CHAPTER 87

COMPREHENSIVE MONITORING OF A BEACH RESTORATION PROJECT

by

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ABSTRACT

This paper outlines the results obtained from monitoring the Beach Nourishment Project at Jupiter Island, Florida. Jupiter Island is a 16 mile long barrier island on the east coast of Florida. Five miles of the beach were nourished in two stages in 1973 and 1974. A total of 3.4 million cubic yards of sand were dredged from an offshore borrow area and placed on the beach. The monitoring program included: seasonal hydrographic surveys of beach and offshore profile to 3000 feet offshore; climatological monitoring of wind, waves, tides and currents over a one-year period; tracer and dye studies; and sand sampling and coring at selected beach and offshore locations. The results indicate that beach restoration has a groin effect in the sense of producing favorable changes in littoral drift due to shore alignment changes. A net accretion updrift of the restored area occurs. The results demonstrate the importance of the offshore profile in accounting for the total sedimentary balance. Shoreline recession coupled by a build up in the offshore profile may reflect accretion rather than erosion. Finally, the results show that the littoral drift formula using the wave climate as input provides inadequate prediction estimates for erosion or deposition following construction of a beach restoration project.

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I. INTRODUCTION

Jupiter Island is a barrier island about 16 miles long on the east coast of Florida. The island lies between St. Lucie inlet, on the north, and Jupiter inlet, on the south, Figure 1. The island has had a long history of erosion problems and has been a subject of extensive studies (see references 1, 2, 3, 4, and 5). In the past several years the residents of Jupiter Island, Florida have financed the construction of seawalls, revetments and groins in an effort to prevent loss of beach-front property. In addition to structural protection, several beach fill techniques have been tested including scrapers and draglines recovering material from the surf zone. These efforts were not successful - [6]. It was proposed that a long term solution to the problem was artificial nourishment of the beach from offshore borrow.

In 1973 the town of Jupiter Island agreed to restore a 5 mile portion of the beach with about 2.4 million cubic yards of sand to be obtained from an offshore borrow area about 3000 feet from the shore [5]. Due to constructional difficulties the restoration project was completed in two stages, 68% of restoration completed in the summer 1973 (Stage I), and 32% completed in the summer of 1974 (Stage II) and a total of 3.4 million cubic yards of sand was placed on the beach. About 1000 feet of beach, public beach in Figure 1, was left unrestored because of an alleged biologically important reef in the surf-zone immediately offshore.

Artificial beach nourishment from offshore borrow as a method to combat beach erosion and provide recreational areas is now utilized over most other engineering practices. The costs of placing large volumes of suitable beach fill are high. It is therefore important that criteria be developed for evaluating and predicting the effectiveness of borrow material from offshore sources. At the present time no completely satisfactory test for evaluating the feasibility of utilizing available offshore borrow has been developed. Though much more work must be done, it has become evident that more emphasis must be given to total onshore and offshore volumetric transport and the range in size gradation of the borrow material.

II. MONITORING OF THE RESTORED BEACH

A monitoring program was undertaken to evaulate the fill performance. The specific objectives were to observe the changes in the sand balance, shoreline shape, sand characteristics, and to explain these changes in terms of caustive factors. The monitoring study was initiated in March, 1974 and included the following:

(1) Seasonal hydrographic surveys of the beach and the offshore profile to 3000 feet offshore along six miles of the restored beach and adjacent areas.
(2) Continuous monitoring of wind, waves, tides and currents over a one year period.
(3) Tracer and dye studies.
(4) Sand sampling and corings at selected beach and offshore locations.

(1) The Hydrographic Surveys

Hydrographic surveys including the offshore profile were conducted along six miles of beach before construction, after first construction

Figure 1. Location Map.

and at different intervals afterwards. Pre-construction and post-construction surveys of stages I and II were conducted by Arthur V. Strock & Associates, Inc. of Deerfield Beach, Florida. Their surveys were limited to 1200 feet from shore. More frequent and detailed surveys were conducted by the Coastal and Oceanographic Engineering Laboratory (COEL), covering the offshore profile to 3000 feet. Table I shows the summary of hydrographic surveys conducted.

