluffline recession is simulated under various storm intensities for both the existing conditions (based on April 1996 survey) and proposed fill conditions. This simulation is applied using the numerical model EBEACH developed by R.G. Dean and D.L. Kriebel (Kriebel, 1984). This is the same model currently used by the Bureau of Beaches & Coastal Systems, Florida DEP for coastal construction permitting and the establishment of the Coastal Construction Control Line (CCCL).

EBEACH Model: EBEACH is a two-dimensional cross-shore model that provides the time dependent beach/dune erosion under various storm conditions. The model is based on the theory developed by Dean (1977) relating the shape of the equilibrium beach profile to the wave energy dissipation in the surf zone. As input, EBEACH requires the points describing the two-dimensional beach/dune profile and a record of the storm hydrograph relating the rise in water level at 1/2 hour intervals.

For this analysis, the profile at monument R-105 representing a "hot spot" area was chosen for evaluating the storm impact under 10, 20, 50, and 100-year storm return periods. The storm hydrograph currently used by DEP for Dade County (example shown previously in Section 2.3.3) is used for the input hydrograph. The hydrograph is extrapolated by EBEACH to match the input storm surge levels of 8.2, 9.8, 12.1, and 14.0 feet NGVD corresponding to the 10, 20, 50, and 100-year surge levels as determined by Dean and Chiu (1981) for central Key Biscayne. The analysis effectively neglects the presence of seawalls or bulkheads giving generally more conservative results.

Simulated Shoreline Recession: The results of this storm erosion analysis are presented in Figure 3.5 both with and without the proposed beach fill. The results indicate that under storm conditions ranging from 10 to 100 year intensity, the associated landward erosion of the existing profile ranged from approximately 100 to 185 feet, respectively, landward of monument R-105. The 100-year erosion in this case reaches to approximately 150 feet landward of the seaward-most face of The Sands Condo. With the proposed fill in place, this landward encroachment is reduced to a range of approximately 25 to 95 feet (10 to 100 year storm) landward of monument R-105. Thus, the 100-year erosion limit with the proposed fill, reaches to approximately 60 feet landward of The Sands, representing potentially a much reduced threat for undermining of the structure.

This analysis indicates that the proposed fill, while only increasing the beach width by approximately 60 feet at R-105 (equilibrium fill), will potentially reduce the landward erosion limit during a 100-year storm event by approximately 90 feet.

The associated volumetric loss ranges from 26 to 35 cubic yards per linear foot of shoreline for the 10 to 100 year storm events. The majority of this eroded material remains in the nearshore area and typically will migrate back onshore under the predominate wave conditions. Impacted dune areas, however, may take years to recover under natural forces and may require restoration efforts.

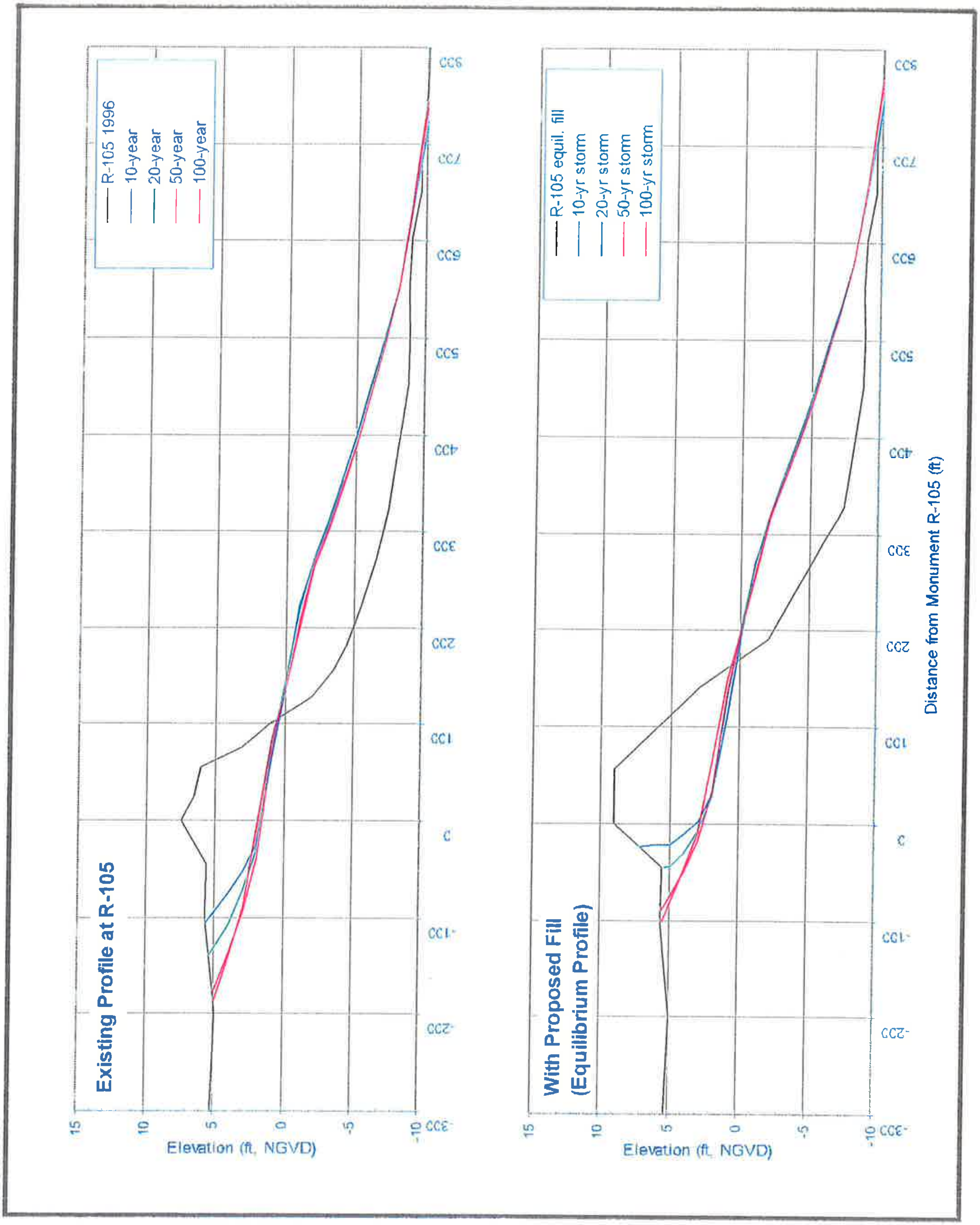

FIGURE 3.5

PREDICTED STORM EROSION
WITH AND WITHOUT PROPOSED FILL

3.3 Sand Sources

Due to the moderate amount of sand needed for this beach nourishment project, no apparent sand source including upland, offshore, and foreign become obviously cost effective under economic consideration. Each sand source has its pros and cons and requires detailed evaluation and comparison. Potential sand sources for the needs of renourishing the beach of the Village of Key Biscayne are categorized into upland, offshore and foreign sources. In general, upland sources are available from numerous pit mines within the State of Florida. Less commonly, material may be available at nearby construction sites where excavation spoil may contain a percentage of beach-compatible material. Offshore sources generally include offshore deposits of sand delineated as borrow sites as well as the ebb and flood shoals associated with navigational inlets. Foreign sand sources mainly located in the Caribbean, have sufficient quantity of beach compatible material that may be suitable for nourishment needs.

3.3.1 Upland Sources

Potential upland sources for this project include beach-quality material from Cape Florida Wetland Restoration project, South, and Central Florida quarries. Detailed description of these sources is summarized as follows:

Cape Florida Wetland Restoration Project: Excavation associated with this wetland restoration project including all phases could generate a total of approximately 100,000 cubic yards of beach-quality material that may be available for the municipality's beach nourishment projects. The quantity of available beach quality material is estimated based on the assumption that 50% of the beach quality material will be lost due to the mixture with finer material during excavation. Presently, approximately 65,000 cubic yards of beach quality material has been trucked and stockpiled on a vacant area located at the south part of the Virginia Key Park. A potential 35,000 cubic yards of beach quality material may be available for the Village of Key Biscayne's beach nourishment project. Currently, the Village is coordinating with the City of Miami, Dade County and the State towards obtaining this beach-quality material for the Village beach project.

