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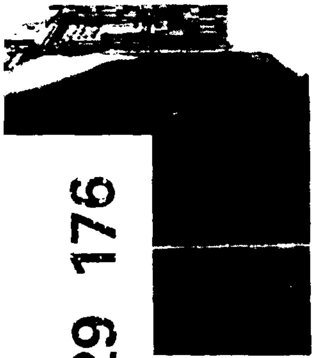

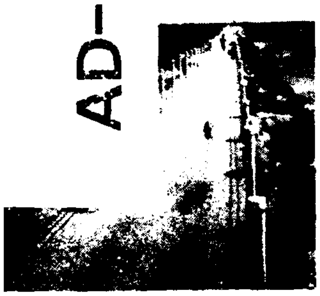

REPAIR, EVALUATION, MAINTENANCE, AND
REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CO-15

FIELD EVALUATION OF PORT EVERGLADES, FLORIDA, REHABILITATION OF SOUTH JETTY BY VOID SEALING

by

Julie Dean Rosati, Thomas A. Denes

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

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Final Report

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	Problem Area		Problem Area
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

COVER PHOTOS:

TOP — South Jetty, Port Everglades, Florida.

MIDDLE — Asphalt cap work platform on top of South Jetty, Port Everglades, Florida.

BOTTOM — Drilling and sealing South Jetty, Port Everglades, Florida.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report presents the results of a monitoring program designed to evaluate the effectiveness of a prototype void and sand-sealing operation. The Port Everglades, Florida, south jetty is a rubble stone structure with large "man-sized" voids. Beach fills placed south of the structure eroded at an extremely high rate, indicating to Broward County and State personnel that material was being lost through the structure into the entrance channel, where it was thought to be a contributing factor to navigation channel shoaling. Sealing of the structure with sodium silicate-cement for filling void cavities and with sodium silicate-diacetin for stabilizing sand-filled voids within the structure formed a barrier to sediment infiltration. This procedure had previously been determined to be a cost-effective alternative to losing beach material through the structure, with resulting navigation channel dredging at inopportune intervals. The structure was sealed during the period September-November 1988. Four site visits were performed as part of the monitoring

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program: (a) reconnaissance trip, (b) preconstruction experiment, (c) during-construction inspection and observation, and (d) postconstruction experiment. The transmission of dye through the structure before and after sealing was used as the primary indicator of structure transmissibility. Also, current meters were placed in structure voids to indicate net flow through the structure before and after construction sealing.

The dye transmission tests indicated that the unsealed structure was, on the average for all flow conditions measured during both pre- and postconstruction experiments, approximately 4.0 percent transmissible (outlier removed), which reduced to 1.9-percent transmissibility after sealing of the structure was completed (nearly 90-percent certainty). When similar flow conditions are compared, the largest difference in structure transmission between pre- and postconstruction observations occurs during peak ebb flow conditions; however, this difference is statistically significant to a rather low level of certainty (not quite 85 percent). Two dye transmission tests conducted on sealed and unsealed sections of the structure during the construction inspection and observations indicated that structure sealing was nearly 100 percent. Current meter data measured during peak flood and high-water slack conditions showed that net flow through the structure in the preconstruction condition was reflected from the sealed structure, further indicating that the structure was less transmissible in the postconstruction condition. Keywords: Rock/gravel/Structures; Earth fills; Sediment transport; Breakwaters/permeability; Grout; Channel/waterways; Channel dredging. (MM)

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PREFACE

The work described in this report was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), as part of the Coastal Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed under Work Unit 32375, "Rehabilitation of Permeable Breakwaters and Jetties by Void Sealing," for which Mr. David P. Simpson, Ms. Julie D. Rosati, Ms. Joan Pope, and Dr. Lyndell Z. Hales of the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), were the Principal Investigators. Mr. John H. Lockhart, Jr. (CECW-H) was the REMR Technical Monitor.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C) was the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Mr. James E. Crews (CECW-OM) and Dr. Tony C. Liu (CECW-ED) served as the REMR Overview Committee; Mr. William F. McCleese (CEWES-SC-A), WES, was the REMR Program Manager. Mr. D. Donald Davidson, Wave Research Branch, CERC, was the Coastal Problem Area Leader.

Personnel who provided technical support and labor in the field during the monitoring program included Mr. Jeffery A. Sewell, Prototype Measurement and Analysis Branch (PMAB), Engineering Development Division (EDD), CERC, and Messrs. Perry L. Reed and Brian O'Neil, Coastal Structures and Evaluation Branch (CSEB), EDD. Dr. Clifford L. Truitt, former Acting Chief, Engineering Applications Unit (EAU), EDD, and Mr. Thomas R. Richardson, Chief, EDD, provided valuable assistance in planning phases of the monitoring program.

Work was performed under the general supervision of Drs. Truitt and Yen-hsi Chu, Chief, EAU; Ms. Pope, Chief, CSEB; Mr. Richardson, Chief, EDD; Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and Dr. James R. Houston, Chief, CERC. Ms. Rosati and Dr. Hales were Co-Principal Investigators of the work unit during this study. This report was prepared by Ms. Rosati and Mr. Thomas A. Denes, EAU.

Commander and Director of WES during the publication of this report was COL Larry B. Fulton, EN. Technical Director of WES was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.028317	cubic metres
cubic yards	0.7645549	cubic metres
cubic yards per year	0.000000024	cubic metres per second
cups	0.0002366	cubic metres
degree (angle)	0.01745328	radians
feet	0.3048	metres
feet per year	0.000000010	metres per second
gallons (US liquid)	3.785	cubic decimetres
grams	0.001	kilograms
hours	3600.0	seconds
inches	25.4	millimetres
knots (international)	0.5144444	metres per second
miles (US statute)	1.609347	kilometres
ounces (US fluid)	0.00002975	cubic metres
pounds (force) per square inch	6.894757	kilopascals
tons (2,000 pounds, mass)	907.1847	kilograms

FIELD EVALUATION OF PORT EVERGLADES, FLORIDA, REHABILITATION OF SOUTH JETTY BY VOID SEALING

PART I: INTRODUCTION

Purpose of the Study

1. Sodium silicate-cement and sodium silicate-diacetin chemical sealants were used to seal voids in the Port Everglades, Florida, south jetty and to eliminate the transmission of sand through the structure into the navigation channel. Prior to sealing, "man-sized" voids existed in the structure, impairing its function as a terminal groin for beach fills placed south of the structure. Continual erosion of the beach located immediately downcoast of the south jetty to Port Everglades entrance, owned by the State of Florida, prompted Broward County and the State to fund a jetty rehabilitation project and subsequent beach fill of the adjacent beach south of the structure. A monitoring plan to ascertain the effectiveness of the Port Everglades sealing project through a field evaluation was conducted by the US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC), with the cooperation of Broward County, the State, and the sealing contractor.

Background

2. Stone and concrete units are often used in coastal structures for their durability and dissipative characteristics. However, large void spaces between units resulting from cross-sectional design or structure degradation through time (e.g., loss of core stone, settlement, etc.) may impair structure functionality. A breakwater designed to protect a harbor area by reflecting and dissipating incoming waves may allow an unacceptable amount of wave energy in the protected region, if void spaces are too prevalent. Likewise, a jetty designed to stabilize a channel and reduce the amount of shoaling may allow an excessive quantity of longshore-moving material through large structure voids, thereby impairing channel functionality. A similar phenomenon may occur at a terminal groin designed to retain a placed beach fill. Here, fill material may pass through structure voids. These functionality problems can be

corrected through structure rehabilitation using various structure sealing techniques.

3. Void spaces can be reduced in existing structures by using one or more of the following methods: (a) utilizing smaller stone to fill voids in either the structure core or exterior; (b) placing steel sheet piles adjacent to the structure, thereby forming a barrier to wave energy and sediment transport; (c) utilizing either prefabricated concrete units or cast-in-place concrete to reduce void volume; (d) using controlled demolition to reduce interior structure stone size, and thus structure permeability; or (e) using cementitious and chemical sealants (flowable mixtures that harden or gel within prescribed time limits) to fill voids and stabilize sand-filled regions. Sediment infiltration through void spaces also can be reduced with the use of a sixth method, use of geotextile fabrics that facilitate the exchange of fluid from one side of the structure to another while preventing sediment transfer. These six methods are discussed by Thomas and Truitt.*

4. Sodium silicate-cement and sodium silicate-diacetin chemical sealants were selected for sealing the south jetty at Port Everglades, Florida. Here, it was necessary to stabilize the sand layer underneath the rubble stone comprising the structure and the voids within the structure, which were filled with sand. Sodium silicate-diacetin can be forced into sand voids by pressure grouting techniques and will stabilize the sandy material. Sodium silicate-cement was then used to fill the voids that existed with the structure above any sand-filled sections.

* Jeffrey L. Thomas and Clifford L. Truitt, "Sand Sealing Coastal Structures," Technical Report in preparation, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

PART II: SOUTH JETTY REHABILITATION

Port Everglades Entrance

Navigation project

5. Port Everglades is a Federal navigation project located in Broward County approximately 48 miles* south of Palm Beach Harbor and 23 miles north of Miami Harbor (Figure 1**). The navigation project was authorized by the Rivers and Harbors Act of 3 July 1958 (House Document 346, 85th Congress, Second Session) and was modified based on a resolution adopted 30 September 1964 by the Committee of Public Works of the House of Representatives.† The initial project was for a channel 40 ft deep and 500 ft wide through the ocean bar, tapering to 37 ft deep and 300 ft wide between the rubble stone entrance jetties to the turning basin of a similar depth. In 1984, new improvements pertinent to the present study included (a) increasing the channel depth to 42 ft in the entrance channel and main turning basin, with an additional 3-ft wave allowance in the ocean entrance; (b) widening the 300-ft-width section of the entrance channel to 450 ft; and (c) removing part of the north jetty to accommodate channel widening. In addition, an asphalt fishing walkway on the south jetty was completed in April 1986 by Broward County.†

Coastal processes

6. The net sediment transport rate at Port Everglades has been estimated to be approximately 50,000 cu yd/year to the south, with the net sediment transport rate "between 2.4 and 5 percent of the gross transport in the project area."† The mean and spring tide ranges at Port Everglades are 2.6 and 3.2 ft, respectively. Average maximum tidal currents at Port Everglades are about 5.0 and 6.8 ft/sec on the flood and ebb tides, respectively.†

Beach south of Port Everglades

7. Shoreline recession for the 2-mile reach immediately south of the entrance channel (Figure 2) averaged about 5 ft/year for the period 1929 to

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

** After Broward Country Environmental Quality Control Board (BCEQCB), 1986 (June), "Broward County, Florida: Port Everglades to South County Line, Beach Erosion Control Project, General Design Memorandum, Addendum 1, Revised January 1987," Fort Lauderdale, FL.

† BCEQCB, op. cit.

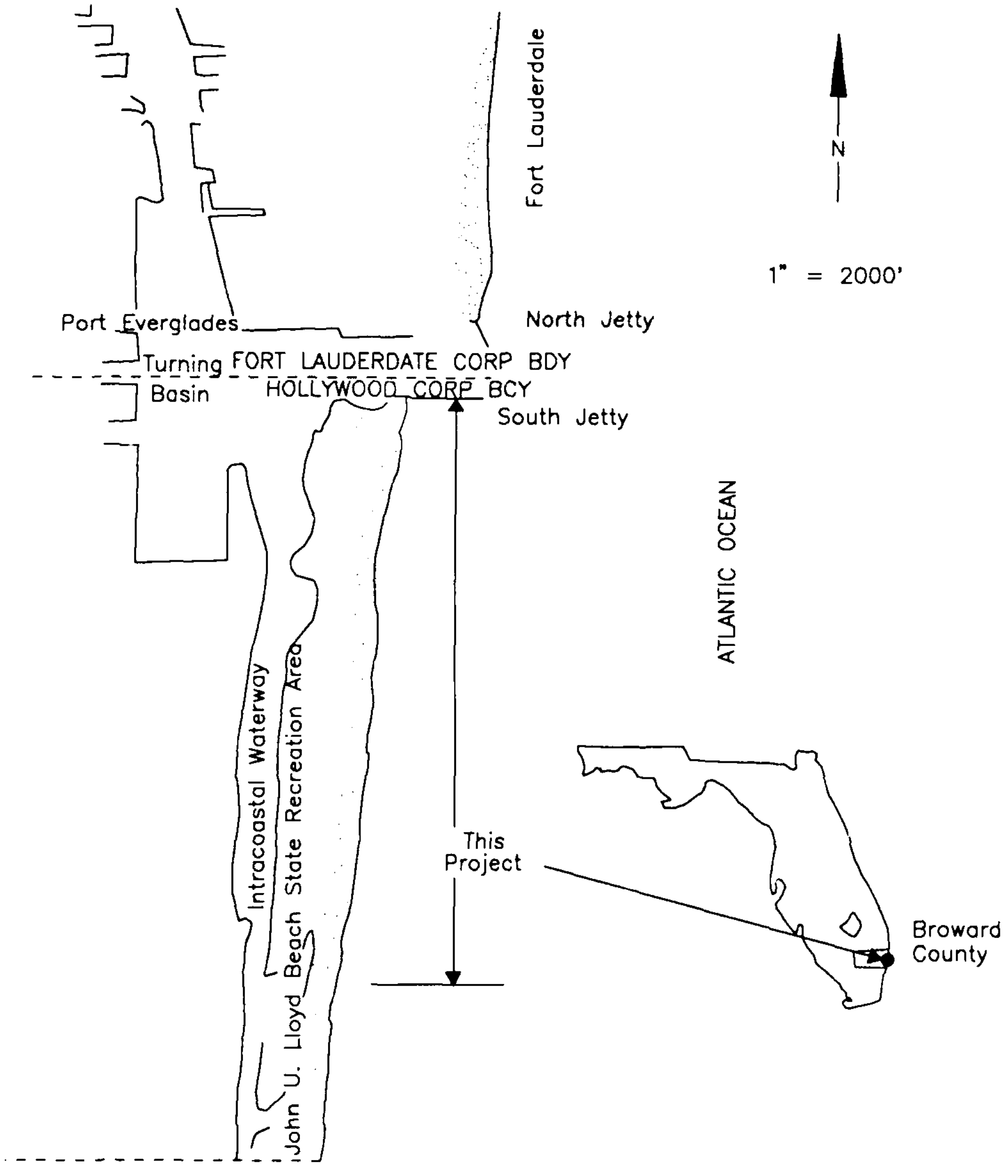

Figure 1. Location map, Port Everglades, Florida, south jetty rehabilitation

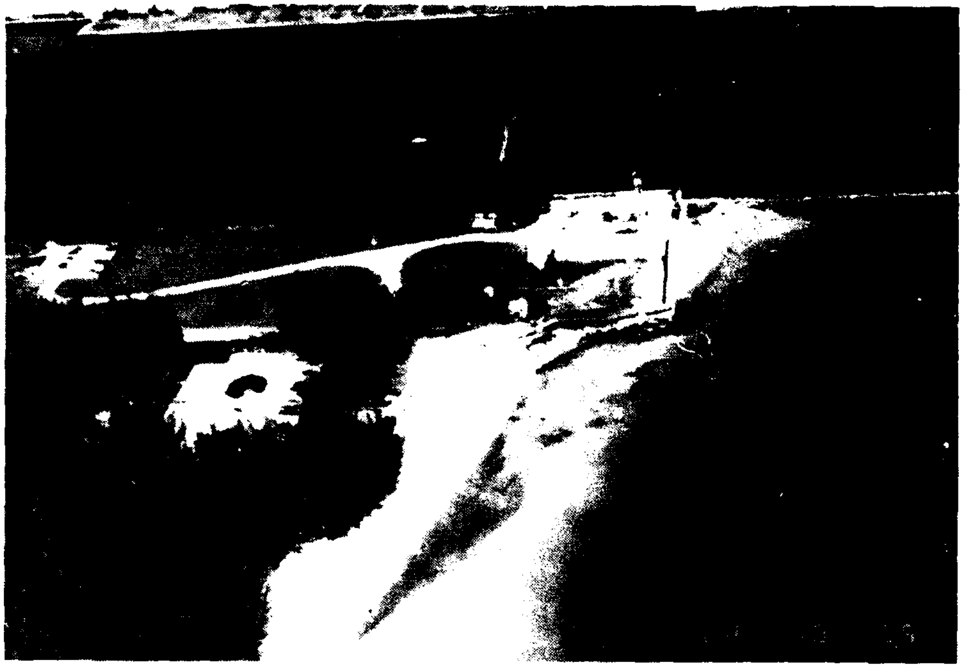

Figure 2. John U. Lloyd State Park immediately south of entrance channel to Port Everglades, Florida, site of continual beach erosion

1961.* From 1961 to 1965, compatible dredged material from the entrance channel was placed on the south beach (county owned at that time), totaling approximately 729,000 cu yd. In late 1976 and early 1977, a beach fill consisting of 1,090,000 cu yd of material dredged from borrow sites located 2 miles offshore of the south beach was placed along the 1.5-mile section of John U. Lloyd State Park.* The beach-fill shoreline retreated at an average rate of 13 ft/year from 1978 through 1985, with the greatest losses occurring along the 4,000-ft section south of the south jetty. No material from the 1984 channel deepening was placed on the south beach. During site visits conducted in the present study, the south beach was observed to have a scarp approximately 6 ft in height. The high erosion rate of the artificial beach at John U. Lloyd State Park and the lack of a large fillet immediately south of the structure (Figure 3) indicated to Broward County personnel that the south jetty was permeable, thus allowing northerly moving material to pass through the structure to the channel.