Table I. Summary of Hydrographic Surveys.

Date	Description	Surveyed By	Reference Date
June-Sept., 73	Pre-Construction stage I	Strock&Assoc. Inc.	June, 1973
July-Nov., 73	Post-Construction stage I	Strock&Assoc. Inc.	Nov., 1973
May-June, 74	Follow-up (This also serves as pre-constr. for stage II)	COEL, Strock &Assoc., Inc.	May, 1974
June-July, 74	Post-Construction stage II (This is a partial survey covering only stage II fill area)	Strock&Assoc. Inc.	June, 1974
Aug., 74	Summer survey	COEL	Aug., 1974
Nov., 74	Fall survey (after Oct.	COEL	Nov., 1974

(2) Monitoring of Wind, Waves, Tide, and Currents

a) Continuous recordings of wind speed and direction were obtained from March 1974 to May 1975. Use was made of a MRI Anemometer Model 1071. The anemometer was installed on a tower 30 feet above ground level inside the study area, shown as square number 1, in Figure 2.

b) Continuous recordings of the tide were obtained from March 1974 to May 1975. A Leipold Stevens tide gauge, type F, was placed at the end of a pier 10 miles south of the south end of the study area.

c) The monitoring of waves presented a more troublesome task than anticipated. No piers or other convenient structures could be found near the study area. It was decided to use a self recording pressure type wave gauge, Bass Engineering model WG/100M, which was installed in 20 feet depth within the study area (square number 2 in Figure 2). This gauge did not perform satisfactorily and no significant data was collected during the period of use. An Ocean Applied Research (OAR) Telemetry Wave Gauge was subsequently installed at a depth of 30 feet in October 1974 (square number 3 in Figure 2). It operated satisfactorily until January 1975. In April 1975 a Hydroproducts Wave and Tide gauge, Model 621, was installed. The shore based monitor was connected to an offshore pressure transducer by a 3000 foot armored cable. The location of this installation is shown as square number 4 in Figure 2. The latter gauge operated satisfactorily