These materials will almost be "cost free" to the Village since the trucking cost would have been paid by the Wetland project.

Central/South Florida: Upland sources of sand are available through many large contractors mining sand at sites throughout central and south Florida. The nearest sites are located in Dade County, Caloosa, Lake Wales, Pompano, West Palm Beach, and Carol City (Figure 3.6).

Sand source costs are shown in Table 3.1 for many of these potential upland sources. In general, the quality of sand obtained from these upland sources is very good since these sites essentially represent preexisting shorelines that have been covered through geologic processes. Organics and silts are typically below one percent for these clean sand sources. Because of this, and the fact that no offshore dredging is involved with the use of these sources, permits are much easier to obtain for construction.

On the other hand, many of these upland sources have a smaller median grain size than native beach sand, ranging from 0.20 mm to 0.35 mm. With the sorting action of waves and currents, a portion of the placed fill may migrate offshore potentially impacting seagrass and hardbottom. A higher overfill factor will be required for the initial construction fill to offset this anticipated offshore loss. Grain size analysis of some of these potential sources is compared to the native sand in Figure 3.8 at the end of this section.

Any use of upland sand sources will have to consider the potential impact to roadways and traffic. It is estimated that more than 6,250 truckloads would be necessary to complete the proposed 100,000 cubic yard fill project (16 cubic yards per truck). This high level of usage may produce accelerated wear on local and state roadways and bridges as well as potentially disrupting local traffic flow.

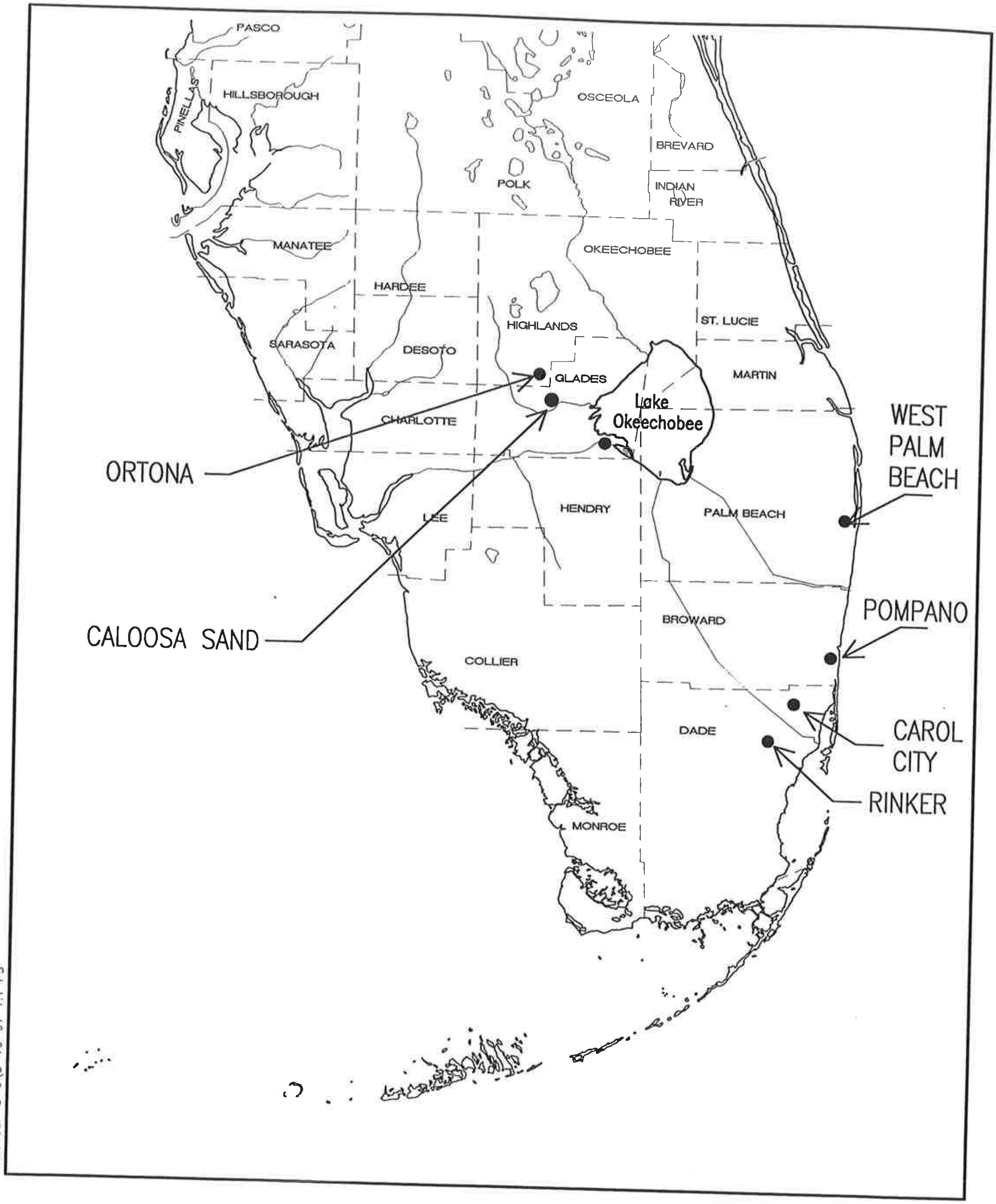

FIGURE 3.6
UPLAND SAND SOURCES

TABLE 3.1

POTENTIAL UPLAND SAND SOURCES

CONTRACTOR	SAND SOURCE LOCATION	QUANTITY AVAILABLE (cu. yd.)	APPROX.[2] UNIT COST ($/cu. yd.)	DESCRIPTION
Rinker Trucking	Inland - Dade County	>1,000,000	9.80[3]	Light brown, medium-coarse grain sand <3% fines
Southport Dredging, Inc.	Inland Sand Pit - Dade County	>1,000,000	17.50[1]	Light gray, medium-fine to fine grain sand with 25% shell & rock fragments
Florida Rock Industries	Caloosa and Lake Wales	>2,000,000	14.80	Medium to fine grain silica sand with <1% fines
MAP Construction, Inc. (#1)	Inland Limestone Quarry - West Palm Beach	>2,000,000	14.90	Light gray, medium to fine grain carbonate sand with <5% fines
MAP Construction, Inc. (#2)	Inland Sand Pit - West Palm Beach	>2,000,000	15.90	Light brown, medium grain silica sand with <1% fines
Environmental Salvage Team	Inland Sand Pit - Northeastern Florida	>5,000,000	16.20	White, fine grain silica sand with almost no silt, shell or rock
Tri-City Excavation, Inc. (#1)	Inland Sand Pit - Cocoa Beach Area	>1,000,000	17.00	Medium brown, medium grain silica sand with <1% fines
Tri-City Excavation, Inc. (#2)	Nearshore Dredge Site - Sebastian Inlet	>400,000	17.00	Medium to light brown, medium grain silica sand with <1% fines
Austin Tupler Trucking (#1)	Pompano - Inland Lake	>1,000,000	12.70	Light brown, medium to fine grain silica sand with <1% fines
Austin Tupler Trucking (#2)	Carol City - Inland Dade County	>1,000,000	11.30	Light tan, fine grain silica sand with <1% fines
Marin & Marin Construction	Nearshore Dredge Site - Ft. Meyers	400,000	18.90	Light gray,medium-fine to fine grain sand silica with 10% shell & rock fragments

Notes:

1. This cost includes trucking sand to the beach and beach regrading.
2. The unit cost in cubic yards is calculated based on the contractor's quoted unit cost (in ton) multiplied by a factor of 1.35.
3. The cost includes only trucking sand to the beach.