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* BCEQCB, op. cit.

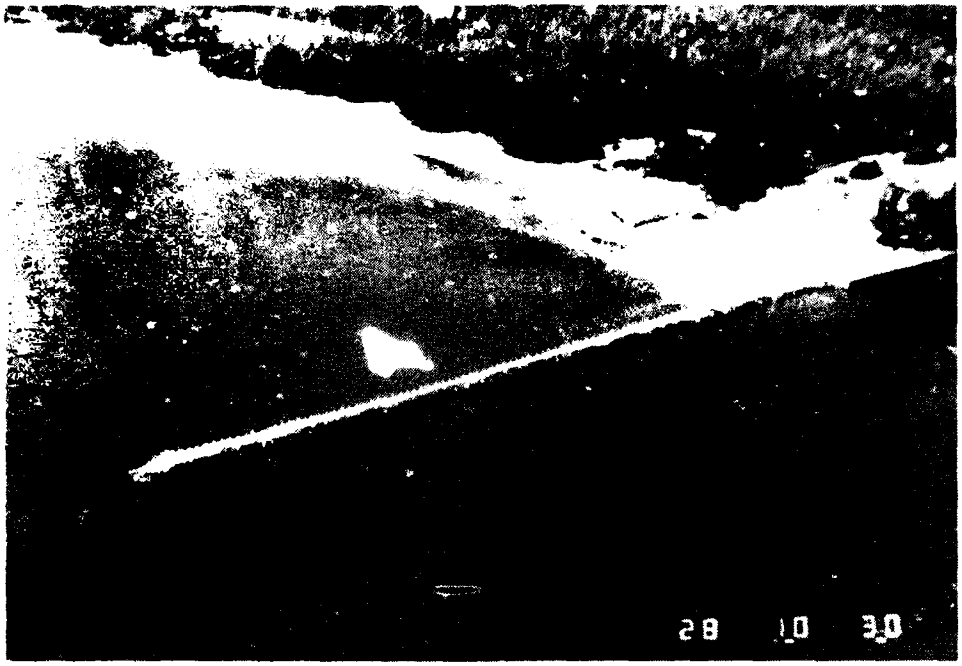

Figure 3. Absence of sand fillet formation adjacent to south jetty at entrance to Port Everglades, Florida, indicating transport through structure

South jetty

8. The Port Everglades south jetty is a 1,000-ft-long rubble-mound structure constructed of 5- to 7-ton stone, approximately 30 ft wide at the base and 11 ft wide at the crest (Figure 4). The asphalt-paved fishing walkway on top of the structure (Figure 5) is approximately 10 to 12 ft wide and 4 to 12 in. thick, with a chinking stone subgrade base varying in thickness (Figure 6). The structure was constructed during 1926-1927 of native coquina rock, with an original bend towards the channel at Sta 8+00. The jetty was rebuilt in 1940 with granite placed over the coquina base, straightening the structure to its present east-west orientation.* A diver reconnaissance conducted by Broward County personnel during February 1985 indicated that the jetty was ". . . ill-maintained and in disrepair, evidenced by the numerous large gaps and voids near the base . . . ."** County personnel discussed the lack of sand accumulation on either side of the structure and concluded

* Personal Communication, 17 November 1989, Stephen H. Higgins, Hydrologic Engineer/Diver, Erosion Control District of the Environmental Quality Control Board of Broward County, Fort Lauderdale, FL.

** BCEQCB, op. cit.

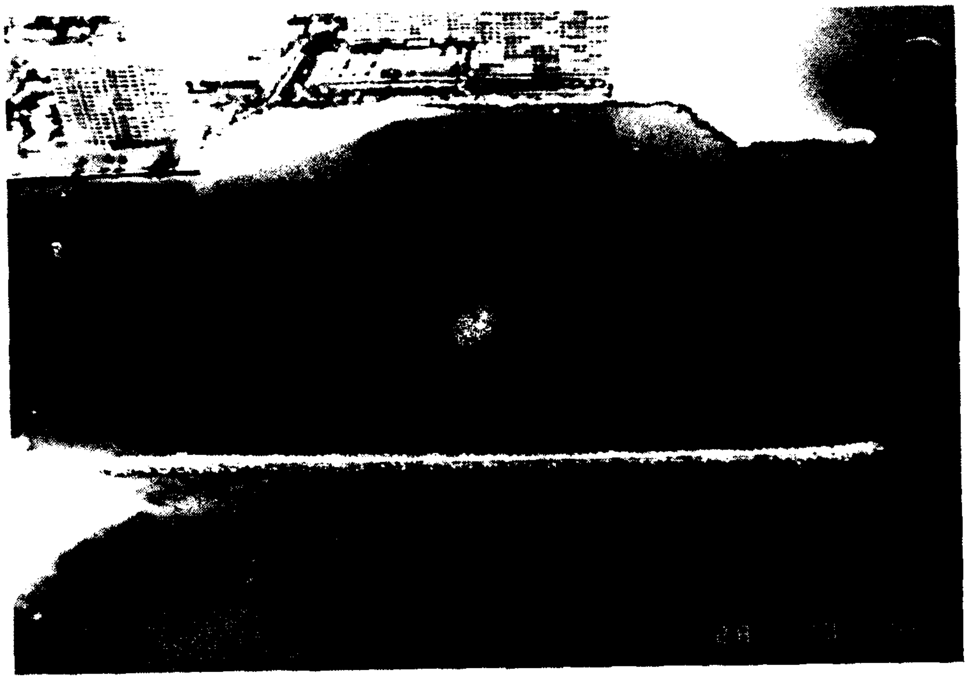

Figure 4. South jetty at entrance to Port Everglades, Florida, June 1988

Figure 5. Asphalt-paved fishing walkway on top of south jetty at entrance to Port Everglades, Florida

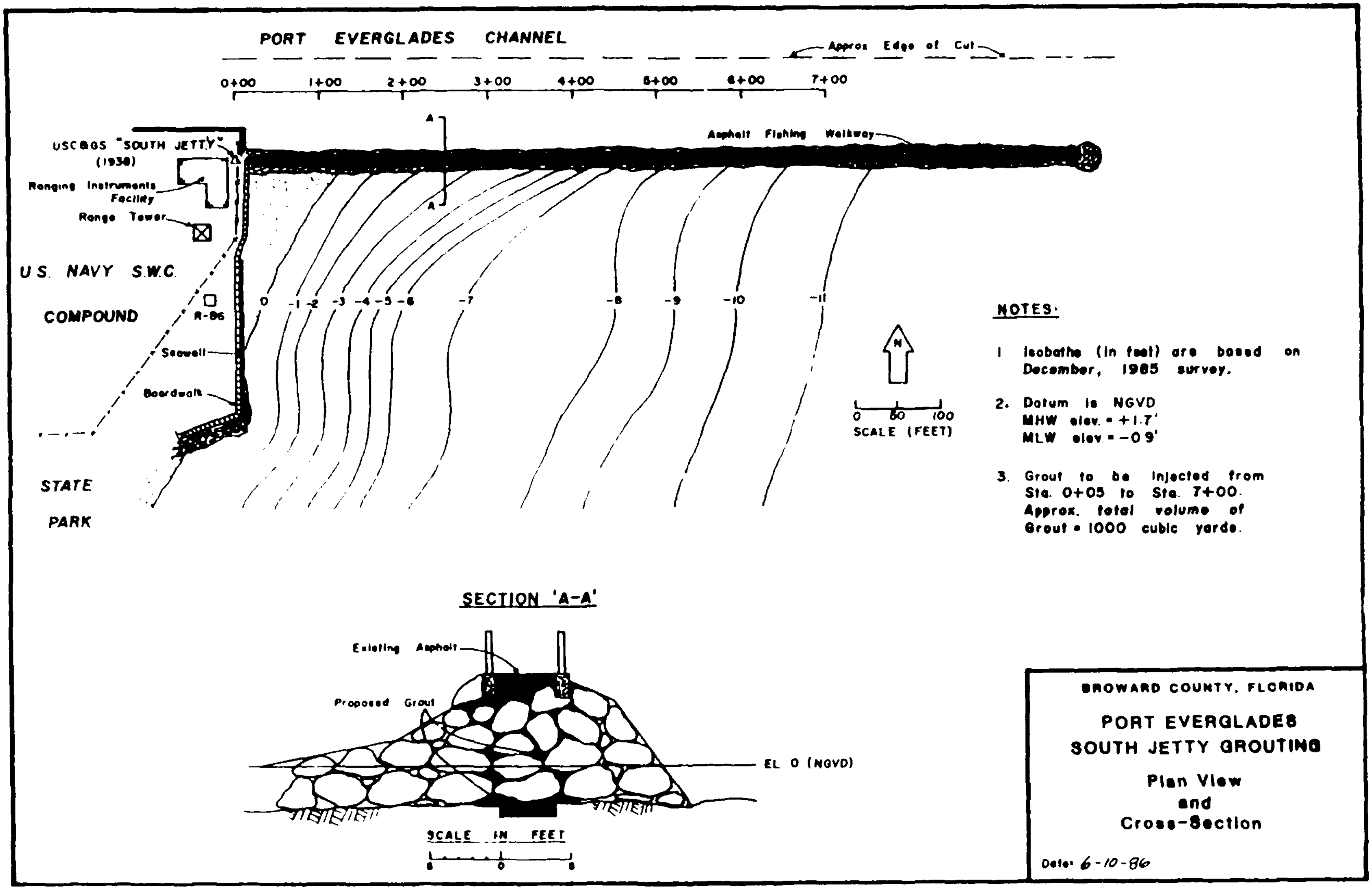

Figure 6. Plan view and cross section, Port Everglades, Florida, south jetty rehabilitation project (after BCEQCB, op. cit.)

that ". . . if sand is passing through the structure, it happens during periods of high waves from the southeast, and is spread out by the ebb current along and into the Port Everglades channel . . . ."*

9. Based on entrance channel dredging quantities from 1934 to 1962 totaling 5,078,000 cu yd and survey records showing growth of the north fillet to be approximately 24,000 cu yd/year, Broward County personnel concluded that the inlet channel is nearly a complete barrier to the southward movement of littoral sediments. The 26,000 cu yd/year that presumably bypasses the north jetty apparently never reaches the beach south of the inlet.*

10. During periods of northerly sediment transport, a buildup of a fillet at the south jetty would be expected. However, only a small accumulation has been apparent, possibly due to loss of material through the porous south jetty. A dye study also conducted by Broward County personnel in February 1985 confirmed that the structure was very permeable, and it was estimated that at least 5,000 cu yd/year passed through the structure and accumulated in the navigation channel, primarily on ebb tides. However, the methodology used to estimate this quantity passing through the structure was not discussed. Nourishment of the 7,920-ft section south of the south jetty with 500,000 cu yd of material was planned to restore the beach (Figure 7), and the proposed sealing of the south jetty was determined to be a cost-effective alternative to losing the estimated 5,000 cu yd/year of beach material through the structure. Sealing the portion of the jetty that would be adjacent to the beach fill, the shoreward 700 ft, was estimated to save approximately $159,000/year as opposed to replacing the estimated quantity of littoral material lost through the structure.*

Jetty Drilling and Sealing

11. The voids in the Port Everglades south jetty were sealed with sodium silicate-cement sealant such that it would function as a terminal groin to the John U. Lloyd State Park beach fill. The sand layer beneath the jetty and the voids within the structure filled with sand were stabilized with sodium silicate-diacetin sealant. The rehabilitation effort began in September 1988 and was completed in November 1988. The contractor, W. G. Jaques Company, Des Moines, IA, was required to complete sealing the landward

* BCEQCB, op. cit.

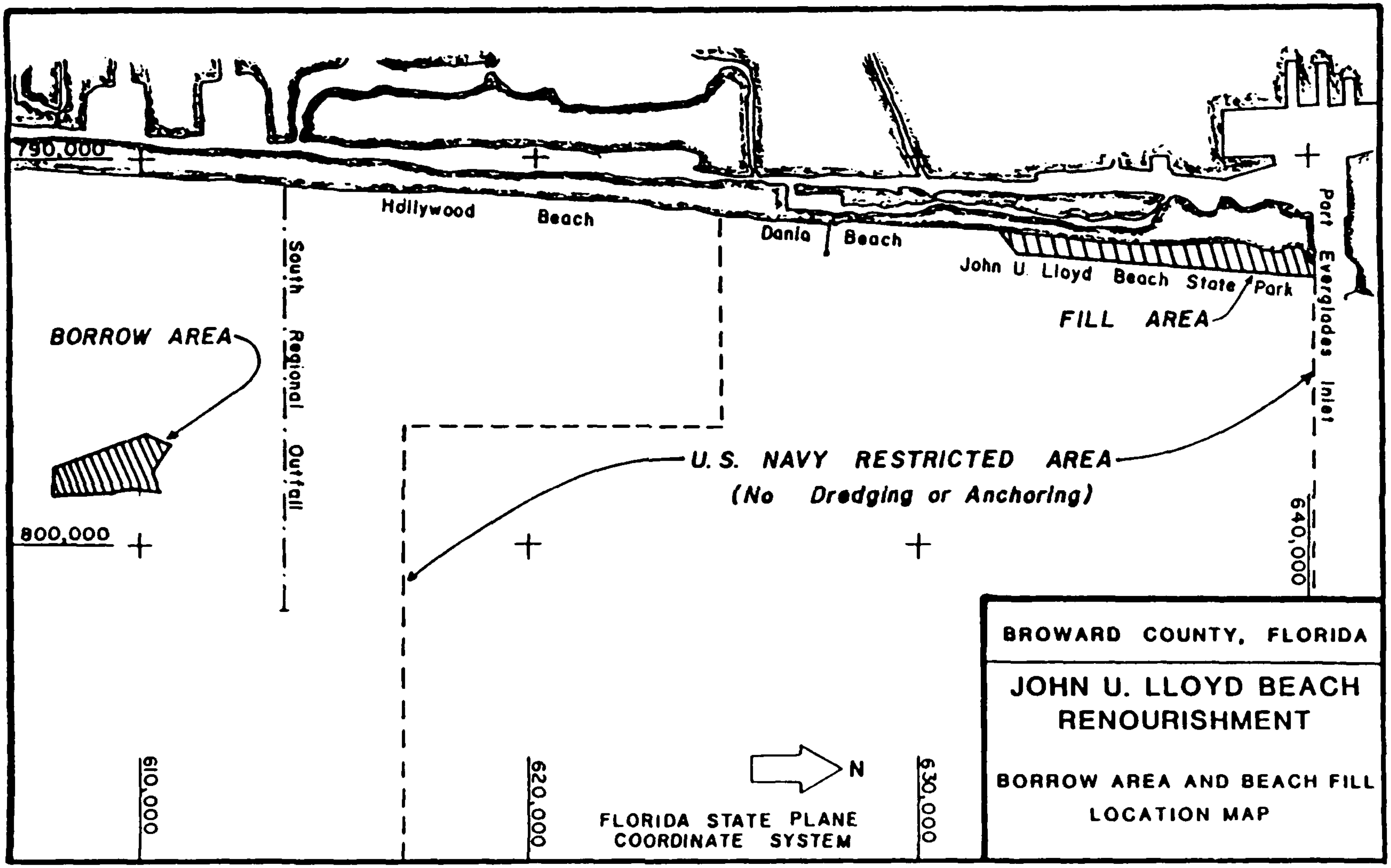

Figure 7. Location of beach fill along John U. Lloyd Beach State Park, adjacent to south jetty, Port Everglades, Florida (modified after BCEQCB, op. cit.)

half of the structure prior to the placement of beach fill. All sealing was actually completed before placement of the beach fill in May 1989.