3.3.2 *Offshore Sources*

Two potential offshore borrow sites exist directly offshore of Government Cut and south of the Key Biscayne Lighthouse, as shown in Figure 3.7.

Dredging from these borrow sites can be accomplished with either a hydraulic cutterhead dredge or hopper dredge. In general, the hydraulic dredges are more efficient for this type of job, less expensive to operate, and produce less turbidity. However, these advantages can only be realized during relatively calm sea conditions that occur more frequently during the summer months. Hopper dredges, while more expensive, can work for a longer extended period in the heavy winter seas than a hydraulic dredge. The choice of dredge type for this project will be determined by a number of factors including the time of year when dredging is proposed to be conducted, turbidity requirements at the borrow site and project area, and whether or not dredging will be allowed during the sea turtle nesting season (May 1 through October 31).

For large fill quantities, costs for these offshore sand sources are typically less expensive than upland sources of the same quality. However, it is not necessarily true for projects with moderate fill quantities, like the proposed project. Costs for pumping sand on the beach will generally range from approximately $4.00 to $8.00 per cubic yard based on the dredge type and working efficiency (down time, etc.). With added mobilization/demobilization costs of an estimated $750,000, unit costs range from approximately $11.50 to $15.50 per cubic yard for this proposed project. Sand grain size curves for the 1987 borrow site are compared with the native sand and other potential fill sources in Figure 3.8.

3.3.3 *Foreign Sources*

The two most commonly mentioned foreign sand sources for beach nourishment come from the Bahamas and Turks and Caicos Islands. Pros and cons of using these foreign sand sources for beach restoration projects are detailed in the following:

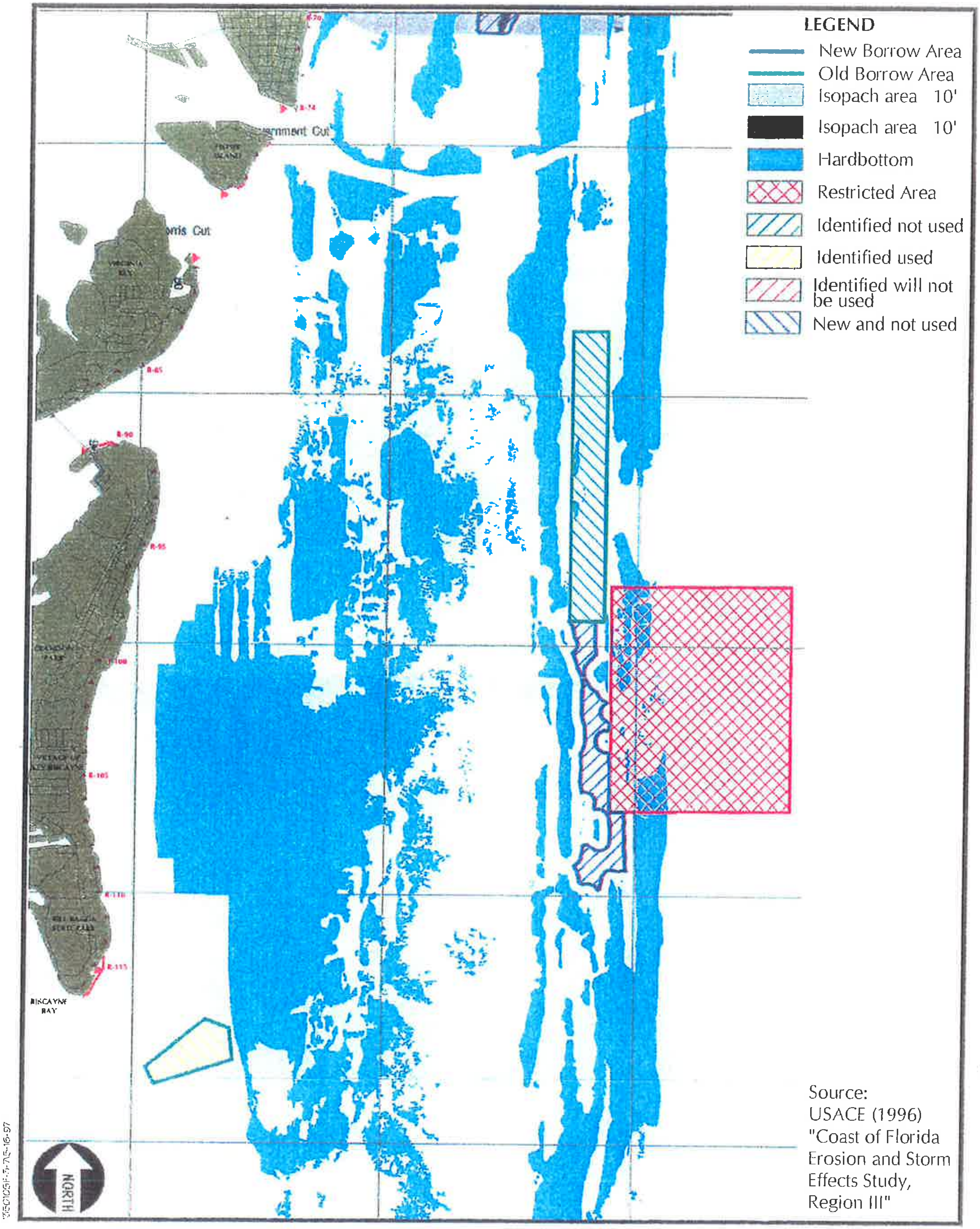

FIGURE 3.7

OFFSHORE BORROW SITE AND HARDBOTTOM COVERAGE

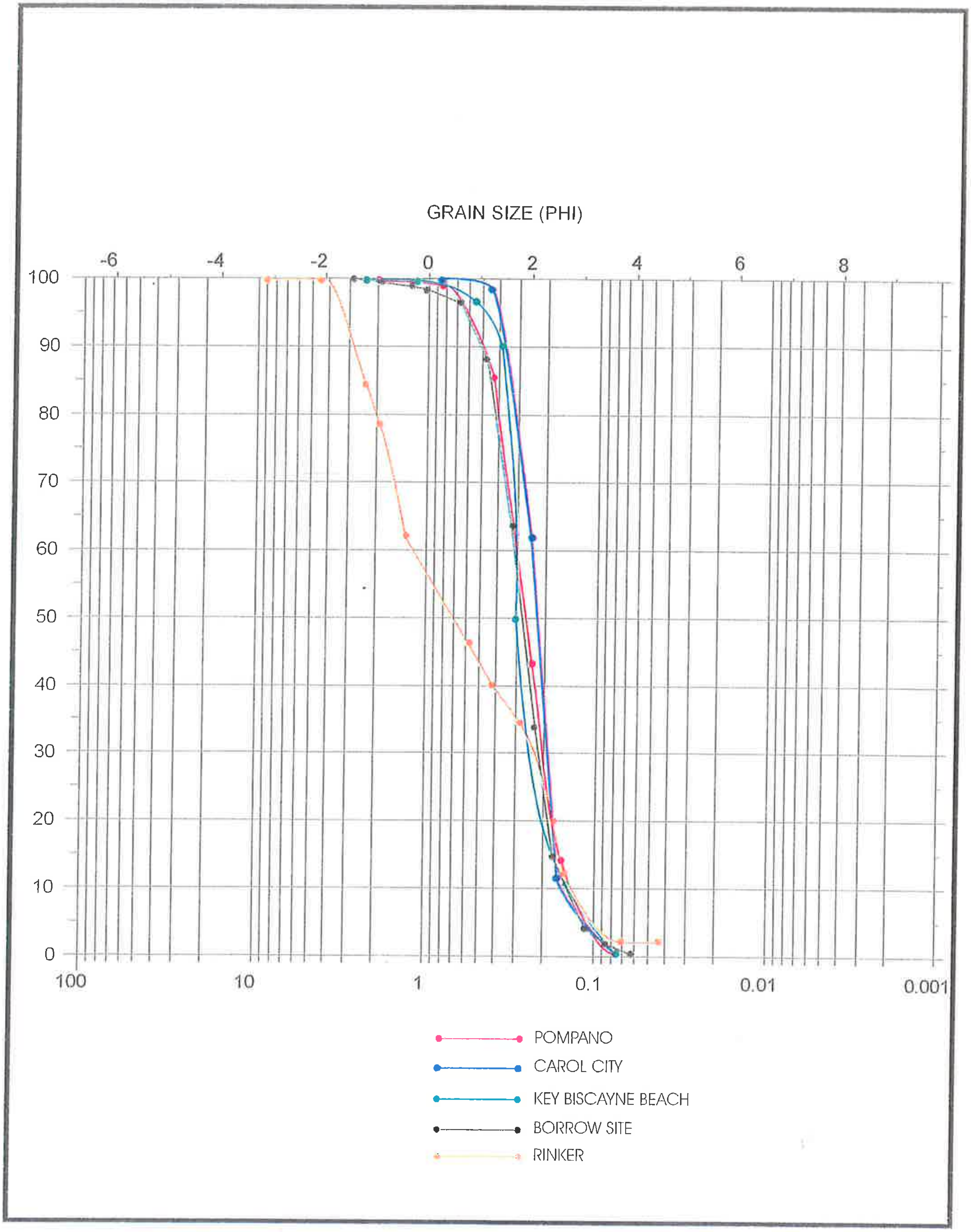

FIGURE 3.8
GRAIN SIZE ANALYSIS

Bahamas Sand: Since the early 1960's, Bahamas aragonite sand has been proposed as a potential source for beach restoration projects in the state of Florida. Aragonite sand is a clean, white, uniform sand that has a median grain size of approximately 0.3 mm. Due to environmental concerns, Bahamas aragonite has not been widely used as compatible beach fill, even though it is feasible economically due to the increase in cost of offshore dredging. Only one small-scale beach fill project using Bahamas aragonite was documented for physical changes subsequent to the beach fill construction. This project placed approximately 25,000 cubic yards of aragonite along the Fisher Island Atlantic shoreline in 1991 (Olsen and Bodge, 1991). However, the subsequent monitoring program did not include environmental effects associated with the placement of aragonite sand (a separate study discussed in 3.4.1, however, examined effects on sea turtle nesting). Due to increasing demand of sand sources for beach nourishment projects in the State of Florida, aragonite sand from the Bahamas becomes attractive due to its nearby location approximately 50 miles east of Miami with sufficient quantity of sand to meet the demand.

The U.S. Army Corps of Engineers presently agreed to move forward with two testing projects, one in Dade County and one in Broward County, to evaluate potential environmental impacts, particularly for sea turtle nesting associated with the placement of aragonite sand. The experimental testing projects are currently scheduled for the year 1999 with subsequent extensive environmental monitorings. The results from these experimental projects may become available around the years 2003 and 2004. Prior to the approval of regulatory agencies for the use of Bahamas aragonite in Florida, local project sponsors may still be able to utilize this sand source if reasonable justification is provided. The cost of using Bahamas aragonite sand is estimated in the range of $15 to $20 per cubic yard in place.

Turks and Caicos Sand: Proposals for utilizing sand in the Turks and Caicos Islands are presently being developed and may provide a long-term sand source for beach nourishment, if a means of cost-effective long-distance transportation can be developed. This sand is a tan, medium to fine-grained aragonite sand with almost no silt, shell, or rocks. Due to the long distance of transporting sand from the Turks and Caicos to Dade

County, use of this sand source is more expensive than other sources with an estimated unit cost of $23.00 per cubic yard. In addition, special approval will be required prior to importation of this sand for beach restoration projects.

3.4 Environmental Considerations

The environmental considerations of the proposed beach nourishment at Key Biscayne primarily concerns the potential impacts to nearshore seagrasses, hardbottom communities, and endangered sea turtles. The proposed nourishment may potentially provide long-term benefits to sea turtle nesting and native dune colonization.

3.4.1 Potential Impacts

Seagrasses: Impact to seagrasses primarily involves the area of nearshore beds that may be covered by the toe of the initial fill with the potential for additional coverage through the equilibrium spreading of the fill. This was a major concern leading up to the 1987 fill project that led to many design modifications involving both a reduction in total fill volume and change in design template and slopes to lessen the impact to seagrasses. The final 1987 fill placement was determined to have impacted 28.6 acres of seagrass due to direct burial (Flynn et al, 1991). However, this coverage represented only 1.4% of the total 2,000 acres of seagrass reported offshore of the project site (USACE, 1984).

The present proposed project is anticipated to have only minimal impacts, being designed to the same construction footprint as the 1987 project . Based on the recent February 1997 DERM investigation of the nearshore seagrass limits and 1996 aerial photographs, an estimated 2.6 acres may be impacted directly with an additional 4.1 acres potentially impacted due to the equilibrium adjustment of the toe of fill.

Nearshore seagrasses in general, will tend to mirror the landward movement of the eroding shoreline, such that any proposed fill project will invariably involve the coverage of some seagrass. Establishment of a dedicated fill template for periodic nourishment may help to alleviate future environmental concerns over seagrass impact as well as simplify the permitting process.

Hardbottom: Potential impacts to hardbottom areas generally include direct burial by sediments or turbidity occurring either during or after construction. Hardbottom areas are generally located offshore of the proposed project area within the Village such that no direct impact is anticipated from the beach fill. Any impacts associated with increased turbidity are expected to be short-term only and relatively minor. There is potential for direct impact of hardbottom associated with the dredging of the offshore borrow site located directly east of Key Biscayne. This new borrow area is located between two high-relief hardbottom ridges. Another potential borrow site used for the 1987 fill project is located within the shoals southeast of Cape Florida. Use of this borrow site is expected to have only minimal impact since the shoals represent an area of dynamic shifting sand with little biological productivity (USACE, 1984).

Sea Turtles: Direct impact to sea turtles can generally be avoided by scheduling the nourishment outside of the window for nesting which runs from May 1 to October 31. June and July, however, are generally considered the ideal months for dredge-related nourishments due to the relatively calm seas and fair weather conditions that occurs during this time of the year. Nourishment projects may be conducted during the nesting season, providing that the applicant performs the necessary comprehensive monitoring as required by DEP. These monitoring requirements for sea turtles are summarized in Section 4.3.2. Projects using an upland sand source, however, will not be dictated by sea conditions and can therefore be constructed outside of the nesting season.

Another issue concerning sea turtle nesting is the compatibility of the beach fill in terms of grain size, chemical composition, compaction levels, and the creation of beach scarps (common to renourished beach slopes as they equilibrate). Use of Bahamian oolitic aragonite, which is chemically different from the native quartz-carbonate sand, was found to have no significant impact on the nesting success of the loggerhead sea turtle over a 3-year study at Fisher Island. Aragonite sand temperatures, however, were slightly cooler (due to the lighter sand color), extending incubation times by 5-6 days and possibly altering natural sex ratios of the hatchlings (Milton, et al, 1995).

Problems associated with compaction and the formation of beach scarps that present potential problems for nesting sea turtles can be largely eliminated with periodic tilling of the beach face. Use of beach cleaning equipment on a regular basis may help to reduce beach scarps, and reduce surface level compaction.

3.4.2 Potential Benefits

Sea Turtle Nesting: With proper planning and management, nourishment of beaches may potentially produce long-range environmental benefits supporting sea turtle nesting. The most obvious and direct benefit is the restoration of beaches that may have been completely eroded away or the creation of additional beach area providing increased substrate for sea turtle nesting.

In general, sea turtles dig their nests in the region between the MHW and the top of the primary dune (Nelson, 1991). Turtles attempting to nest on eroding beaches that lack adequate substrate may be turned away or dig nests at too low of an elevation, potentially resulting in inundation by waves and high tide. Management of this critical beach habitat through periodic nourishment is therefore key to supporting sea turtle nesting in areas of continuous erosion such as occurs along the Village.