12. The state-of-the-art procedures and material characteristics for sealing coastal structures with cementitious and chemical grout sealants for this project are discussed in detail by Simpson* and Simpson and Thomas.** The 3-1/2-in.-diam sealant holes at 3-ft spacings along the center line of the structure were drilled to previously specified elevations beneath the bed of the structure. The asphalt fishing walkway provided an ideal foundation from which to operate the drilling and sealing operation. Initially, every other hole (primary) was sealed with sodium silicate-cement sealant, which began to "set up" in 70 to 80 sec. After the primary holes were sufficiently strengthened (approximately 24 hr), secondary holes between the primary holes were sealed with the sodium silicate-cement sealant. Usually the quantity of sealant required for the secondary holes was on the order of only 10 percent of the adjacent primary hole quantity. It was expected that this procedure would result in a 4-ft-wide sealant curtain longitudinally within the structure.

13. After the secondary holes had strengthened, the primary holes were redrilled, and a quick-set sodium silicate-diacetin sealant designed to permeate any sand-filled areas beneath the structure and in structure voids that had become filled with sand was pumped into the holes. The pumping requirements for the sealant were at least 30 gal/min of sealant slurry and at least 100 lb/sq in. of pressure. The holes were capped with a nonviscous cement designed to flow into any small voids left open and provide a durable surface on the asphalt walkway. The drilling and sealing procedures are shown in Figures 8 through 13. Quantities of sodium silicate-cement sealant and sodium silicate-diacetin pumped into each hole along the length of the jetty are displayed in Figure 14. The corresponding elevation of the jetty crest, average sand elevation at the jetty base, and depth of drilling as a function of jetty length are shown in Figure 15.

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* David P. Simpson, 1989 (Apr), "State-of-the-Art Procedures for Sealing Coastal Structures with Grouts and Concretes," Technical Report REMR-CO-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

** David P. Simpson and Jeffrey L. Thomas, 1990 (Mar), "Laboratory Techniques for Evaluating Effectiveness of Sealing Voids in Rubble-Mound Breakwaters and Jetties with Grouts and Concretes," Technical Report REMR-CO-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

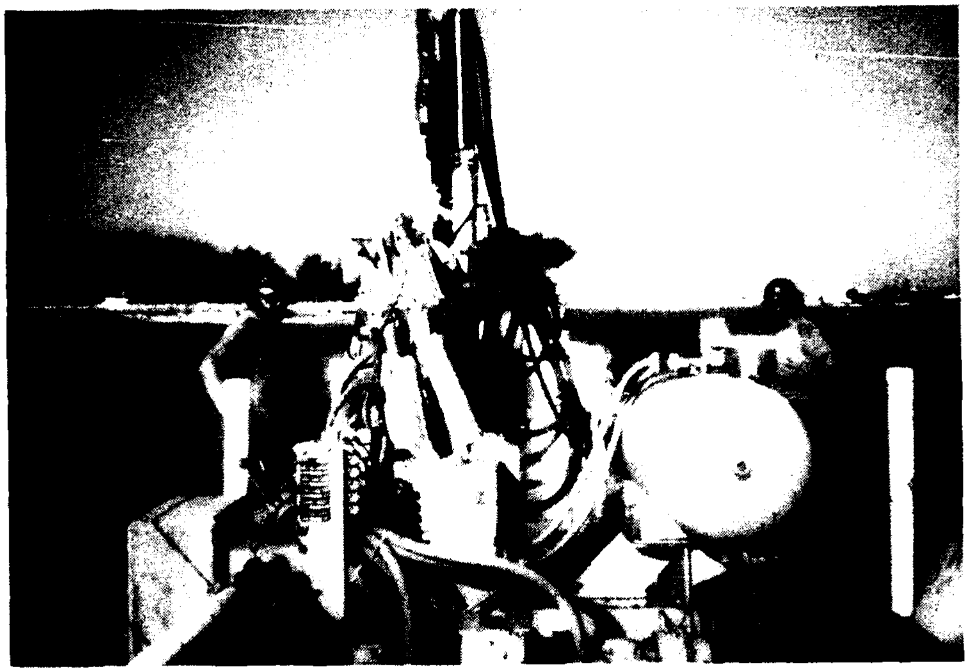


Figure 8. Drilling south jetty at entrance to Port Everglades, Florida

Figure 9. Placing sealant into south jetty at entrance to Port Everglades, Florida

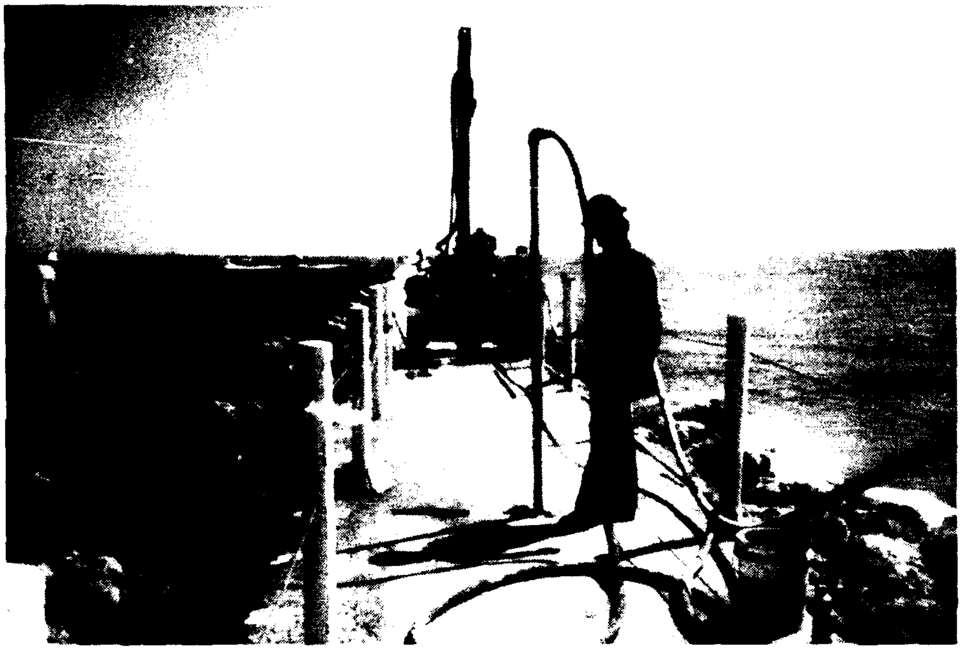


Figure 10. Monitoring sealant level in south jetty at entrance to Port Everglades, Florida

Figure 11. Regulating volume flow rate of sodium silicate-cement sealant during sealing south jetty at entrance to Port Everglades, Florida

Figure 12. Injecting sodium silicate-cement sealant during sealing south jetty at entrance to Port Everglades, Florida

Figure 13. Determining drill hole location for sealing south jetty to Port Everglades, Florida

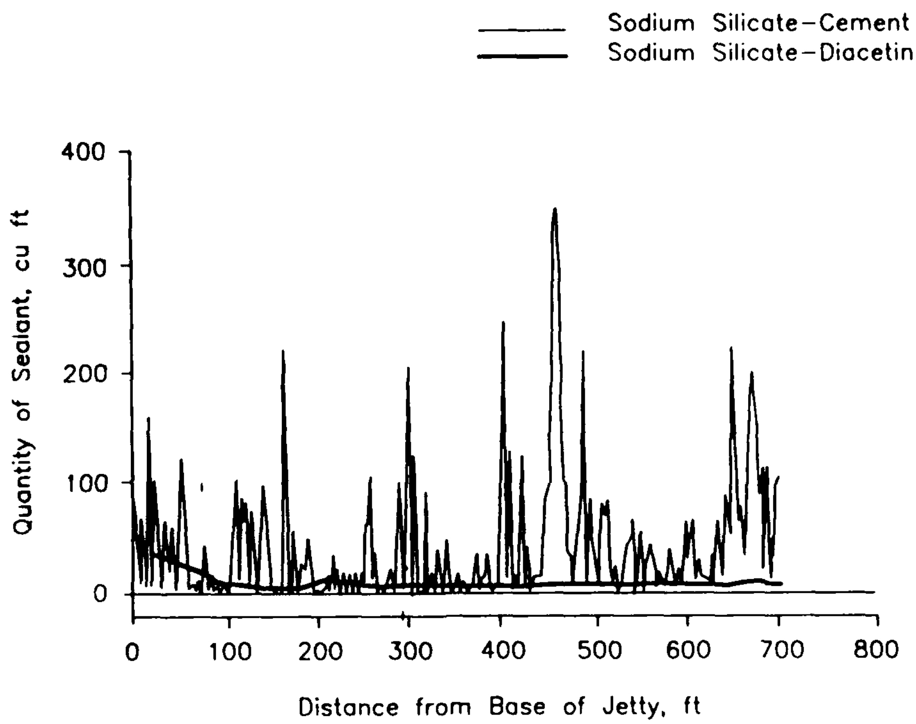


Figure 14. Quantities of sodium silicate-cement and sodium silicate-diacetin sealants placed into south jetty at entrance to Port Everglades, Florida

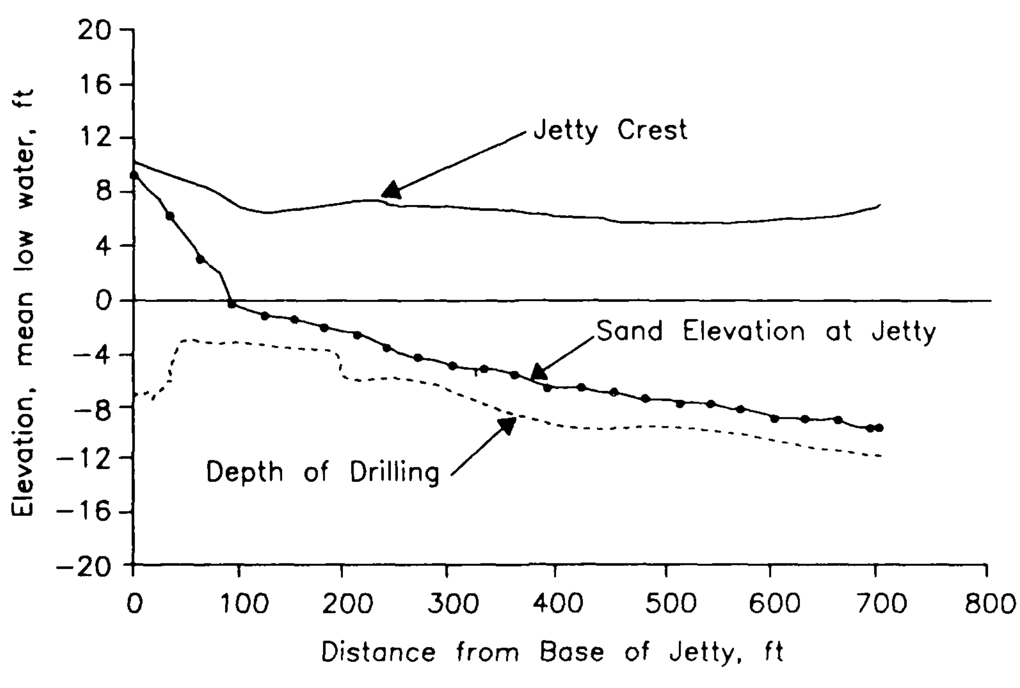


Figure 15. Depth of drilled holes for placing sodium silicate-cement and sodium silicate-diacetin sealants into south jetty at entrance to Port Everglades, Florida

14. An effort was made to obtain postproject cores of selected structure sections by Broward County to evaluate the effectiveness of the sealing operation. However, the alternating degrees of hardness between jetty stone and sealant material caused the cores to crumble during the drilling, and an evaluation could not be accomplished. The determination of the effective useful life and durability of cementitious and chemical grout sealants used in this project is being evaluated by long-term exposure monitoring and testing at three different weathering stations: (a) Treat Island, ME; (b) Duck, NC; and (c) Miami, FL.

PART III: FIELD MONITORING PROGRAM

15. The purpose of the monitoring program was to evaluate the degree of structure permeability both before and after grouting. Qualitative information, such as the condition of the structure determined from underwater inspection and the presence or absence of bed forms and shoals, was used as indicators of structure permeability. The amount of water exchange from one side of the structure to the other, as indicated by the movement of dye, was used as the primary quantitative indicator of structure permeability. Current velocities in structure voids before and after grouting were also measured in an attempt to quantify the rate of net fluid movement through the structure. Attempts to quantify sand transport through the structure using suspended load sand traps and bed-load pan samplers were unsuccessful, primarily due to the lack of littoral transport during the experiment intervals. Large quantities of material may move through the structure only during storm events.

16. The monitoring program consisted of four phases: (a) reconnaissance evaluation designed to obtain preliminary information so that later phases of the monitoring program could be better planned, (b) preconstruction experiment to qualitatively and quantitatively evaluate the presealing condition of the structure, (c) during-construction observations of the drilling and sealing techniques, and (d) postconstruction experiment that repeated tests conducted during the preconstruction phase so that the degree to which structure sealing occurred could be assessed.

Reconnaissance Evaluation

17. The purpose of the reconnaissance trip, conducted during the period 27-29 June 1988, was to obtain detailed information about the south jetty infrastructure, current patterns, and surrounding beach and bathymetry conditions so that later phases of the monitoring program could be better planned. In particular, the following information was collected: (a) locations, dimensions, and photographs of structure voids for possible future mounting of current meters and sediment traps; (b) characteristics and photographs of the seabed north and south of the jetty; (c) current velocities and patterns through the structure during peak flood and ebb flows; and (d) sketches and photographs of dye dispersion through the structure during peak flood and ebb flows.

Structure voids

18. On the morning and early afternoon of 27 June 1988, a snorkeling inspection of the north and south sides of the south jetty was conducted. Larger structure voids that extended far into the structure were located and measured (Figures 16 through 18), and three voids on the south side of the jetty were identified for possible placement of current meters and sediment traps during future experiments. These voids extended deep into the structure, were at least partially filled with water at all tide levels, and were located approximately at the toe of the proposed beach fill (Sta 6+40), at the crest of the proposed beach fill (Sta 4+70), and near the existing storm breaker line (Sta 3+76, 6-ft mean water depth).

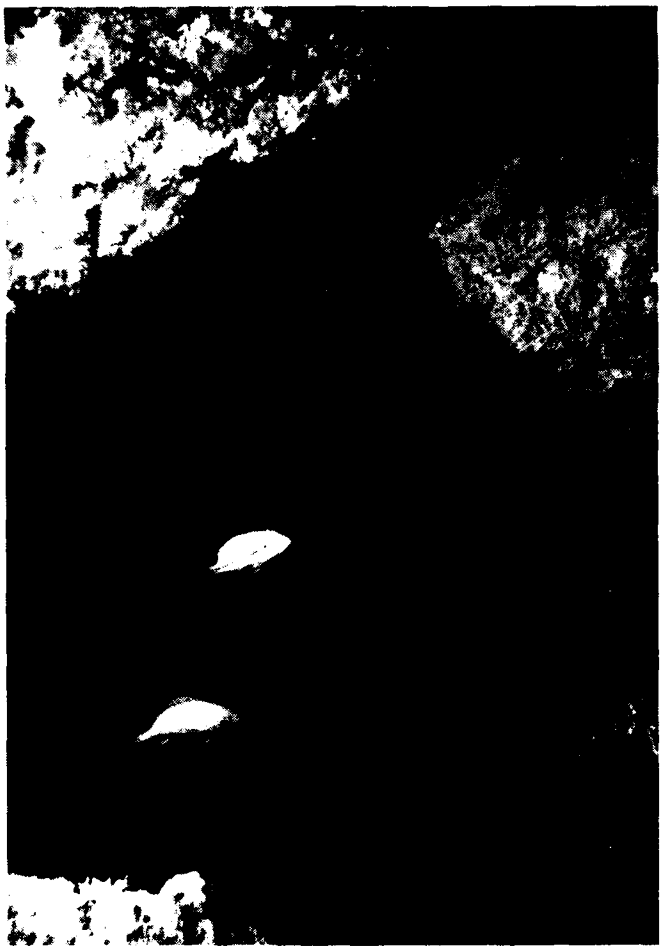


Figure 16. Large structure voids on south side of jetty at entrance to Port Everglades, Florida, where current meter was deployed

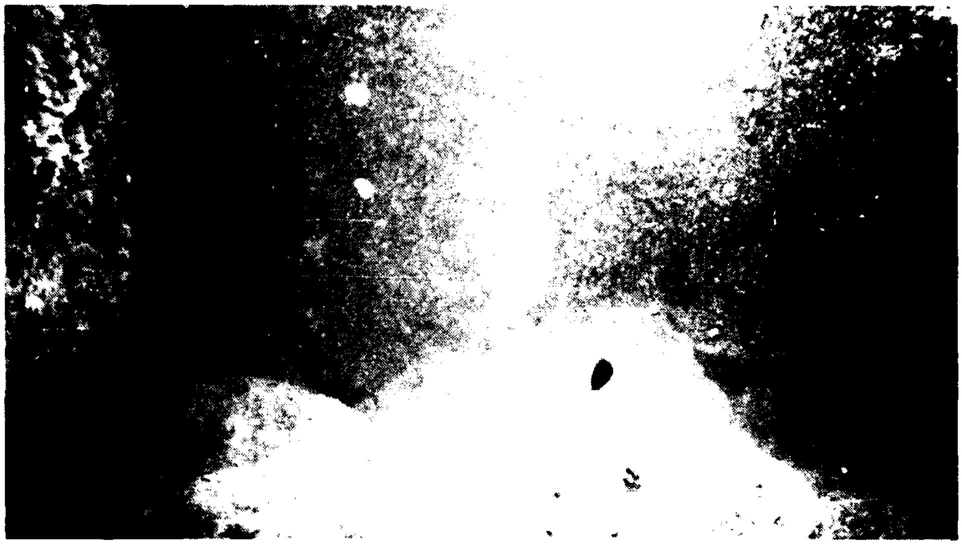


Figure 17. Large structure voids on south side of jetty at entrance to Port Everglades, Florida, where sediment trap was deployed

Characteristics of the seabed

19. During the structure void inspection, characteristics of the seabed north and south of the structure were also noted. Except for an area on the shoreward end of the north side of the jetty, the seabed extending from 5 to 15 ft out from the sides of the structure consisted of small pieces of coral. The region extending farther than 15 ft from the structure was sandy, with wave-induced ripples in shallower water. The seabed extending for approximately 100 ft along the shoreward portion of the north side of the jetty was mostly sandy, although some coral fragments were visible. No shoals or large sediment deposits along the length of the structure were noted, indicating that, if sediment passed through the structure, it was carried away from the sides of the jetty. The small area of the seabed visible inside structure voids was composed of fine sand.

Currents through the structure

20. Current velocity through the structure were not measured during the reconnaissance phase due to an equipment failure and logistical problems in obtaining a replacement current meter.

Dye dispersion through the structure

21. Three dye dispersal tests were conducted during two peak flood flows and an ebb flow to determine extent of voids and transmission through the structure. (Dye transmission through the structure may more accurately

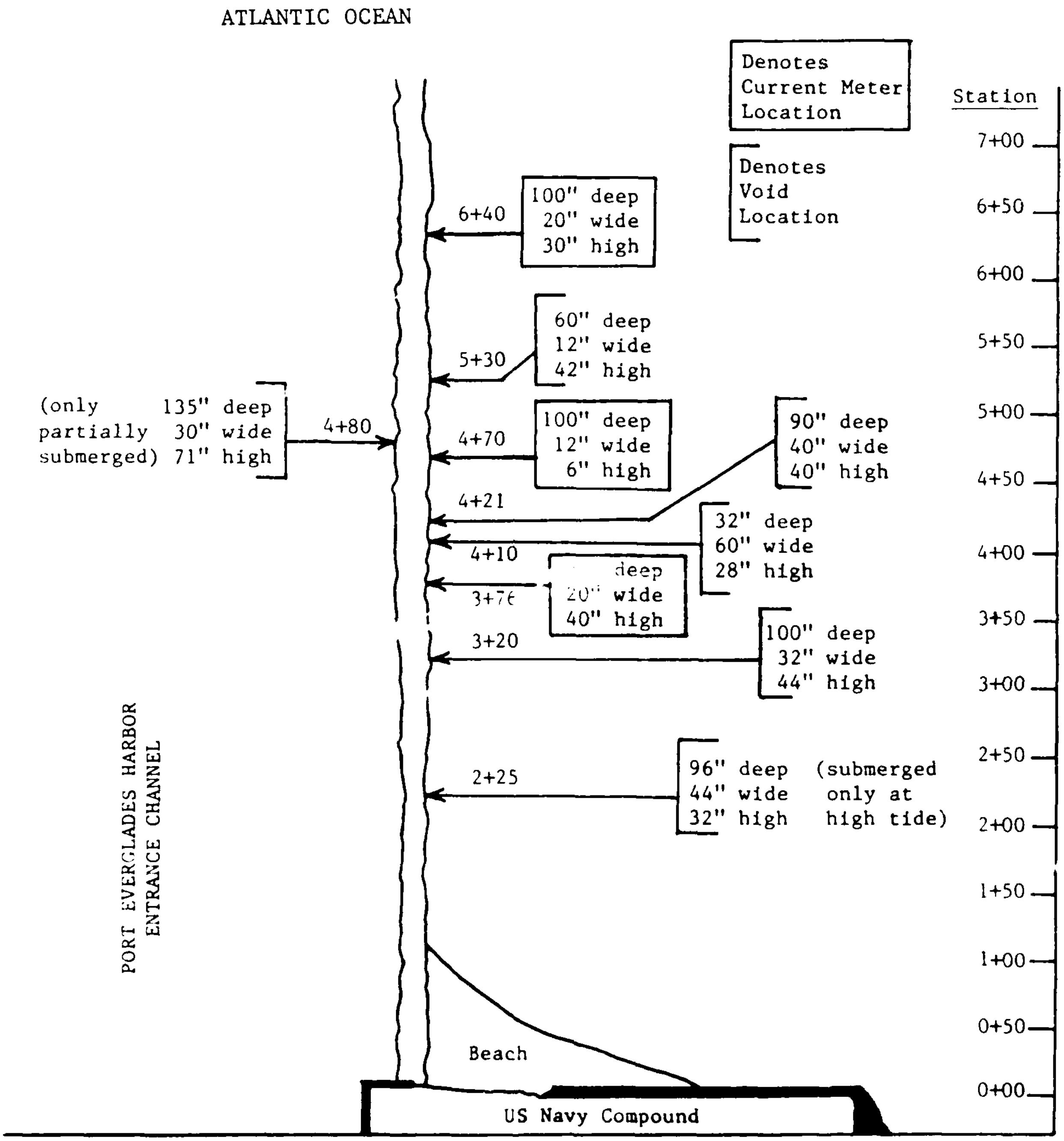


Figure 18. Locations and dimensions of larger structure voids along south jetty at entrance to Port Everglades, Florida

indicate transport of suspended material; bed-load transport mechanisms may give a different pattern.) Sand sample bags weighted with rocks and filled with approximately 1/4 to 1/3 cup of powdered fluorescein dye proved to provide the continuous dye source necessary for dye visibility and longevity. Injecting voids with liquid dye from a pressure sprayer did not provide the continuous, concentrated quantity of dye required. On the afternoon of 27 June 1988, a large quantity of powdered dye in a weighted sand sample bag was placed in a void (Sta 4+10) on the south side of the jetty just prior to peak flood flow (0.9 ft/sec). The dye was placed as close to the center of the structure as possible, and the dispersion of dye through time was mapped in planform (Figure 19). During the test, the wind speed was from 10 to 12 mph from the southeast, and 2-ft-high waves from the southeast were breaking at an angle of 45 deg to the shoreline. The test indicated that a portion of the dye passed through the structure in approximately 10 min; however, a large portion of the dye was carried offshore, along the length of the structure and into the channel by the flood flow approximately 1 hr after dye release.

22. The dispersion of dye placed at two voids on the north side of the south jetty (Sta 4+10 and Sta 4+80) 10 min prior to peak ebb flow (1.1 ft/sec) on the morning of 28 June 1988 was documented with oblique aerial photography for an hour after peak ebb flow. The dispersion of dye through time is mapped in Figure 20. The dye passed through the structure to the south side at two locations within 10 min. Winds were calm, with a breaking wave height of about 0.5 ft at approximately 10 deg to the shoreline from the southeast.

23. The third dye dispersal test was conducted on the afternoon of 28 June 1988 at peak flood velocity (1.1 ft/sec). Winds were approximately 8.5 to 9.5 mph, and 2-ft-high waves from the southeast were breaking at a 45-deg angle to the shoreline. The dispersal of dye was documented with oblique aerial photography for approximately an hour after dye release. Weighted sand sample bags partially filled with powered dye were placed as close to the structure as possible in voids at Sta 3+76, Sta 4+70, and Sta 6+40 on the south side of the structure. A weighted dye packet was also thrown into the surf zone from the south end of the Navy Compound to indicate the direction and relative magnitude of any longshore current. The dispersion of dye from the structure voids was similar to that observed on the afternoon of 27 June 1988, with the same tendency for offshore movement of dye along the length of structure (Figure 21). Dye passed through the structure voids at

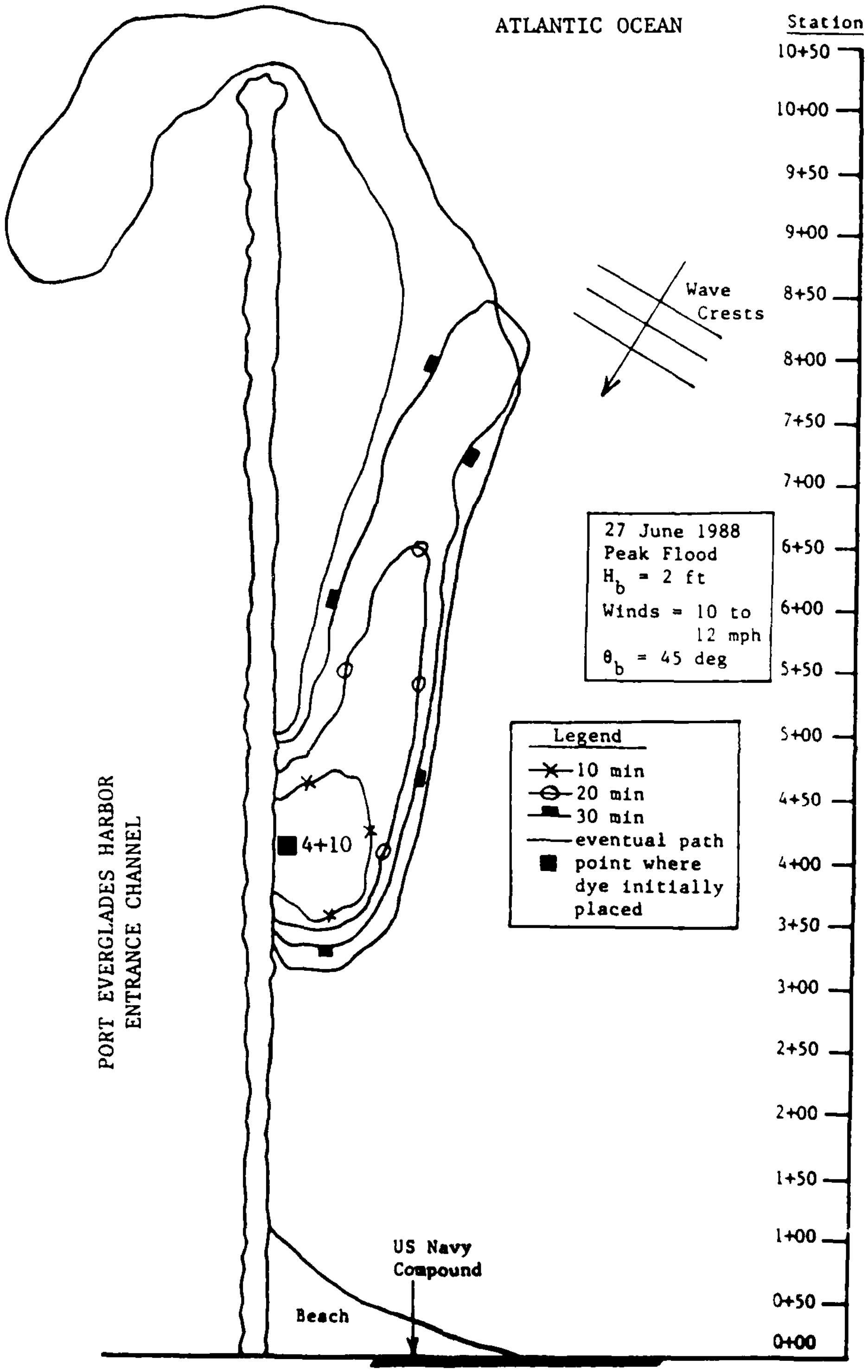


Figure 19. Visually observed dispersion of dye through south jetty at entrance to Port Everglades, Florida, peak flood flow, 27 June 1988

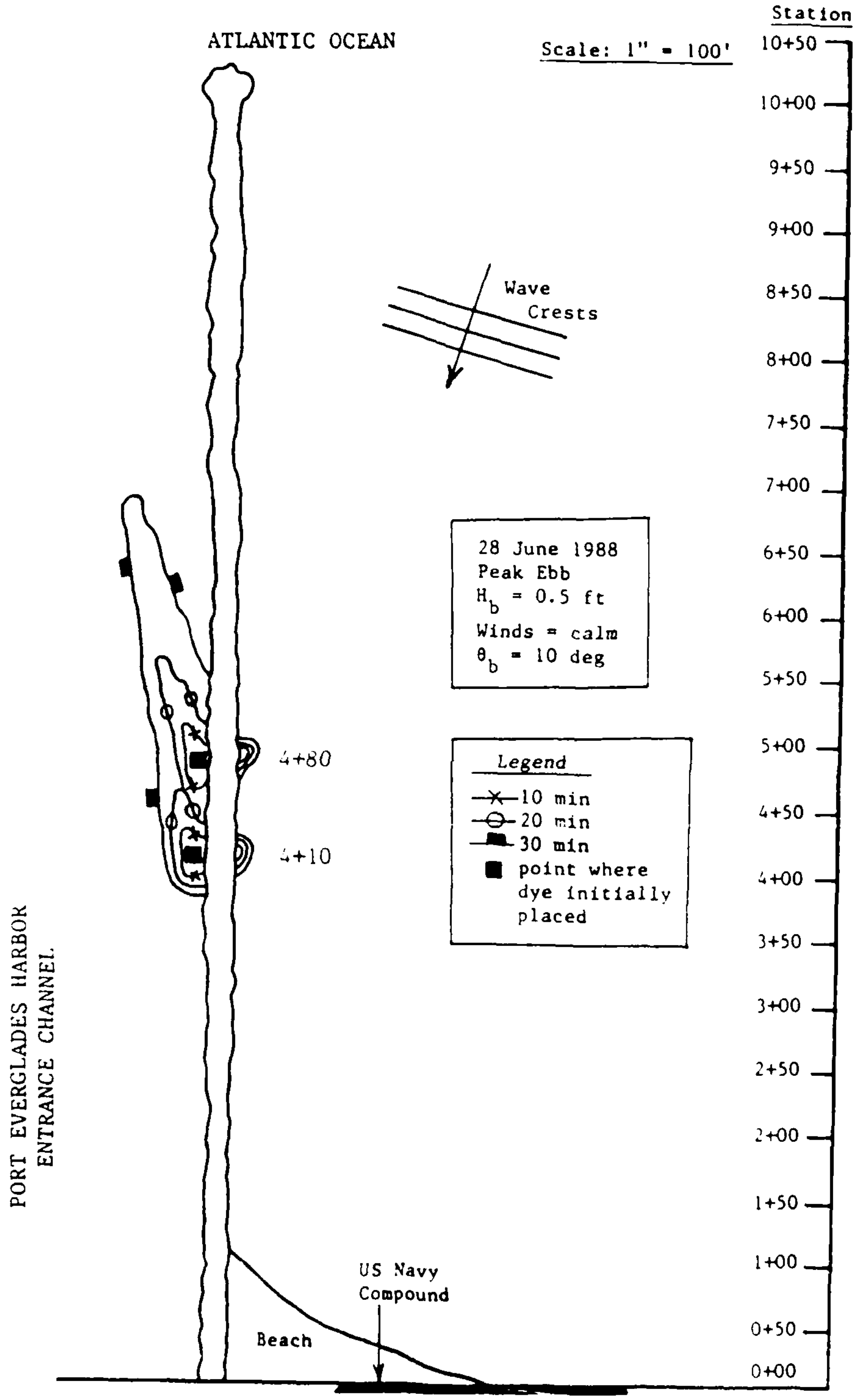


Figure 20. Visually observed dispersion of dye through south jetty at entrance to Port Everglades, Florida, peak ebb flow, 28 June 1988