Dune Restoration: Historical erosion along the Village has typically resulted in the loss of substantial dune habitat due to the close proximity of the seawall/structures. Periodic nourishment can help to preserve a continuous dune habitat which has benefits to the Village both environmentally and esthetically. The natural formation of the "pioneer" and "fore" dunes is primarily a result of wind-blown sand being trapped and stabilized by beach grasses. The role of the dune in beach littoral process is mainly that of a "soft" structure or levee providing protection to the uplands and as a sand reservoir to eroding beaches.

Dune restoration, while potentially benefiting sea turtle nesting as described above, can also support a large diversity of native vegetation including sea-rockets, sand triplex, beach-evening-primrose, sea-oats, bitter panicum, and beach-elder.

4.0 - PLAN IMPLEMENTATION

4.1 General

This chapter outlines a plan of implementation for the proposed beach nourishment along the Village of Key Biscayne. This process will require considerable coordination with Federal, State, and Local agencies to meet all of the regulatory requirements. Construction and monitoring tasks are presented for both an offshore dredge-based operation and upland trucking operation. Issues concerning beach maintenance and public education addressing the importance of a regular periodic nourishment program is also included. The economics of the proposed project are investigated including funding potential, long-range budget planning, and scheduling of the required task.

4.2 Permitting

This Section outlines permitting requirements that will be required by Federal, State, and local regulatory agencies prior to their issuance of permits for the Key Biscayne Beach nourishment project. The regulatory agencies will review the proposed project and evaluate potential impacts on marine resources within the project vicinity as mentioned in Section 3.4. The expected permitting requirements are discussed herein.

4.2.1 Jurisdictional Regulatory Agencies

The Federal, State, and local agencies will review the project and supporting documents to ensure the project is in compliance with environmental requirements. The agencies involved in regulating the beach nourishment project and issuing the required easements and permits include:

U.S. Army Corps of Engineers (USACE): The USACE is responsible for regulating all dredge and fill activities within navigable waters of the United States. In evaluating a new project, the USACE will coordinate with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to ensure that the project, as proposed, is in compliance with all applicable Federal laws and regulations.

Florida Department of Environmental Protection (DEP): The Florida DEP has various divisions that are responsible for regulating activities proposed on State-owned lands, influence the delineation of public and private property that are seaward of the Coastal Construction Control Line (CCCL), and/or involve dredging and filling within the waters of the State. All required State approvals will be issued jointly under the new Florida Joint Coastal Permit (JCP) program which was adopted to streamline the permitting process and reduce the time required to obtain permit approval.

Dade Environmental Resources Management (DERM): As DERM is responsible for regulating dredging and filling activities within the waters of Dade County, a DERM Environmental Resource License is required for the proposed project.

Village of Key Biscayne: The Village of Key Biscayne is required to review and pass a resolution supporting the project, prior to issuance of the State JCP permit.

4.2.2 Regulatory Agency Requirements

A typical beach nourishment project, depending on the source of sand used, will require submittal of substantial physical and environmental data to the regulatory agencies prior to their issuance of permits. This data entails details of physical conditions and marine resources within the project vicinity. Specific plans and monitoring program need to be developed to ensure the water quality (turbidity) and sand cross-shore and longshore movement during and after the construction will not impact adjacent seagrass and hardbottom.

Monitoring components required by the regulatory agencies are covered in more detail in Section 4.3.2. These requirements in general include beach profile and borrow site surveys, marine surveys of the seagrass and hardbottom communities, sediment analysis of the native beach and borrow site, core borings of borrow site, turbidity monitoring, and sea turtle monitoring.

Environmental Impact Assessment: An environmental impact assessment (EIA) may be required by the regulatory agencies to document the extent of habitat and associated biota which potentially may be impacted by the proposed project. In general, the EIA will involve extensive surveys to create an inventory of the biota and marine environment characteristics combined with relevant historical data. These surveys will usually include, but are not limited to, dune areas and vegetation, nearshore seagrass/hardbottom with associated fauna and flora, and nearshore/offshore infaunal benthic invertebrates. In addition, a study of the physical conditions of the area would include monitoring of the water quality, extent and location of hardbottom areas, seagrass beds, and offshore reefs, and characteristics of native beach sands and proposed offshore borrow sites.

4.3 Construction/Monitoring Plan

4.3.1 Construction

Construction methodology associated with the beach nourishment project at the Village will vary depending on whether an offshore, upland, or imported sand source is utilized. The general construction methods involved for these three alternatives are discussed below.

Beach Fill Using Offshore Sand Source: A fill project of this type would typically involve the use of a hydraulic cutterhead dredge pumping sand from the borrow site to the beach via steel pipeline. In general, these dredging operations would take place during the winter months outside of the sea turtle season (May 1 to October 31). The size of the required dredge is anticipated at 20 to 27 inches depending primarily on the depth of the borrow site. In general, these hydraulic dredges can pump large amounts of sand relatively quickly, on the order of 10,000 to 20,000 cubic yards per day. Thus the total construction duration for 120,000 cubic yards of fill, including allowances for mob/demob and weather downtime, is anticipated at approximately 2 to 3 weeks.

The steel pipelines would need to be routed to the shoreline along predetermined corridors, established to avoid any hardbottom or other environmentally sensitive areas. The pipeline exists at the beach where sand is pumped into a trench constructed in the beach face and separated from the ocean by a shore-parallel sand dike. The purpose of the trench/dike construction is to reduce turbidity. This construction process effectively traps the sand/water slurry mixture and allows the sediment to fall out of suspension before the runoff returns to the ocean. The fill is pumped on the beach usually starting at one end and progressing towards the other. One or more bulldozers will generally follow behind scraping down the dike landward into the beach face to form the construction profile.

Beach Fill Using Upland Sand Source: Use of any of the potential upland sand sources will require delivery of the sand by trucking. As discussed previously in Section 3.3.1, the total proposed fill placement of 120,000 cubic yards will involve approximately 7,500 truckloads based on an average capacity of 16 cubic yards per load.

The total duration of the construction using an upland source may vary considerably depending on the number of trucks used, the distance to the sand source, and the truck capacity. Assuming a minimum of 30 trucks, each making 3 trips a day from an upland sand source less than 100 miles away, approximately 84 working days or 108 calendar days (15.4 weeks) will be required to complete the fill project (assuming there will be no operation during the weekend due to safety issues). At this rate, a truck would arrive at the site approximately every 7 minutes during working hours. If 40 trucks were available, this trucking time would reduce to approximately 63 working days or 81 calendar days (11.6 weeks), with a truck arriving approximately every 5 minutes during working hours. Once placed, the fill will be spread and shaped to the dimensions defined by the construction profile using bulldozers.

With trucks arriving at the project site every 5 to 7 minutes, considerable planning and coordination will be needed to regulate the traffic flow, including selection of construction accesses and the location of a construction staging area. Potential construction accesses are presented in Figure 4.1 connecting the project site to Crandon Boulevard. These potential construction accesses are temporary and used only during the construction. In