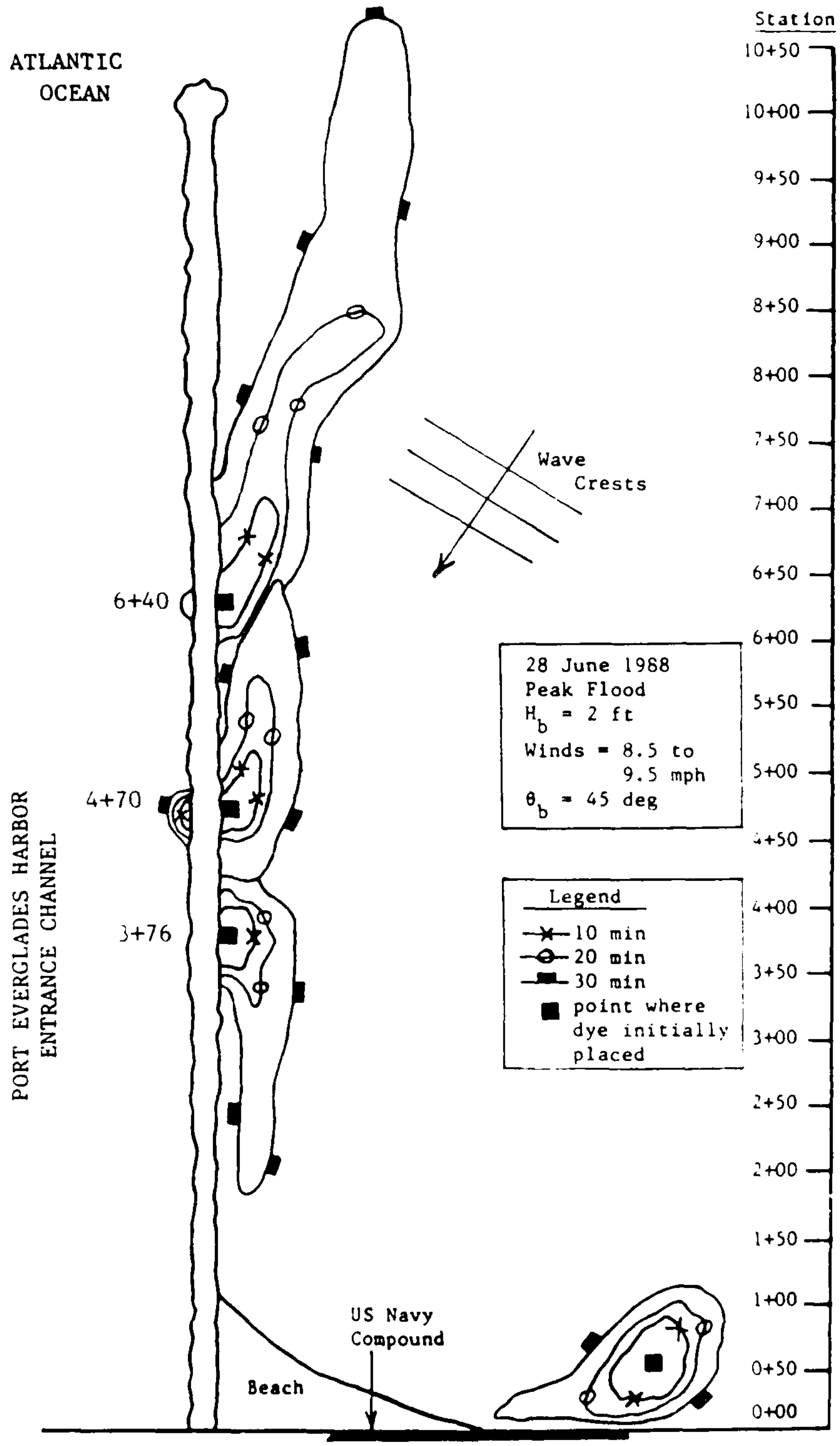


Figure 21. Visually observed dispersion of dye through south jetty at entrance to Port Everglades, Florida, peak flood flow, 28 June 1988

Sta 4+70 in approximately 10 min, and at Sta 6+40 in approximately 20 min. The dye thrown into the surf zone at the south end of the Navy Compound dissipated, only indicating a slight longshore current.

Sediment transport indication

24. Several qualitative measurements of sediment transport through the structure were made, using suspended bottle sediment samplers, a streamer trap nozzle, and a pan bed-load sampler. Three suspended sediment samples were collected at the bed, middepth, and surface elevations using an 8-oz bottle on the south side of the south jetty on the afternoon of 27 June 1988. Approximate weights of sediment in the bottom, middepth, and surface samples were 2, 1, and 0.5 g, respectively.

25. A streamer trap nozzle was placed in the void at Sta 3+76 near the bed on the morning of 28 June 1988. The mouth of the nozzle was oriented such that sediment entering the structure at that location would be collected in the streamer. The streamer bag extended deep into the void. The nozzle was removed on the afternoon of 28 June 1988, and it was observed that the streamer bag extended out of the void such that the streamer mouth was effectively closed by the streamer bag. Very little sediment had been collected in the streamer.

26. An attempt was made to bury a pan bed-load sampler to the depth of the bed; however, it was difficult to dig a trough in the coral bed near the structure during higher wave action. Instead, two pan bed-load samplers were weighted with pieces of coral and placed in two voids at Sta 4+21 and Sta 5+30 on the afternoon of 27 June 1988. The pan in void Sta 4+21 was retrieved on the morning of 28 June and had not collected any sediment; the pan in void Sta 5+30 was lost. It was decided that the sediment traps and bed-load pan samplers would not be used to measure sediment transport through the structure in later phases of the monitoring program.

Preconstruction Experiment

27. The preconstruction experiment, conducted during the period 22-26 August 1988, consisted of collecting current magnitude and direction data in three structure voids and measuring the time rate of dye dispersal through the structure with a fluorometer. Data were collected for an hour, beginning 1/2 hr prior to either peak flood, peak ebb, or slack flow.

Dye study

28. One-fourth of a rhodamine dye "donut" (3-in. diameter) was placed in sediment sample bags weighted with coral, and the packets were placed as far into structure voids as possible at the start of each data collection (Figure 22). Rhodamine dye rather than fluorescein was used during all

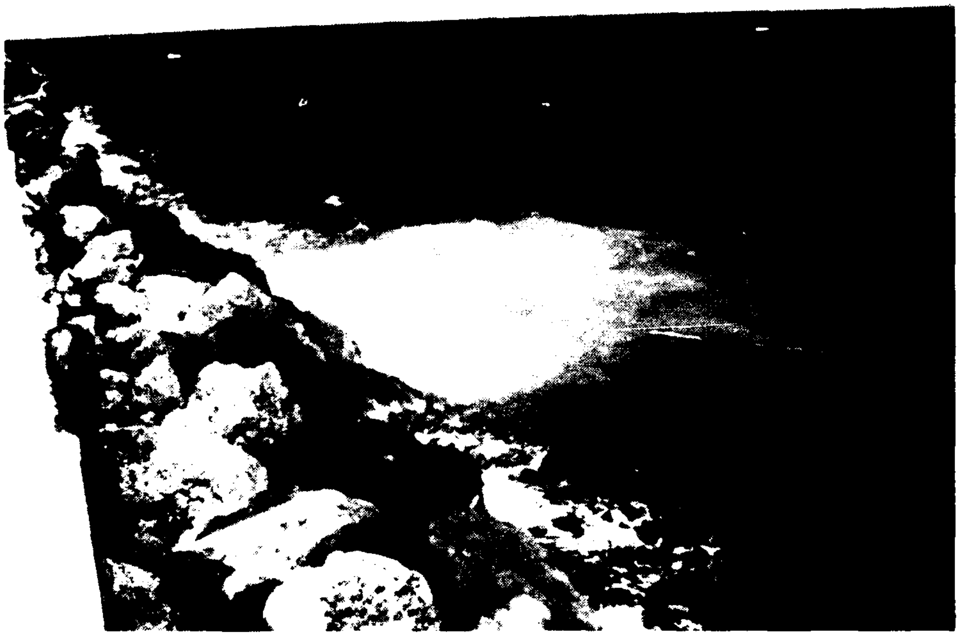


Figure 22. Preconstruction dye transmission test at south jetty to entrance at Port Everglades, Florida

experiments after the reconnaissance trip because of the extreme sensitivity of the fluometer to this type of dye. During peak flood conditions, the packets were placed on the south side of the structure in voids at Sta 3+76, Sta 4+70, and Sta 6+40. During peak ebb, the packets were placed in crevices on the north side corresponding to these voids. Dye packets were placed on the side of the structure with the most wave action during slack flow conditions. Surface water samples were taken every 10 min for an hour at all three stations, both on the south and north sides of the structure. Water samples were also taken at the seabed for several tests to determine if dye transmission was uniform with depth. Samples were retained and analyzed at the site after each test was completed using portable field fluorometer. Seven dye transmission tests were conducted during the preconstruction experiment, one at high-water slack and two each at low-water slack, peak ebb flow, and peak flood flow. A summary of the data collected and description of site conditions during the tests are presented in Appendix A (Tables A1 through A7).

Current meters

29. One-inch diameter Marsh-McBirney electromagnetic current meters (Figure 23) were mounted in voids at Sta 3+76, Sta 4+70, and Sta 6+40 using a

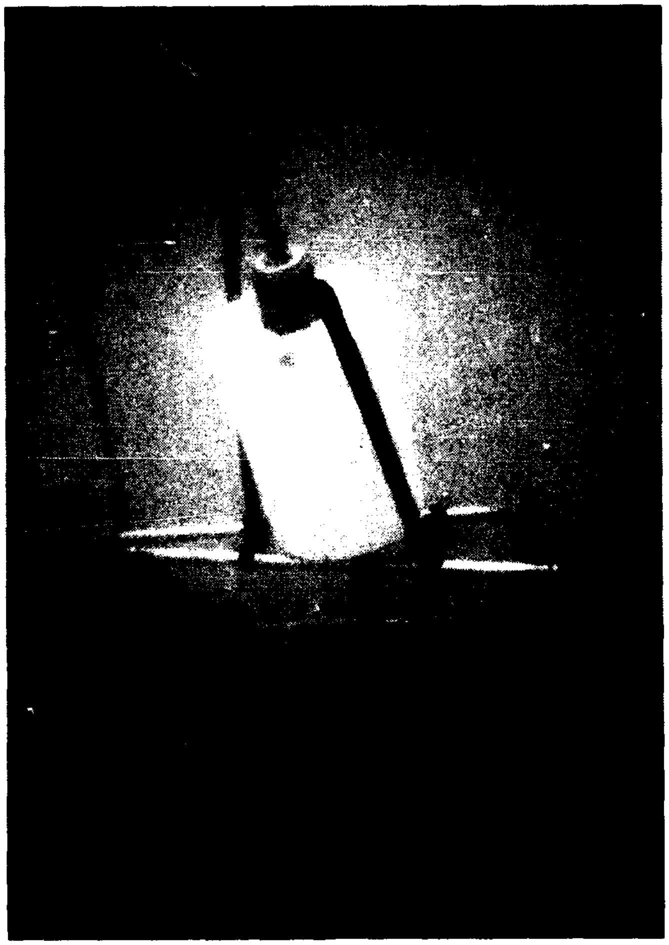


Figure 23. Marsh-McBirney electromagnetic current meter for velocity measurements through south jetty at entrance to Port Everglades, Florida

turnbolt bracing system. The current meter mounting system was stabilized as the braces were tightened against the armor stone so that the current meter was positioned in the center of the void. The current meters were cabled to shore, and data were stored in a portable computer. The current meter data are tabulated in Appendix B (Table B1).

During-Construction Observations

30. Details of the drilling and sealing procedure were observed during the period 9-11 October 1988. In addition, a dye test designed to evaluate the degree to which the sealant permeated the structure voids in a representative section was conducted. At the time of the site visit, both sodium silicate-cement and sodium silicate-diacetin sealing had been completed in the shoreward 350 ft of the structure, and primary hole sodium silicate-cement sealing was continuing in the seaward portion of the structure.

Underwater inspection

31. An inspection of the underwater portion of the jetty was conducted using snorkeling gear. Small portions of sealant could be occasionally observed in smaller voids located farther in the structure, indicating that the material had indeed filled the voids in that area. A 50-ft-wide area of sealant extending south from Sta 3+15 (section already completed) was observed on the seabed. A thin crust had formed on the top of the material, which was primarily cement. Extending out 150 ft from Sta 3+15, 0.5- to 1-ft-diam "sealant stones" were lying on the seabed. These stones were composed primarily of sodium silicate. The sealant stones became brittle when left out of the water overnight, and outside layers of sealant easily crumbled off. This region of sealant south of Sta 3+15 was discussed and observed by the contractor and county personnel. Both the county and contractor believed the most likely reason for the sealant in the area was due to the contractor's practice of flushing the sealant pipe over the side of the jetty when it occasionally became clogged with a stiff sealant mixture, rather than extensive loss of sealant through large structure voids.

Dye dispersal test

32. The dispersal of dye from an unsealed secondary hole adjacent to two unsealed primary holes (representative unsealed section) was compared with the dispersal of dye from an unsealed secondary hole adjacent to two sealed primary holes (representative sealed section). The time history of dye dispersal was measured during a peak ebb flow. On 10 October 1988, one-fourth of a rhodamine dye "donut" was placed in an unsealed secondary hole at Sta 4+68 approximately 30 min prior to peak ebb flow (Figure 24). Water samples were taken at 10-min intervals on the north and south sides of the structure for 1 hr. These data are presented in Appendix A (Table A8). Dye was visually observed to pass through the structure within 1 min. A similar procedure was

Figure 24. Portion of dye "donut" being placed in sealant drill hole during sealing of south jetty at entrance to Port Everglades, Florida

followed for a test of an unsealed secondary hole bordered by two sealed primary holes at Sta 3+75 on 11 October 1988. Dye was never visually observed to pass through the structure, although the florescence of the water did increase slightly during the 1-hr measurement period (Appendix A, Table A9).

Postconstruction Experiment

33. The postconstruction experiment was conducted from 29 January through 1 February 1989 and consisted of collecting data similar to those measured in the preconstruction experiment phase. Dye transmission and current meter data were measured at one peak ebb, two high-water slack, and two peak flood conditions, with tidal currents similar to those that occurred in the previous tests. The dye tests were conducted with the same techniques used in the preconstruction tests, with packets released in voids at Sta 3+76, Sta 4+70, and Sta 6+40. Occasionally, dye packets released from a previous test were visually observed to be emitting dye prior to the start of a later test conducted on the same day. For these situations, additional dye was not released for the later test. One-inch Marsh-McBirney current meters were positioned in the three voids, with an additional 3-in. Marsh-McBirney current

meter deployed approximately 50 ft south of the void at Sta 4+70 for all but one test, in which it was positioned approximately 50 ft north of the same void. Dye transmission data are presented in Appendix A (Tables A10 through A15), and current meter data are presented in Appendix B (Table B2).