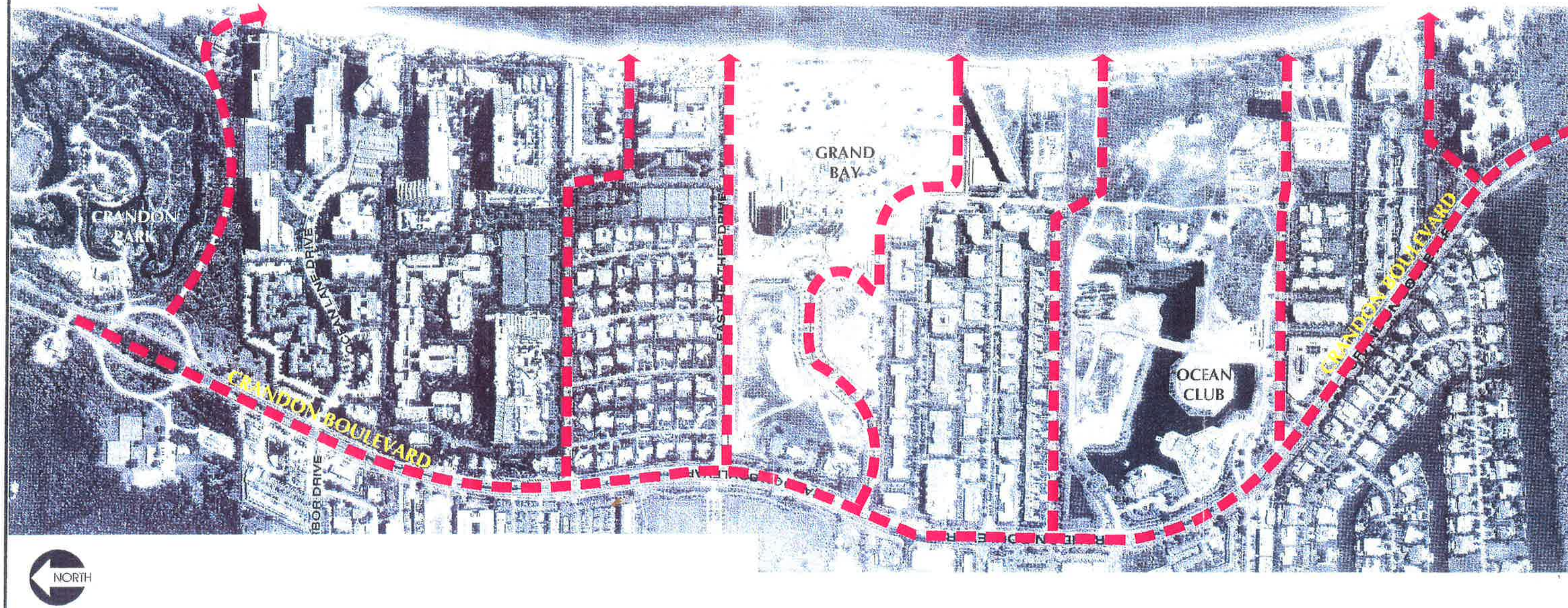

FIGURE 4.1
CONSTRUCTION ACCESS ROADS

general, a minimum access width to the beach of 12 feet will be needed with preference given to larger accesses to allow for two-way traffic.

Beach Fill Using Foreign Sand Source: Imported sand from potential foreign sites such as the Bahamas and the Turks & Caicos can be transported in fairly large quantities by ship. Getting the sand to the beach can involve different scenarios as discussed below:

One method developed by Marcona Ocean Industries for transporting aragonite from Ocean Cay, Bahamas, uses a ship with 50,000 cubic yards capacity that transports the sand to a mooring location offshore of the project site. Sand can then be transferred directly to a hopper dredge (moored alongside) that pumps the sand to the beach via pipeline, similar to a normal dredging operation. Continuous operation for large fill projects could be accomplished using two transport ships.

Another option would involve the transportation of sand by ship directly into the Port of Miami. Sand could then be transported into trucks with continuous delivery to the project site. These two options, in general, would involve the same type of beach construction methodologies as presented previously for offshore dredging and upland trucking, respectively.

4.3.2 Monitoring

In general the required monitoring components of the project will involve both physical and environmental monitoring of the project site, vicinity and any proposed offshore borrow site(s). The physical monitoring is required to document the beach fill performance which will aid substantially in the evaluation of future nourishment needs. The environmental monitoring is required to document any impacts caused by the proposed project on the surrounding environment. A general outline of the expected monitoring components is presented in Table 4.1. Each of these monitoring tasks is discussed separately below:

TABLE 4.1

PHYSICAL AND ENVIRONMENTAL MONITORING COMPONENTS

MONITORING TASK	FREQUENCY
I. PHYSICAL MONITORING	
A. Profile Surveys B. Aerial Photography C. Borrow Surveys	Pre and post-construction, 6 months, annually thereafter for at least 5 years.
II. ENVIRONMENTAL MONITORING	
A. Pre-construction 1. Turbidity 2. Sediment Analysis 3. Seagrass/Hardbottom Survey 4. Sea Turtle[1]	Once prior to construction.
B. Construction 1. Turbidity 2. Sea Turtle[1]	Duration of construction.
C. Post-Construction 1. Turbidity 2. Sediment Analysis/Compaction 3. Seagrass/Hardbottom Survey 4. Sea Turtle[1]	Generally at yearly intervals for 5 years or to be determined by permit requirements.

Notes:

[1] Sea turtle monitoring only required during nesting season, May 1 - October 31.

Beach Profile Surveys: Extensive hydrographic surveys will be required to collect the most recent topography and bathymetry along the 4.4 miles of Atlantic shoreline at Key Biscayne. The survey transects need to align with DEP's monuments with spacing no greater than 500 feet. Each beach profile should be surveyed extending from existing beach dune or seawall to approximately 2,500 feet offshore. This survey also requires the delineation of the Mean High Water (MHW) and Mean Low Water (MLW) lines within the survey limits.

In addition, a survey of bathymetry of the offshore borrow site is also necessary if an offshore sand source is chosen for the proposed beach fill. The regulatory agencies would typically also require an annual hydrographic survey for five years after the construction to monitor the movement of sand. This long-term survey data will allow the comparison of expected and observed post-construction longshore and cross-shore sand movement and its associated impacts to nearshore seagrass and hardbottom.

Turbidity Monitoring Plan: State of Florida water quality regulations require that turbidity levels outside the mixing zone not exceed 29 NTU's above background at any time during the dredging operation or sand placement on the beach. A water quality (turbidity) monitoring plan is required to demonstrate the activities proposed to maintain ambient water quality standards outside the allowed mixing zone. A "mixing zone variance" may be requested from the agencies to extend the typically allowed mixing zone according to the type of operation required for sand source. In addition, this plan is required to outline all remedial action that will be taken to restore ambient water quality standards should turbidity violations occur during the dredging or beach fill operation.

Core Boring and Sediment Analysis: If an offshore sand source is selected and used, core boring logs from representative points throughout the selected borrow site need to be obtained and core sediments need to be analyzed for grain size distribution and organic contents. Core boring logs should extend at least two feet below the proposed excavation bottom elevation. The depth of each visible stratum in the log should be documented relative to NGVD and the material in each stratum is classified according to grain size.

The core boring spacing should be no greater than 1,000 feet apart. Based on the USACE's 1986 design documents for Key Biscayne's 1987 beach nourishment project, the borrow site south of Key Biscayne lighthouse was used as a sand source and was excavated down to an elevation of -10 feet Mean Low Water, or -11.3 feet NGVD. Thickness of cut in the borrow site typically varied from 4 to 7 feet. Sediment grain-size analysis of the native beach will be needed both before construction and as a periodic post-construction monitoring.

Seagrass/Hardbottom Community Surveys: A survey of the extent and location of all nearshore and offshore seagrass and hardbottom in the project vicinity is required to evaluate predicted physical impacts within the project area resulting from the proposed beach fill design template and borrow site. Natural community surveys are required to evaluate the biological impacts to seagrass and hardbottom communities that may be expected within the project vicinity. Long-term biological monitoring surveys of all seagrass and hardbottom areas within the project site may be required by the regulatory agencies. This data would allow the evaluation of the impact of the project on the fauna and flora communities.

Sea Turtles: Impacts to the endangered sea turtle nesting season which runs from May 1 to October 31 can be avoided by conducting construction activities outside of this season. However, in some cases nourishment projects may be approved during the summer months provided the applicant can provide the required monitoring components as imposed by the DEP. These general monitoring requirements for marine turtle protection are listed below (Arnold, 1995):

1) When work is proposed during nesting season, daily morning nest surveys are required starting 65 days in advance of the construction.
2) Nests that will be affected by the construction shall be relocated to an approved nearby self-release site.
3) Relocated nests and a random sample of undisturbed nest shall be evaluated for hatchling success rates.

4) If monitoring reveals beach compaction levels exceeding approved levels the beach must be tilled.

5) Scarps that form on the nourished beach must be removed.