PART IV: OBSERVATIONS AND CONCLUSIONS

Observations

Reconnaissance

34. Information gathered during the reconnaissance evaluation indicated that a current might be diverted offshore at the Port Everglades south jetty during certain wave and tidal conditions, surmised from both the absence of sediment near the structure and the offshore movement of dye along the length of the structure during peak flood flows with onshore winds. A streamer trap that had been placed in a structure void was displaced, with the orientation of the streamer bag extending out from the void. The bag orientation indicated that there may be some reflection of wave energy away from the structure that might contribute to the offshore current. The offshore current could be a contributing factor in the persistent erosion of the south beach; however, a strong current would be necessary to entrain sediment through the 12- to 15-ft water depths at the head of the structure. In addition, the absence of sediment along the major length of the structure might indicate only that the source for sediment movement through the structure had been depleted.

During-construction dye transmission

35. The rates of dye transmission through unsealed and sealed sections of the structure were evaluated during the site visit to observe the sealing operation. Dye was placed in hollow sealant holes during two peak ebb conditions. The first test measured dye transmission from a hollow sealant hole adjacent to two hollow sealant holes (unsealed test). During the second test, dye was placed in a hollow sealant hole adjacent to two sealed holes (sealed test). Results of these tests are presented in Table 1.

36. Assuming that the same concentration of dye existed in each drill hole (similar quantity of dye released, same water level in voids, etc.), then transmission of the sealed section decreased 99.9 percent on the south side and 100.0 percent on the north side of the structure. If it is assumed that the cross sections of the structure at these stations were originally similar with similar permeabilities and that these two sections were representative "unsealed" and "sealed" sections, this test suggests that sealing of the structure was extremely successful in filling structure voids.

Table 1

During-Construction Dye Transmission South Jetty Sealing, Port Everglades, Florida

Location	Date of Test	Peak Ebb Current knot	Concentration, ppm South	North
"Unsealed" Sta 4+68	10/10/88	0.6	92.3	17.0
"Sealed" Sta 3+76	10/11/88	0.6	0.1	0.0

Pre- and postconstruction
dye transmission comparison

37. Table 2 presents the concentration of dye for the source (location dye was placed) voids and sink (location dye transmitted) voids, averaged over the data collection interval (usually 60 min) for both the pre- and postconstruction experiments. The average percent transmission was computed by dividing the sink concentration by the source concentration and multiplying by 100. The percent transmission (also referred to as transmission coefficient) is tabulated in the last column for each void during each test. The average percent transmission prior to the sealing was 5.6 and 1.9 percent after the sealing (t-statistic = -1.35). This t statistic indicates that there is an 80-percent probability that a statistically significant difference exists between the two construction conditions. The low-water slack flow condition occurs only during the presealing phase. It is reasonable to remove these measurements from the data set to increase uniformity in flow conditions between the pre- and postsealing conditions. Removing these data reveals an average percent transmissibility prior to sealing of 8.0 and 1.9 percent after sealing (t-statistic = -1.96). There is a nearly 95-percent probability that the difference is statistically significant.

38. Because of the nonuniformity in flow conditions between the pre- and postsealing events, each flow condition should be examined separately. The largest difference between the pre- and postsealing situations occurred during peak ebb flow conditions. During peak ebb, there is at least a 90-percent probability that a significant difference exists between the two construction conditions (t-statistic = -1.93). During peak flood events, there is no significant difference between the two construction conditions (t-statistic = -0.88). A comparison of the high-water slack events also shows

Table 2

Average Concentration and Percent Transmission for South Jetty Pre- and Postconstruction Sealing Tests, Port Everglades, Florida

Flow Condition	Date	Location Station	Average* Concentration, ppm Source	Sink	Percent Transmission
High-water slack	8/23/88	3+76	44.8	0.0	0.0
High-water slack	8/23/88	4+70	21.0	1.8	8.6
Peak ebb	8/24/88	3+76	22.8	0.7	3.1
Peak ebb	8/24/88	4+70	11.5	0.9	7.8
Low-water slack	8/24/88	3+76	13.4	0.1	0.7
Low-water slack	8/24/88	4+70	70.8	0.1	0.1
Low-water slack	8/24/88	6+40	13.2	0.0	0.0
Peak flood	8/24/88	3+76	3.7	0.0	0.0
Peak flood	8/24/88	4+70	1.2	0.1	8.3
Peak ebb	8/25/88	3+76	3.5	1.7	48.6
Peak ebb	8/25/88	4+70	8.3	0.9	10.8
Low-water slack	8/25/88	3+76	7.0	0.0	0.0
Low-water slack	8/25/88	4+70	3.2	0.0	0.0
Peak flood	8/25/88	3+76	20.4	0.0	0.0
Peak flood	8/25/88	4+70	11.1	0.1	0.9
Peak flood	8/25/88	6+40	0.6	0.0	0.0
	Presealing Average Transmission Coefficient:				5.6
Peak ebb	1/30/89	3+76	123.9	0.5	0.4
Peak ebb	1/30/89	4+70	164.1	13.2	8.0
Peak ebb	1/30/89	6+40	84.1	0.3	0.4
Peak flood	1/31/89	3+76	120.0	2.0	1.7
Peak flood	1/31/89	4+70	346.5	1.9	0.5
Peak flood	1/31/89	6+40	397.1	1.7	0.4
High-water slack	1/31/89	3+76	35.2	0.2	0.6
High-water slack	1/31/89	4+70	79.3	0.4	0.5
High-water slack	1/31/89	6+40	20.9	0.4	1.9
Peak flood	2/01/89	3+76	125.1	0.3	0.2
Peak flood	2/01/89	4+70	278.9	0.5	0.2
Peak flood	2/01/89	6+40	210.4	0.6	0.3
Peak flood	2/01/89	7+00	74.7	0.8	1.1
High-water slack	2/01/89	3+76	8.6	0.2	2.3
High-water slack	2/01/89	4+70	5.4	0.2	3.7
High-water slack	2/01/89	6+40	9.9	0.3	3.0
High-water slack	2/01/89	7+00	8.6	0.5	5.8
Peak ebb	2/02/89	3+76	176.1**	1.0**	0.6
Peak ebb	2/02/89	4+70	79.8**	6.0**	7.5
Peak ebb	2/02/89	6+40	102.0**	0.1**	0.1
Peak ebb	2/02/89	7+00	97.8	1.0	1.0
	Postsealing Average Transmission Coefficient:				1.9

* Averaged over data collection period.

** Prior measurement subtracted from succeeding data to obtain average.

no significant difference (t-statistic = -0.76) between the pre- and post-sealing situations. A tabulation of the statistics is presented in Table 3.

Table 3

Statistics on Percent Transmission for Different Flow Conditions, Sealing South Jetty, Port Everglades, Florida

Flow Condition	Percent Transmission Presealing Mean	Percent Transmission Postsealing Mean	t-Statistic	Percent Significant
Combined flow	5.6	1.9	-1.35	81.4
Combined flow w/o low-water slack	8.0	1.9	-1.96	94.0
Peak ebb flow	17.6	2.6	-1.93	91.4
Peak flood flow	1.8	0.6	-0.88	60.3
High-water slack	4.3	2.5	-0.76	53.0

39. These results must be interpreted with caution for the following three reasons. First, the transmission coefficients in the presealing condition are not normally distributed but are rather positively skewed. This is caused by the 48.6-percent transmission which occurred on 25 August 1989 during peak ebb flow. This outlier is very much larger than the other data points and has a strong effect on raising the mean. If this outlier is removed from the data set, the statistical differences between the pre- and postsealing conditions weakens. For example, the probability of a statistically significant difference between the transmissibility coefficients during the pre- and postsealing conditions for the entire data set slips from just over 80 percent (t-statistic = -1.35) to no significance (t-statistic = -0.72). When considering the data set with the low-water slack data removed, the probability of a significant difference between the transmissibility coefficient in each data set slips from nearly 95 percent (t-statistic = -1.96) to less than 90 percent (t-statistic = -1.67) when the outlier is removed. When isolating the peak ebb flow conditions, the probability of a significant difference between the pre- and posttransmissibility data is

reduced from over 90 percent (t-statistic = -1.93) to less than 85 percent (t-statistic = -1.78). The revised statistics are presented in Table 4.

Table 4

Statistics on Percent Transmission with Outlier Removed, Sealing South Jetty, Port Everglades, Florida

Flow Condition	Percent Transmission Presealing Mean	Percent Transmission Postsealing Mean	t-Statistic	Percent Significant
Combined flow	2.7	1.9	-0.72	52.6
Combined flow w/o low-water slack	4.0	1.9	-1.67	89.5
Peak ebb flow	7.2	2.6	-1.78	84.0
Peak flood flow	1.8	0.6	-0.88	60.3
High-water slack	4.3	2.5	-0.76	53.0

40. Second, a significant relationship between the source and sink data in either the pre- or postsealing conditions appears only during the peak ebb flow condition. One would expect that during the presealing condition, as more dye is added to the water, more dye should move through the structure. Such a relationship does not exist when all the flow data are analyzed together. A regression of sink concentration as a function of source concentration shows a coefficient of determination, r^2, of 0.008 in the presealing condition and 0.029 during the postsealing phase. The coefficient of determination is used to ascertain the variability in the data that may be explained by the correlation between variables. In this case, the sink concentrations are completely independent of the source concentrations. Table 5 shows the coefficients of determination for the different types of flow regimes investigated.

41. The only flow condition that shows a statistical relationship between the source and sink concentrations is the peak ebb flow regime during the presealing condition. In this case the r^2 of 0.632 indicates that a regression line explains 63.2 percent of the variation seen. The F-statistic

Table 5

Coefficient of Determination for Different Flow Conditions, Sealing South Jetty, Port Everglades, Florida

Flow Condition	Coefficient of Determination, r^2		F-Statistic		Percent Significant	
	Preseal	Postseal	Preseal	Postseal	Preseal	Postseal
Combined flow	0.008	0.029	0.12	0.57	26.2	54.1
Combined flow w/o low-water slack	0.003	0.029	0.03	0.57	13.2	54.1
Peak ebb flow	0.632	0.129	3.43	0.74	79.5	57.1
Peak flood flow	0.019	0.148	0.06	0.87	17.3	60.7
High-water slack	--	0.052	--	0.28	--	37.8

can be used to test the significance of the r^2 statistic. The F-statistic tests the hypothesis that the linear slope of the dependent variable (sink concentration) is zero. In this case, the high F-statistic of 3.43 allows almost 80-percent confidence that the regression line explains at least 63.2 percent of the variation in the amounts of concentration on the source and sink sides of the jetty during the presealing phase of the peak ebb regime.

42. Third, although the same amount of dye was added to the source side of the jetty during each experiment, the resulting concentrations during the postsealing condition were an order of magnitude higher (121.4 ppm) than that during the presealing condition (16.0 ppm). This may bias the study results. These source-side concentrations are significantly different to greater than 99 percent (t-statistic = 3.78). However, the concentrations of dye measured on the sink side of the jetty do not as readily show a significant difference. They are only significantly different to 85 percent (t-statistic = 1.49). Again, the transmission coefficient is obtained by dividing the sink concentrations by the source concentrations and multiplying by 100. Because the

postsealing sink concentrations are divided by numbers an order of magnitude larger than the presealing sink concentrations, they will yield a much smaller transmissibility coefficient.

43. It is important to understand why the concentrations of dye were so much higher during the postsealing phase. The most probable explanation is that the success of the sealing allowed less dye to seep into (and eventually through) the structure. The dye could only increase in concentration (as the pellet degraded) on the source side of the jetty. The data also indicate that the highest source side concentrations were measured during the peak flow conditions. This indicates that the high flow conditions provided added agitation that helped disintegrate the dye pellets.

44. The sealing may be viewed as reducing the permeability of the jetty only during peak ebb flow conditions, and then only to nearly 85-percent statistical certainty.

Pre- and postconstruction current meter data

45. Evaluation of the current meter data was complicated by the fact that some or all of the current meters were above the water level during all or part of the low-water slack tests. Therefore, comparison of the pre- and postconstruction current meter data is limited to the peak flood, high-water slack, and peak ebb tests.

46. Averaging the x- and y-components of the flow for the three current meters deployed during a test results in average magnitude and direction vectors for the pre- and postconstruction experiments. These components are presented in Table 6, and the vectors are displayed in Figure 25 for the peak flood, high-water slack, and peak ebb tests. For the preconstruction tests, average currents move through the structure into the channel for all three flow test conditions. However, the vectors are directed away from the structure in the postconstruction tests, nearly perpendicular to the preconstruction vectors. This change in vector direction demonstrates a deflection in current flow and wave action, indicating a more reflective (hence, less transmissible) cross section.

Conclusions

47. The evaluations conducted during the monitoring of the Port Everglades, Florida, south jetty sealing project indicate that the transmissibility of the structure has been reduced. Comparison of the concentration of dye

Table 6

Average Current Data for Pre- and Postconstruction Conditions, Sealing South Jetty, Port Everglades, Florida

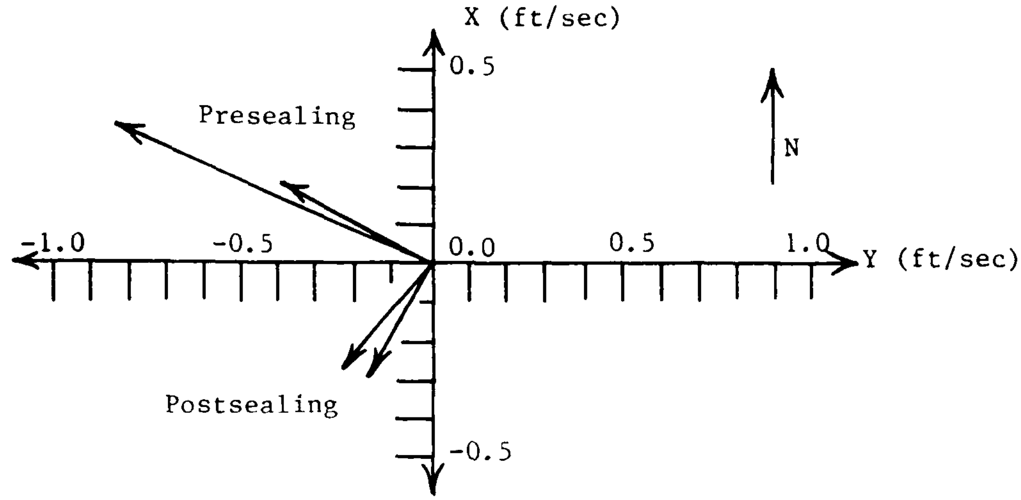
Flow Condition	Preconstruction X_{AVG} ft/sec	Preconstruction Y_{AVG} ft/sec	Postconstruction X_{AVG} ft/sec	Postconstruction Y_{AVG} ft/sec
Peak flood	0.32	-0.86	-0.30	-0.16
	0.19	-0.40	-0.29	-0.22
	0.03	-0.05	--	--
High slack	0.06	-0.34	-0.36	-0.19
Peak ebb	0.27	-0.55	-0.01*	0.17*
	0.09	-0.55	-0.23	-0.15

* Data available from only two current meters.