6) All marine turtle activities must be recorded and submitted in a report.

4.4 Beach Maintenance/Public Education

4.4.1 Beach Maintenance

Maintenance of the beach area mainly involves the action of cleaning the beach face to remove deposited seaweed and trash. Although mainly considered as an aesthetic benefit to the beach, periodic cleaning may potentially produce other benefits. As discussed in Section 3.4.1, regular maintenance of the beach with beach cleaning equipment can help to eliminate beach scarps (commonly forming after nourishment) that present potential problems for nesting sea turtles. In addition, the action of beach cleaning may help to reduce compaction of the upper surface of the beach face (although the weight of the equipment may increase compaction deeper within the sediment).

Currently, the Village contracts an independent contractor for periodic beach cleaning services. The contractor provides a raking vehicle and an operator to clean the beach 3 days a week, 6 hours a day to remove the seaweed along the shoreline and bury it at the toe of the existing dune. We do not expect that the Village beach cleaning practice would increase or accelerate beach erosion in Key Biscayne.

4.4.2 Public Education

Public education is important to the Village, both for keeping the public informed on upcoming projects and as a means to provide education on the significance of maintaining a viable beach and dune system. Some of the major aspects of public education that were initially touched on in Section 1.4 are discussed below:

1) **Economic Benefits:** The beach is a key recreational feature of the Village. As such, it represents a substantial economic value for attracting residents/visitors and maintaining Village property value. The quality of the Village beach may indirectly

effect the larger area of Key Biscayne including Bill Baggs State Park and Crandon County Park which draw a large number of tourist and economic benefit. Public education should focus on this high economic value of the beach. The public should additionally be made aware of the importance of the beach/dune in providing storm protection to the upland structures and buildings and the potential economic savings in reduced or subverted storm damage.

2) **Expedient Action:** All too often, the impetus to nourish beaches occurs after severe erosion has already stripped away significant beach area and dune habitat. Under these conditions, seawalls and upland structures may be highly vulnerable to direct wave attack, particularly during storm conditions. Part of public education/ awareness should include the importance of starting and establishing a plan of action before the beach is in a state of critical erosion.

3) **Environmental Issues:** Public awareness on environmental issues pertaining to those addressed in Section 3.4.1 include potential impacts to nearshore seagrasses and hardbottom communities. Long-term benefits associated with the re-establishment of a dune system with the colonization of native vegetation and the maintenance of a stable beach for sea turtle nesting should also be addressed.

4) **Funding/Permitting:** Education relating to the funding process including the importance of providing an annual allocation of tax dollars devoted to beach nourishment/enhancement. This would include education on the development of the 10-year budget plan and the requirements imposed by DEP to receive funding eligibility.

4.5 Economics

4.5.1 Funding

Potential funding sources for this proposed beach nourishment project include those associated with Federal, State, and Local Agencies. Local sources include Dade County and the Village of Key Biscayne.

Federal: According to "The Coast of Florida Study" (USACE 1996) and our discussion with Mr. Charles Stevens, the Army Corps of Engineers project manager for Dade County beach nourishment projects, the Village of Key Biscayne shoreline protection project was not recommended for Federal funding. Due to budget constraints, the administration limits Federal participation in funding new beach erosion control projects, which are not already authorized by Congress. The chances to obtain Federal funding for this project is considered to be very small at the present time.

State: Pursuant to Section 161.101, Florida statutes, the Florida Beach Erosion Control Assistance Program is authorized and administered under the provisions of Chapter 62B-36, Florida Administrative Code, by the Department of Environmental Protection (DEP). The Florida Beach Erosion Control Assistance Program is a grant-in-aid program established for the purpose of working in cooperation with Local, State, and Federal entities to achieve the protection, preservation, and restoration of the coastal sandy beach resources of the State. The Department is authorized to provide up to 50% of the non-Federal costs of the approved beach nourishment project. Typically, the State will cost share feasibility study, sand search, environmental and other related costs for beach nourishment projects. However, State funding for beach nourishment projects and related studies are based upon the amount of public access and parking established by Department standards.

Local: According to Section 161.25 and 161.37 Florida statutes, the Board of Dade County Commissioners is provided with the power to act as the beach and shore preservation authority and is authorized to use any available County funds for beach erosion control projects. To provide for the capital, operation and maintenance costs of the Beach and Shore preservation program, Dade County has the authority to levy ad valoiem pass and issue bonds.

Funding Processes: Starting the Fiscal Year 1998-99, DEP requests each local sponsor, i.e. county or local municipality, to submit a long-range budget plan with supporting documents in their application for State funding. This long-range budget plan includes a

10-year budget projection for a beach erosion control project with a detailed first five year budget and estimate of funding needs for the following five years. The documents submitted will be reviewed by State and prioritized for funding.

The long-range beach erosion control budget plan and supporting documents need to be submitted to DEP no later than March 31 for each fiscal year. Upon receipt of these submittals, DEP will review, validate, prioritize and consolidate into the fixed capital outlay legislature budget request. This budget request will subsequently be submitted to the Governor and Cabinet, the Governor's office, and finally to the Legislature for funding appropriation. The funds may become available on July 1, if the funding request for this project is approved by the Legislature. The chance of receiving a grant for this project depends on total funds appropriated by the Legislature and the project ranking by DEP. If the funding request is not approved for the fiscal year, it will automatically be shifted for next year's consideration.

Funding Eligibility: To be eligible for State financial assistance, pursuant to Sections 161.101 and 161.161, Florida statutes, the project needs to be:

(a) Designed to protect, preserve, maintain, or enhance beach or dune resources.
(b) Located in an area which has been designated as a critical erosion area by DEP pursuant to Section 161.101, Florida statutes.
(c) Cost effective, with tangible benefits which exceed costs.
(d) Designed to provide a net positive enhancement to the environment and protect historically established habitats.
(e) Consistent with the local comprehensive plan and Chapters 161.253, 258, and 373, Florida statutes.
(f) Accessible to the general public.

Public Access: Publicly owned or controlled beach access ways will be granted eligibility for the shoreline length of the access site. Public lodging establishment, i.e. hotels and motels licensed with the Department of Business and Professional Regulation, Division of

Hotels and Restaurants will be granted 100% eligibility for its beach front property. This factor specifically excludes apartment buildings, rooming houses, rental condominiums, time-shares, and transient apartments. To be eligible for consideration of State funding, the public parking facilities must be located no further than one-quarter mile walking distance from a public beach access site. Public parking spaces and beach access site must be opened and available to the general public on an equal serve basis.

Based on the Village's documentation (De Cocq, 1996), the Village currently has 3,540 feet public access, that would increase to 4,640 feet if the proposed beach-front park is complete. This represents approximately 74 percent of the total length of Village beach, 6,304 feet. These public accesses would make the Village eligible for State funding at 50% of the 74% of total project cost, i.e. 34 percent of costs for construction and related studies.

Project Ranking: DEP has developed and utilized the following criteria to prioritize funding applications, which are submitted for beach erosion control projects, pursuant to Section 161.101, Florida statutes. The ranking criteria are divided into two categories as outlined as follows:

I. PROJECT PERFORMANCE CRITERIA

(a) Degree of Erosion
(b) Mitigation of Inlet Effects
(c) Threat to Existing Development
(d) Benefits (Recreational or Economic)
(e) Performance of the Project

II. SUPPLEMENTAL CRITERIA

(a) Federal Funding
(b) Innovative Technology
(c) Local Commitment
(d) State Commitment

4.5.2 Long-Range Budget Plan

Project Costs: The total cost for the proposed beach nourishment project at the Village of Key Biscayne is estimated at 2.67 million (Table 4.2). This estimate includes costs associated with the engineering, design, permitting, and the required physical and environmental monitoring components. This estimate does not include the costs associated with the use of the offshore borrow site near the Key Biscayne lighthouse. To obtain a State approval to use this borrow site, the Village may need to perform the studies and field investigation including marine resources, mapping, geotechnical investigation, environmental impact assessments, archeological search, hydrographic and easement surveys at this borrow site. With the assumption that the project will be performed outside of the sea turtle nesting season, the presented monitoring costs do not include sea turtle monitoring components.

Based on a 34% costs sharing, both State and Local will pay approximately $988,000 and $1.68 million, respectively. Dade County may potentially share up to 100% of the Local costs depending on funding availability. Further consultation and negotiation with Dade County are recommended.

50-Year Costs: Over a projected 50-year time span, a total of 5 nourishments are anticipated based on a 10-year nourishment interval. Each of these beach nourishments is expected to incur approximately the same total costs of 2.67 million in present day value not considering potential effects due to sea level rise and global warming. The Local share (63%) of these 5 nourishments amortized over 50 years is approximately $330,000, annually, based on an USACE adopted interest rate of 7.625 % and a yearly inflation of 3.0%.

Project Schedule: The anticipated project schedule for implementation of the required tasks is shown in Table 4.3. The funding and permitting processing is currently underway and is expected to reach completion by spring 1999. During this time, other tasks may be completed including the selection of a sand source, field investigations including hydrographic surveying and marine resource mapping, and development of a preliminary design. After the completion of the permit processing, the final design can be developed with construction bidding starting in the fall, 1999. Construction is anticipated to begin in

November (1999) after the end of the sea turtle nesting season. Post-construction monitoring including both physical and environmental components will generally be required on an annual basis for 5 years after the construction.

TABLE 4.2

ESTIMATED COST FOR
VILLAGE OF KEY BISCAYNE BEACH NOURISHMENT PROJECT

PROJECT ITEMS	1st BEACH PROJECT			PROJECTED LOCAL SHARE FOR EACH PROJECT OVER 50-YEAR LIFE[2]					
	TOTAL	STATE[1]	LOCAL	FY 99-09	FY 09-19	FY 19-29	FY 29-39	FY 39-49	TOTAL
Engineering/Design/Permitting	$320,000	$118,000	$202,000	$202,000	$271,000	$365,000	$490,000	$659,000	$1,987,000
Monitoring, Physical & Environmental	$350,000	$130,000	$220,000	$220,000	$296,000	$397,000	$534,000	$718,000	$2,165,000
Beach Fill Construction	$2,000,000	$740,000	$1,260,000	$1,260,000	$1,693,000	$2,276,000	$3,058,000	$4,110,000	$12,397,000
Total	$2,670,000	$988,000	$1,682,000	$1,682,000	$2,260,000	$3,038,000	$4,082,000	$5,487,000	$16,549,000

1. Based on 74% public access of the entire Village beach
2. Assuming 3% annual inflation rate

TABLE 4.3

SCHEDULE FOR PROJECT IMPLEMENTATION
KEY BISCAYNE BEACH NOURISHMENT PROJECT

DESCRIPTION OF ACTIVITY	1997										1998												1999											
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
I. LONG-RANGE BEACH RENOURISHMENT PLAN (including review)	■	■	■	■	■	■																												
II. SELECTION OF SAND SOURCES							■	■																										
III. FUNDING APPLICATION AND PROCESSING																																		
a) Funding Applications	■																																	
b) Funding Processing		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
IV. PERMIT APPLICATION AND PROCESSING																																		
a) Permit Sketches and Application	■																																	
b) Permit Processing		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
V. FIELD INVESTIGATIONS																																		
a) Hydrographic Survey											■																							
b) Resource Mapping/EIA											■	■																						
VI. PRELIMINARY AND FINAL DESIGN																																		
a) Preliminary Design													■	■																				
b) Final Design																											■	■						
VII. CONSTRUCTION ADMINISTRATION																																		
a) Bidding and Contract Award																													■	■	■	■		
b) Construction Administration																																	■	■
VIII. POST-CONSTRUCTION MONITORING																																	Annually	
a) Hydrographic Surveys																																	For	
b) Biological Surveys																																	5 Years	

5.0 - CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations for this Long-range Beach Nourishment Plan developed for the Village of Key Biscayne are summarized in the following:

5.1 Conclusions

1. The opening of Government Cut in 1904 and subsequent widening and deepening improvements have caused significant erosion along Key Biscayne, Virginia Key and Fisher Island as determined by the historic Mean High Water shoreline data. The most significant long-term shoreline erosion has occurred within the Village and near the tip of the island with both of these locations eroding more than 400 feet by 1945.

2. The shallow littoral sand platform at both north and south ends of Key Biscayne is largely absent along the Village shoreline, making this area much more vulnerable to wave impacts. The results of the REF/DIFF numerical modeling show wave energy focusing occurring along the Village shoreline under predominant wave conditions in concurrence with the known erosion "hot spots."

3. An average erosion rate of approximately 12,000 cubic yards per year has been occurring since the 1987 beach fill project based on examination of the April 1996 survey data. There has been a total loss of approximately 107,000 cubic yards from the Village since the 1987 beach fill. The greatest erosion ("hot spots") occurred at the Silver Sand (R-103) and the Sands Condo (R-105) with an erosion rate at 3.5 cubic yards per year.

4. The proposed nourishment design, as of 1997, consists of approximately 120,000 cubic yards of fill placed from Commodore Club to the Towers in the Village, with a berm height of +9 feet NGVD and a slope of 1V:14H. This

project will increase the beach width a maximum of 60 feet after equilibrium adjustment. Nourishment life is expected at 10 years.

5. The proposed beach nourishment project will provide storm protection benefits, contribute to property value appreciation, enhance tourism and recreation for residents. In addition, this beach nourishment will also preserve natural habitat for sea turtle nesting and beach dune planting.

6. Due to the moderate quantity of sand need for this project, no clear cost advantages exist between the potential offshore, upland and foreign sources. The cost for offshore, upland and foreign sources is estimated to be in the range of $11.5 to $15.5, $13 to $17, and $15 to $23 per cubic yard, respectively. However, both offshore dredging and imported foreign sources may involve more complicated permitting requirements due to the need for additional environmental, monitoring, and/or geotechnical, archeological investigations.

7. The Federal, State, and County permits are required prior to construction of the proposed beach nourishment. Dade County (DERM) is currently processing the permit application. Extensive field investigations will be required to provide the data needed to address the concerns by various permitting agencies. It will take approximately 12 to 24 months to secure all permits.

8. Total estimated cost for the proposed nourishment is $2.67 million including construction, engineering, design, permitting, and monitoring. This cost does not include the cost associated with exploration of an offshore borrow site. The local, including County and/or Village, may be eligible for State funding up to 37% of the total cost, or approximately $988,000. Local has to pay for the remaining non-State cost of approximately $1.68 million. The annual amortization cost for local share will be $330,000 over the next 50 years for a

total of 5 beach nourishment projects. The project is expected to be under construction in the winter of 1999.

5.2 Recommendations

1. The Village should continue to coordinate with the State and the County towards obtaining potential beach quality material from the Cape Florida Wetland project. The Village should continue to follow up with the U.S. Army Corps of Engineers regarding the progress of investigating the existing offshore borrow site near the Key Biscayne lighthouse and of developing technical specifications for use of a foreign sand source as beach fill.

2. The Village should work with DERM of Dade County towards expediting the permitting processes by addressing the questions and/or concerns that may be raised by various permitting agencies.

3. Based on the County's funding of beach projects at other local municipalities, the County may potentially fund the entire non-State cost of approximately $1.68 million. However, the Village should consult with Dade County regarding their participation in this beach nourishment project.

4. The local may be eligible for State funding up to $988,000, based on the qualified public beach access. However, due to funding availability, the State in the past was only able to fund the highly ranked projects. The ranking criteria for State funding is presented in Section 4.5.1 of this report. To increase the ranking of this project, the Village should make the State aware of the importance of this project and its associated benefits. A strategy should be developed to ensure a higher funding ranking for this project.

5. A contingency financial plan for the proposed beach nourishment project should be developed to address the needs in the event of an emergency situation when the State and/or County's funding is not available.

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