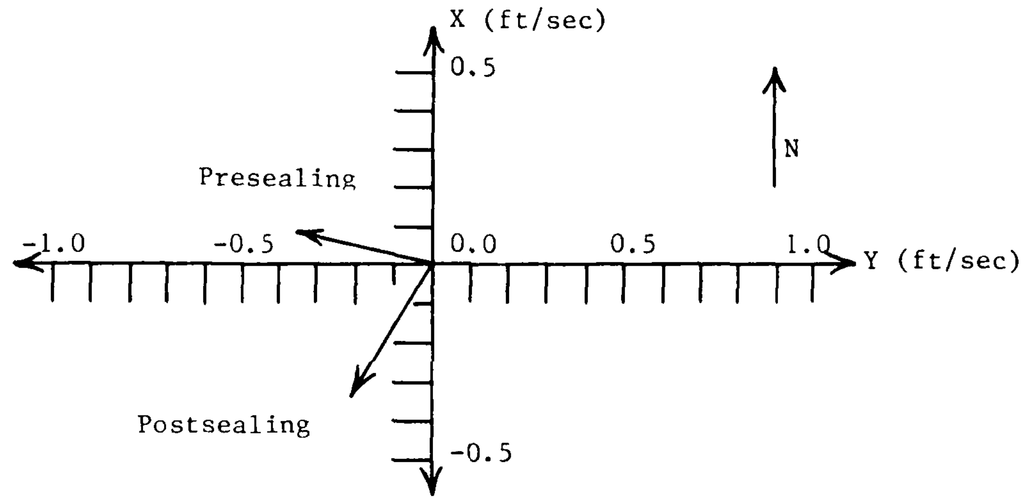
transmitted from one unsealed section and from one sealed section of the structure indicated that the sealing operation decreased structure transmission by almost 100 percent. Dye transmission data obtained before and after structure sealing for the entire sealed structure under all flow conditions indicated that average structure transmissibility had been reduced from 2.7 percent (outlier removed) to 1.9 percent, significant to only a 53-percent level. If the low-water slack test cases are eliminated from the preconstruction test data (to obtain uniformity between the pre- and postconstruction data sets), the unsealed structure was approximately 4.0 percent transmissible (outlier removed), which reduced to 1.9-percent transmissibility after sealing of the structure was completed (nearly 90-percent certainty). A larger decrease in structure transmissibility was observed when the pre- and postconstruction peak ebb flow data were compared; however, this decrease is significant only to a low statistical level (not quite 85 percent). A change in average current vector direction, measured during peak flood, high-water slack, and peak ebb conditions, indicated that the structure was more reflective in the postsealing condition and, therefore, less transmissible.

48. Considering the very low compressive strengths of sodium silicate-cement and sodium silicate-diacetin test specimens,* and the observed rapid erosion and deterioration of such specimens at long-term exposure field stations presently being monitored as part of the Repair, Evaluation,

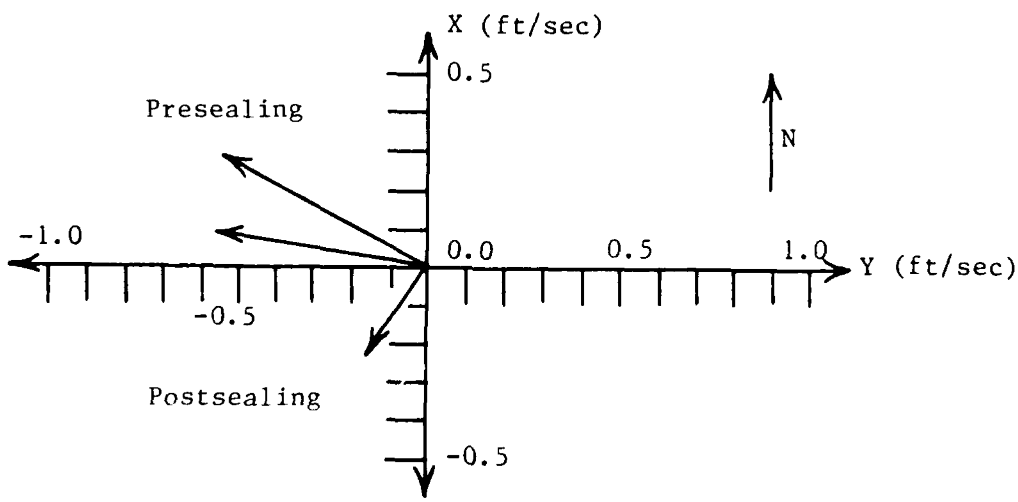
* Simpson and Thomas, op. cit.



a. Peak flood



b. High water slack



c. Peak ebb

Figure 25. Average currents measured in structure voids for pre- and postsealing conditions at south jetty, Port Everglades, Florida

Maintenance, and Rehabilitation Program investigations, it is essential that prototype monitoring of completed sealing projects be performed. It is highly recommended that periodic reevaluation of the effectiveness of the sodium silicate-cement and sodium silicate-diacetin sealant placement at Port Everglades, Florida, south jetty (and the previously completed sealing project at West Palm Beach, Florida, south jetty) be conducted to ascertain the actual useful life of these sealing efforts so that true economic benefits and cost comparisons of all alternatives are realistic.

49. Hazardous or toxic substances should never be used in the marine environment. Reasonable caution should guide the preparation, operation, and cleanup phases of repair activities involving potentially hazardous or toxic chemical substances. Manufacturers' directions and recommendations for the protection of occupation health and environmental quality should be carefully followed. Material safety data sheets should be obtained from the manufacturers of such materials. In cases where the effects of a chemical substance on occupational health and environmental quality are unknown, chemical substances should be considered hazardous or toxic until their health and environmental consequences are determined.

50. The use of synthetic materials such as those used in this application at Port Everglades, Florida, continues to draw scrutiny from various environmental advocacy groups. The US Army Corps of Engineers (USACE) is in full agreement with such concerns and recognizes the health, safety, and water quality aspects associated with such materials. The USACE is committed to fully understanding all environmental consequences associated with their utilization and will adhere to all standards, specifications, and safeguards pertaining thereto.

APPENDIX A: DYE TRANSMISSION DATA, REHABILITATION OF SOUTH JETTY BY VOID SEALING, PORT EVERGLADES, FLORIDA

Table A1

High-Water Slack Dye Transmission Through Jetty on 23 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.1	0.03
4+70 S	0	1.8	1.1
	10	2.8	1.8
	20	3.6	2.3
	30	3.2	2.0
	40	2.8	1.7
3+76 N	0	63.8	40.0
	10	18.0	11.3
	20	79.0	49.6
	30	65.0	40.8
	40	45.0	28.2**
4+70 N	0	17.0	10.7
	10	120.0	75.3
	20	7.7	4.8
	30	8.3	5.2
	40	14.5	9.2

* Dye placed in voids at Sta 3+76 N (north side) and 4+70 N. Data were collected from 13:15 to 14:15 Eastern Daylight Standard Time (EDST). Windspeed, breaking wave height, and wave period were not measured. Tidal current was 0 knot.

** Omit from average concentration presented in Table 2 in main text to maintain uniformity between data sets.

Table A2

Peak Ebb Dye Transmission Through Jetty on 24 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.1	0.1
	10	0.0	0.0
	20	0.1	0.1
	30	2.8	1.8
	40	1.6	1.0
	50	1.7	1.0
	60	1.3	0.8
4+70 S	0	0.3	0.2
	10	0.0	0.2
	20	0.4	0.3
	30	1.3	0.8
	40	2.1	1.3
	50	2.6	1.6
	60	3.2	2.0
3+76 N	0	18.3	11.5
	10	27.9	17.5
	20	37.8	23.7
	30	32.4	20.3
	40	61.2	38.4
	50	60.0	37.6
	60	16.5	10.4
4+70 N	0	5.5	3.5
	10	13.0	8.2
	20	13.5	8.5
	30	54.0	33.9
	40	13.0	8.2
	50	27.0	16.9
	60	2.3	1.4

* Dye placed in voids at Sta 3+76 N (north side) and 4+70 N. Data were collected from 8:15 to 9:15 EDST. Windspeed was from 6 to 7 mph from the east, breaking wave height was 0.5 ft, wave period was 3.8 sec, and tidal currents were 0.7 knot.

Table A3

Low-Water Slack Dye Transmission Through Jetty on 24 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	1.1	0.7
	10	36.0	22.6
	20	84.6	53.1
	30	22.0	13.8
	40	3.6	2.3
	50	1.4	0.9
	60	1.0	0.6
4+70 S	0	697.5	437.6
	10	43.5	27.3
	20	31.5	19.8
	30	7.2	4.5
	40	2.9	1.8
	50	5.3	3.3
	60	1.8	1.1
6+40 S	0	32.4	20.3
	10	13.0	8.1
	20	28.0	17.6
	30	43.0	27.0
	40	16.0	10.0
	50	11.5	7.2
	60	3.1	2.0
3+76 N	0	0.2	0.1
	10	0.3	0.2
	20	0.2	0.1
	30	0.1	0.1
	40	0.3	0.2
	50	0.2	0.1
	60	0.1	0.1

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, and 6+40 S. Data were collected from 12:15 to 13:15 EDST. Windspeed was from 5 to 6 mph from the southeast, breaking wave height was 0.5 ft, wave period was not measured, and tidal currents were 0 knot.

Table A3 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 N	0	0.2	0.1
	10	0.2	0.1
	20	0.1	0.1
	30	0.2	0.1
	40	0.2	0.1
	50	0.1	0.1
	60	0.1	0.1
6+40 N	0	0.1	0.1
	10	0.4	0.2
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0

Table A4

Peak Flood Dye Transmission Through Jetty on 24 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	7.0	4.4
	10	9.6	6.0
	20	6.7	4.2
	30	14.5	9.1
	40	1.9	1.2
	50	0.7	0.4
	60	0.8	0.5
4+70 S	0	1.0	0.6
	10	4.6	2.9
	20	3.3	2.1
	30	3.0	1.9
	40	0.8	0.5
	50	0.3	0.2
	60	0.5	0.3
3+76 N	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
3+76 N (@ seabed)	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0

(Continued)

* Dye placed in voids at Sta 3+76 S (south side) and 4+70 S. Data were collected from 15:00 to 16:00 EDST. Windspeed was from 8 mph from the southeast, breaking wave height was 0.5 ft, wave period was not measured, and tidal currents were 0.6 knot.

Table A4 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 N	0	0.2	0.1
	10	0.3	0.2
	20	0.1	0.1
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
4+70 N (@ seabed)	0	0.4	0.2
	10	0.4	0.2
	20	0.1	0.1
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0

Table A5

Peak Ebb Dye Transmission Through Jetty on 25 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.1	0.1
	10	4.6	2.9
	20	4.3	2.7
	30	3.7	2.3
	40	1.4	0.9
	50	2.5	1.6
	60	2.1	1.3
3+76 S (@ seabed)	0	0.0	0.0
	10	1.9	1.2
	20	2.3	1.4
	30	2.6	1.6
	40	1.7	1.0
	50	3.2	2.0
	60	3.1	1.9
4+70 S	0	0.1	0.1
	10	2.8	1.8
	20	3.2	2.0
	30	1.6	1.0
	40	1.1	0.7
	50	0.7	0.4
	60	0.4	0.3
4+70 S (@ seabed)	0	0.0	0.0
	10	0.9	0.6
	20	0.9	0.6
	30	0.9	0.6
	40	0.6	0.4
	50	0.2	0.1
	60	0.1	0.1

(Continued)

* Dye placed in voids at Sta 3+76 N (north side) and 4+70 N. Data were collected from 9:55 to 10:55 EDST. Windspeed was from 3 to 4 mph from the southeast, breaking wave height was 0.5 ft, wave period was not measured, and tidal currents were 0.8 knot.

Table A5 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 N	0	27.9	17.5
	10	6.1	3.8
	20	2.4	1.5
	30	1.0	0.6
	40	1.1	0.7
	50	0.2	0.1
	60	0.4	0.3
4+70 N	0	3.5	2.2
	10	79.2	49.7
	20	5.2	3.3
	30	2.8	1.8
	40	1.1	0.7
	50	0.4	0.2
	60	0.1	0.1

Table A6

Low-Water Slack Transmission Through Jetty on 25 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
3+76 S (@ seabed)	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
4+70 S	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
4+70 S (@ seabed)	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0

(Continued)

* Dye placed in voids at Sta 3+76 N (north side) and 4+70 N. Data were collected from 13:15 to 14:15 EDST. Windspeed was from 3 to 4 mph from the southeast, breaking wave height and wave period were not measured, and tidal currents were 0 knot.

Table A6 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 N	0	43.2	27.1
	10	17.5	11.0
	20	5.8	3.6
	30	7.0	4.4
	40	2.9	1.8
	50	1.3	0.8
	60	0.8	0.5
4+70 N	0	14.8	9.3
	10	13.5	8.5
	20	5.6	3.5
	30	0.9	0.6
	40	0.5	0.3
	50	0.4	0.3
	60	0.1	0.1

Table A7

Peak Flood Dye Transmission Through Jetty on 25 August 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	13.6	8.5
	10	44.8	28.1
	20	88.0	55.2
	30	32.8	20.6
	40	20.5	12.9
	50	14.8	9.3
	60	13.5	8.5
4+70 S	0	21.0	13.2
	10	5.8	3.6
	20	23.2	14.6
	30	18.0	11.4
	40	29.5	18.5
	50	14.0	8.8
	60	11.8	7.4
6+40 S	0	1.0	0.6
	10	1.9	1.2
	20	1.2	0.8
	30	0.4	0.3
	40	0.8	0.5
	50	0.5	0.3
	60	0.9	0.6
3+76 N	0	0.2	0.1
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.1	0.1
	50	0.1	0.1
	60	0.0	0.0

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, and 6+40 N. Data were collected from 15:55 to 16:55 EDST. Windspeed was from 8 to 10 mph from the southeast, breaking wave height and wave period were not measured, and tidal currents were 0.7 knot.

Table A7 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 N (@ seabed)	0	--	--
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.0	0.0
4+70 N	0	0.1	0.1
	10	0.1	0.1
	20	0.1	0.1
	30	0.1	0.1
	40	0.1	0.1
	50	0.5	0.3
	60	0.3	0.2
4+70 N (@ seabed)	0	--	--
	10	--	--
	20	0.0	0.0
	30	0.0	0.0
	40	0.0	0.0
	50	0.0	0.0
	60	0.1	0.1
6+40 N	0	0.0	0.0
	10	0.0	0.0
	20	0.0	0.0
	30	0.0	0.0
	40	0.1	0.1
	50	0.1	0.1
	60	0.0	0.0

Table A8

Peak Ebb Dye Transmission Through Jetty on 10 October 1988,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 S	0	0.2	0.1
	10	140.0	87.8
	20	153.5	96.3
	30	262.5	164.7
	40	172.0	107.9
	50	152.0	95.4
	60	150.0	94.1
4+70 N	0	13.0	8.2
	10	80.0	50.2
	20	32.5	20.4
	30	36.5	22.9
	40	11.5	7.2
	50	4.5	2.8
	60	12.0	7.5

* Dye placed in grout hole at Sta 4+70 (center of structure). Data were collected from 11:55 to 12:55 EDST. Winds were from the south, and breaking wave height and wave period were not measured. Tidal current was 1.6 knot.

Table A9

Peak Ebb Dye Transmission Through Jetty on 11 October 1988.*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm	Conc. less prior, ppm
3+76 S	prior	0.4	0.3	--
	0	0.0	0.0	0.0
	10	0.4	0.3	0.0
	20	0.0	0.0	0.0
	30	1.0	0.6	0.3
	40	0.1	0.1	0.0
	50	0.3	0.2	0.0
	60	1.4	0.9	0.6
3+76 N	prior	0.2	0.1	--
	0	0.0	0.0	0.0
	10	0.0	0.0	0.0
	20	0.2	0.1	0.0
	30	0.1	0.1	0.0
	40	0.0	0.0	0.0
	50	0.0	0.0	0.0
	60	0.0	0.0	0.0

* Dye placed in grout hole at Sta 3+76 (center of structure). Data were collected from 12:10 to 13:10 EDST. Winds were from the south, and breaking wave height and wave period were not measured. Tidal current was 0.6 knot.

Table A10

Peak Ebb Dye Transmission Through Jetty on 30 January 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.2	0.1**
	5	0.8	0.5
	10	1.0	0.6
	20	0.3	0.2
	30	0.3	0.2
	40	0.3	0.2
	50	0.5	0.3
	60	2.1	1.3
4+70 S	0	0.1	0.1**
	5	0.5	0.3
	10	50.0	31.4
	20	19.0	11.9
	30	17.0	10.7
	40	33.6	21.1
	50	16.0	10.0
	60	11.5	7.2
6+40 S	0	0.2	0.1**
	5	0.0	0.0
	10	0.2	0.1
	20	0.8	0.5
	30	0.5	0.3
	40	0.5	0.3
	50	0.8	0.5
	60	1.1	0.7
3+76 N	0	0.2	0.1**
	5	212.0	133.0
	10	300.0	188.2
	20	128.0	80.3
	30	136.0	85.3
	40	132.0	82.8
	50	116.0	72.8
	60	358.4	224.9

(Continued)

* Dye placed in voids at Sta 3+76 N (north side), 4+70 N, and 6+40 N. Data were collected from 16:30 to 17:30 EDST. Windspeed was from 12 to 14 mph from the southeast, breaking wave height was 0.5 ft, wave period was not measured, and tidal currents were 0.4 knot.

** Measurement omitted from 60-min average.

Table A10 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 N	0	0.2	0.1**
	5	152.0	95.4
	10	188.0	117.9
	20	344.0	216.0
	30	184.0	115.4
	40	300.0	188.2
	50	358.4	224.9
	60	304.0	190.7
6+40 N	0	0.2	0.1**
	5	92.0	57.7
	10	184.0	115.5
	20	80.0	50.2
	30	148.0	92.9
	40	70.4	44.2
	50	244.0	153.1
	60	120.0	75.3

** Measurement omitted from 60-min average.

Table A11

Peak Flood Dye Transmission Through Jetty on 31 January 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	0.3	0.2**
	5	6.6	4.1**
	10	210.8	132.3
	20	278.8	174.9
	30	266.0	166.9
	40	221.0	138.7
	50	70.0	43.9
	60	100.8	63.3
4+70 S	0	0.2	0.1**
	5	315.0	197.6
	10	486.0	304.9
	20	603.5	378.7
	30	465.0	291.7
	40	586.5	368.0
	50	645.0	404.7
	60	765.0	480.0
6+40 S	0	0.1	0.1**
	5	612.0	384.0
	10	935.0	586.6
	20	595.0	373.3
	30	722.5	453.3
	40	693.0	434.8
	50	294.5	184.7
	60	578.6	363.0
3+76 N	0	0.4	0.3**
	5	1.8	1.1**
	10	4.4	2.8
	20	2.5	1.6
	30	2.8	1.8
	40	3.7	2.3
	50	1.9	1.2
	60	3.1	2.0

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, and 6+40 S. Data were collected from 11:40 to 12:40 EDST. Windspeed was from 7 to 9 mph from the south, breaking wave height and wave period were not measured, and tidal currents were 0.5 knot.

** Measurement omitted from 60-min average.

Table A11 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 N	0	0.3	0.2**
	5	1.7	1.0
	10	3.2	2.0
	20	3.8	2.4
	30	3.7	2.3
	40	2.9	1.8
	50	3.3	2.1
	60	2.9	1.8
6+40 N	0	0.7	0.4**
	5	1.5	0.9
	10	3.0	1.9
	20	3.5	2.2
	30	3.0	1.9
	40	2.7	1.7
	50	2.0	1.2
	60	3.2	2.0

** Measurement omitted from 60-min average.

Table A12

High-Water Slack Dye Transmission Through Jetty on 31 January 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	74.1	46.5
	10	104.5	65.6
	20	42.8	26.8
	30	76.0	47.7
	40	40.9	25.6
	50	26.0	16.3
	60	29.0	18.2
4+70 S	0	265.5	160.9
	10	90.3	56.6
	20	94.0	58.9
	30	112.0	70.3
	40	99.8	62.6
	50	109.3	68.5
	60	123.5	77.5
6+40 S	0	50.0	31.3
	10	20.0	12.5
	20	40.0	25.1
	30	40.0	25.1
	40	29.7	18.6
	50	27.8	17.4
	60	26.0	16.3
3+76 N	0	0.2	0.1
	10	0.4	0.2
	20	0.3	0.2
	30	0.2	0.1
	40	0.4	0.3
	50	0.2	0.1
	60	0.4	0.3

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, and 6+40 S. Data were collected from 15:10 to 16:10 EDST. Windspeed was from 6 to 7 mph from the east-northeast, breaking wave height and wave period were not measured, and tidal currents were 0 knot.

Table A12 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
4+70 N	0	0.5	0.3
	10	0.1	0.1
	20	0.5	0.3
	30	0.3	0.2
	40	0.4	0.3
	50	0.2	0.1
	60	2.0	1.3
6+40 N	0	0.6	0.4
	10	1.0	0.6
	20	0.8	0.5
	30	0.5	0.3
	40	0.5	0.3
	50	0.4	0.3
	60	0.7	0.4

Table A13

Peak Flood Dye Transmission Through Jetty on 1 February 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	8.4	5.3**
	5	79.2	49.7
	10	157.5	98.8
	20	445.5	279.5
	30	115.2	72.2
	40	162.0	101.6
	50	364.5	228.7
	60	72.5	45.5
4+70 S	0	43.5	27.3**
	5	675.0	423.5
	10	241.2	151.3
	20	324.0	203.3
	30	567.0	355.8
	40	688.5	432.0
	50	504.4	316.5
	60	111.6	70.0
6+40 S	0	1.5	0.9**
	5	171.0	107.3
	10	270.0	169.4
	20	421.2	264.3
	30	405.0	254.1
	40	567.0	355.7
	50	216.0	135.5
	60	297.0	186.4
7+00 S	0	0.4	0.2**
	5	45.0	28.2
	10	32.0	20.1
	20	162.0	101.6
	30	109.8	68.9
	40	111.6	70.0
	50	121.5	76.2
	60	251.1	157.6

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, 6+40 S, and 7+00 S. Data were collected from 12:30 to 13:30 EDST. Windspeed was from 2 to 4 mph from the east, breaking wave height and wave period were not measured, and tidal currents were 0.6 knot.

** Measurement omitted from 60-min average.

Table A13 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 N	0	0.3	0.2**
	5	1.2	0.8
	10	0.4	0.2
	20	0.4	0.2
	30	0.4	0.2
	40	0.3	0.2
	50	0.3	0.2
	60	0.3	0.2
4+70 N	0	0.1	0.1**
	5	0.3	0.2
	10	0.2	0.2
	20	1.1	0.7
	30	0.7	0.5
	40	1.2	0.8
	50	0.9	0.6
	60	0.5	0.3
6+40 N	0	0.2	0.2**
	5	0.4	0.2
	10	0.9	0.6
	20	1.5	0.9
	30	0.3	0.2
	40	0.3	0.2
	50	2.0	1.3
	60	1.8	1.1
7+00 N	0	0.1	0.1**
	5	1.0	0.6
	10	1.0	0.6
	20	0.9	0.6
	30	1.8	1.1
	40	0.9	0.6
	50	1.8	1.1
	60	1.2	0.8

** Measurement omitted from 60-min average.

Table A14

High-Water Slack Dye Transmission Through Jetty on 1 February 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 S	0	30.5	19.1
	10	14.5	9.1
	20	28.5	17.9
	30	12.0	7.5
	40	2.8	1.7
	50	5.6	3.5
	60	2.3	1.4
4+70 S	0	11.5	7.2
	10	8.5	5.3
	20	9.0	5.6
	30	9.5	6.0
	40	8.5	5.3
	50	6.6	4.1
	60	7.1	4.5
6+40 S	0	36.5	22.9
	10	22.5	14.1
	20	18.0	11.3
	30	12.0	7.5
	40	10.0	6.3
	50	7.4	4.6
	60	4.4	2.8
7+00 S	0	22.0	13.8
	10	17.5	10.9
	20	15.5	9.7
	30	11.0	6.9
	40	10.5	6.6
	50	9.0	5.7
	60	10.5	6.6

(Continued)

* Dye placed in voids at Sta 3+76 S (south side), 4+70 S, 6+40 S, and 7+00 S. Data were collected from 16:00 to 17:00 EDST. Windspeed was from 7 to 9 mph, breaking wave height and wave period were not measured, and tidal currents were 0 knot.

Table A14 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm
3+76 N	0	0.5	0.3
	10	0.4	0.2
	20	0.2	0.1
	30	0.3	0.2
	40	0.3	0.2
	50	0.2	0.1
	60	0.2	0.1
4+70 N	0	0.3	0.2
	10	0.4	0.2
	20	0.2	0.2
	30	0.3	0.2
	40	0.3	0.2
	50	0.2	0.1
	60	0.2	0.1
6+40 N	0	0.4	0.2
	10	0.4	0.2
	20	0.5	0.3
	30	0.4	0.3
	40	0.7	0.4
	50	0.3	0.2
	60	0.4	0.2
7+00 N	0	1.1	0.7
	10	0.7	0.5
	20	0.8	0.5
	30	0.8	0.5
	40	0.8	0.5
	50	0.4	0.3
	60	0.5	0.3

Table A15

Peak Ebb Dye Transmission Through Jetty on 2 February 1989,*

Rehabilitation of South Jetty by Void Sealing

Port Everglades, Florida

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm	Conc. less prior, ppm
3+76 S	prior	2.1	1.3	--
	0	3.4	2.2	0.9
	10	3.0	1.9	0.6
	20	3.2	2.0	0.7
	30	4.0	2.5	0.8
	40	5.7	3.6	2.3
	50	3.8	2.4	1.1
	60	3.1	2.0	0.7
4+70 S	prior	0.7	0.5	--
	0	2.4	1.5	1.0
	10	1.8	1.1	0.6
	20	2.2	1.4	0.9
	30	2.2	1.4	0.9
	40	3.6	2.3	1.8
	50	43.5	27.7	27.2
	60	15.5	9.9	9.4
6+40 S	prior	0.9	0.6	--
	0	0.9	0.5	0.0
	10	0.8	0.5	0.0
	20	0.7	0.4	0.0
	30	0.4	0.3	0.0
	40	0.7	0.5	0.0
	50	1.2	0.8	0.2
	60	1.3	0.8	0.2
7+00 S	0	0.9	0.6	--
	10	1.6	1.0	--
	20	0.8	0.5	--
	30	1.1	0.7	--
	40	1.8	1.1	--
	50	1.9	1.2	--
	60	3.4	2.2	--

* Dye placed in voids at Sta 3+76 N (north side), 4+70 N, 6+40 N, and 7+00 N. Data were collected from 07:05 to 08:05 EDST. Winds were from the northwest at 2 to 4 mph, breaking wave height was 0.5 ft, wave period was 3.5 sec, and tidal currents were 0.5 knot.

Table A15 (Concluded)

Station	Elapsed Time min	Relative Fluorescence	Concentration ppm	Conc. less prior, ppm
3+76 N	prior	0.2	0.1	--
	0	229.5	145.9	145.8
	10	256.5	163.1	163.0
	20	396.0	251.8	251.7
	30	405.0	257.5	257.4
	40	337.5	214.6	214.5
	50	112.5	71.5	71.4
	60	202.5	128.7	128.6
4+70 N	prior	0.3	0.2	--
	0	71.5	45.5	45.3
	10	216.0	137.3	137.1
	20	196.2	124.7	124.5
	30	50.0	31.8	31.6
	40	263.7	167.7	167.5
	50	52.5	33.4	33.2
	60	31.0	19.7	19.5
6+40 N	prior	0.5	0.3	--
	0	148.5	94.4	94.1
	10	139.5	88.7	88.4
	20	234.0	148.8	148.5
	30	106.2	67.5	67.2
	40	191.7	121.9	121.6
	50	153.0	97.3	97.0
	60	153.0	97.3	97.0
7+00 N	0	77.5	49.3	--
	10	211.5	134.5	--
	20	126.9	80.7	--
	30	405.0	257.5	--
	40	91.5	58.2	--
	50	92.0	58.5	--
	60	72.5	46.1	--

APPENDIX B: CURRENT METER DATA, REHABILITATION OF SOUTH JETTY BY VOID SEALING, PORT EVERGLADES, FLORIDA

Table B1

Pregrouting Current Meter Data Rehabilitation of South Jetty by Void Sealing, Port Everglades, Florida

Date	Time	Tidal Condition	Meter Location	Average X ft/sec	Standard Deviation ft/sec	Average Y ft/sec	Standard Deviation ft/sec	Average Velocity ft/sec	Average Direction
8/23/88	13:16-14:16	Peak flood	3+76	0.38	0.42	-0.35	0.92	1.69	47
			4+70	0.74	0.47	-1.10	1.38	1.29	145
			6+40	-0.17	0.31	-1.14	0.91	1.15	351
8/23/88	16:59-18:01	High slack	3+76	0.22	0.12	-0.09	0.44	0.24	68
			4+70	0.09	0.20	-0.30	0.39	0.32	163
			6+40	-0.12	0.19	-0.63	0.66	0.64	349
8/24/88	08:13-09:15	Peak ebb	3+76	0.20	0.22	-0.18	0.61	0.27	47
			4+70	0.72	0.26	-1.44	0.93	1.60	153
			6+40	-0.10	0.19	-0.04	0.34	0.11	291
8/24/88	12:10-12:20	Low slack	3+76	0.08	0.11	-0.10	0.10	0.13	38
			4+70	-0.65	0.92	-1.07	0.96	1.24	210
			6+40	-0.04	0.29	-0.34	0.46	0.34	352
8/24/88	12:23-13:23	Low slack	3+76	0.06	0.16	-0.01	0.39	0.06	79
			4+70	-1.60	4.60	-2.57	4.26	3.03	212
			6+40	0.01	0.28	-0.06	0.44	0.06	9
8/24/88	14:56-15:56	Peak flood	3+76	0.19	0.19	-0.14	0.64	0.24	54
			4+70	0.46	0.28	-0.98	0.81	1.07	154
			6+40	-0.07	0.21	0.09	0.32	0.11	218
8/25/88	09:50-10:50	Peak ebb	3+76	0.29	0.37	-0.28	0.67	0.41	46
			4+70	0.10	3.88	-1.36	3.40	1.36	175
			6+40	-0.11	0.16	0.003	0.27	0.11	268
8/25/88	13:10-13:40	Low slack	3+76	0.02	0.03	-0.03	0.04	0.04	41
			4+70	0.09	2.55	0.00	2.40	0.09	89
			6+40	0.01	0.07	-0.01	0.12	0.01	35
8/25/88	15:46-17:01	Peak flood	3+76	0.04	0.03	-0.03	0.12	0.05	51
			4+70	0.09	0.09	-0.19	0.20	0.21	155
			6+40	-0.04	0.04	0.06	0.08	0.07	210

Table B2

Postgrouting Current Meter Data Rehabilitation of South Jetty by Void Sealing, Port Everglades, Florida

Date	Time	Tidal Condition	Meter Location	Average X ft/sec	Standard Deviation ft/sec	Average Y ft/sec	Standard Deviation ft/sec	Average Velocity ft/sec	Average Direction
1/30/89	16:21-17:39	Peak ebb	3+76	-1.03	2.50	0.74	3.25	1.27	294
			4+70*	0.65	1.11	0.34	0.56	0.74	287
			6+40	1.01	1.39	-0.40	1.43	1.09	248
1/31/89	11:25-12:48	Peak flood	3+76	0.04	0.64	0.06	1.02	0.07	208
			4+70	-1.26	0.65	-0.62	2.06	1.41	273
			4+70*	0.42	0.37	0.24	0.24	0.48	284
			6+40	0.32	0.32	0.09	0.48	0.34	285
1/31/89	15:02-16:18	High slack	3+76	0.02	0.43	0.08	0.84	0.08	224
			4+70	-1.30	0.64	-0.68	1.69	1.47	272
			4+70*	0.31	0.36	0.18	0.25	0.35	284
			6+40	0.21	0.39	0.03	0.44	0.21	277
2/01/89	09:54-11:03	Low slack	3+76	-0.32	1.16	0.36	1.32	0.49	281
			4+70	-2.33	1.85	-2.52	2.34	3.43	252
			4+70**	0.37	0.55	0.90	0.54	0.98	112
			6+40	0.39	0.43	0.20	0.45	0.44	297
2/01/89	12:28-13:36	Peak flood	3+76	0.05	0.74	0.11	1.16	0.12	215
			4+70	-1.39	0.77	-0.90	2.45	1.66	267
			4+70*	0.37	0.64	0.07	0.59	0.38	170
			6+40	0.46	0.48	0.12	0.50	0.47	284
2/02/89	07:20-08:12	Peak ebb	3+76	0.03	1.05	0.18	1.78	0.18	229
			4+70	-1.46	1.33	-0.74	3.58	1.63	273
			4+70*	0.40	0.60	1.06	0.66	1.13	110
			6+40	0.75	0.78	0.10	0.74	0.76	277

* Current meter was located offshore, approximately 50 ft south of Sta 4+70.
** Current meter was located offshore, approximately 50 ft north of Sta 4+70.