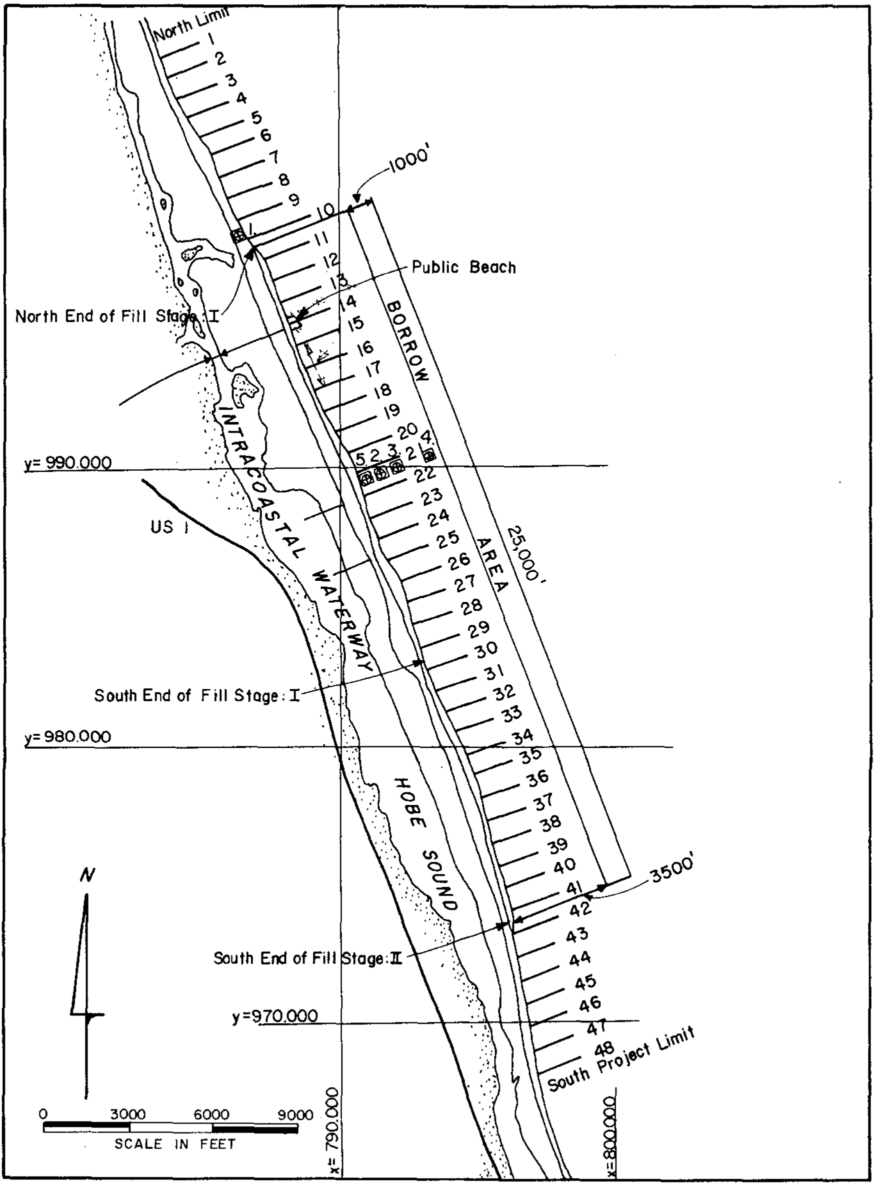


Figure 2. Profile lines and instrument location map.

until the end of the study period (May 1975). Wave directions were obtained by measuring the angle between the shoreline and the breaker line. These measurements were obtained at two locations two to five times a day during the periods of wave recording. One observation post was immediately shoreward of the wave gauge and the other was at the pier near the tide gauge installation.

d) Current measurements were obtained using a Bendix Model Q-16 self-recording current meter. This meter was installed in 11 feet water depth. The impeller duct was placed 3 feet above the bottom (square number 5 in Figure 2). Current magnitudes and directions were continuously recorded from October 1974 to May 1975 with only intermittent failures.

(3) Tracer and Dye Studies

The littoral drift pattern and longshore velocities in the study area were periodically measured. Fresh water filled ballons with attached fluorescent dye bags were placed at different distances from shore. Each balloon was followed along its travel path and its speed recorded. At the same time wave characteristics, beach profiles and wind speeds were recorded.

In August 1974 a tracer study was conducted in the study area. Four tons of original borrow material were treated in the Laboratory. The sand was sieved into three different diameter size categories and each size dyed with different fluorescent dye colors. The quantities dyed and their respective diameters were: 4000 lbs. with a median diameter of 0.13mm, 1350 lbs. with a median diameter of 0.21 mm and 1350 lbs. with a median diameter of 0.50 mm. The various color sands were then mixed and point injected at the beach face during low tide. The position of the tracer particles in the dynamic zone were monitored after 1/2, 2, 10 and 40 tidal cycles by taking sand samples at established grid points. Profile locations were sampled at high water mark, low water mark, and at depths 3 feet, 5 feet, 10 feet, 15 feet, and 20 feet.

(4) Sand Sampling and Coring

A limited coring program was completed in May 1974 in which continuous cores, four to ten feet in length were obtained from the beach face, the breaker bar and at distances of 500 and 1000 feet offshore. Relatively undisturbed subsurface samples were obtained by utilization of a double walled piston coring device which employed circulating drillers mud to overcome external friction on the core barrel. It was anticipated that sampling lines at the north, center and southern end of the beach fill would best represent the adjusted areal and stratigraphic distribution of the artificially placed sediment. However, bedrock was encountered at a shallow depth in the first two cores attempted at the north end of the project and the line of sampling was not completed. Thus, multiple cores were obtained only from lines 31 and 37, Figure 2.

Grain size frequency, bulk density, grain density and percent shell were determined in subsequent laboratory analysis. The cores were zoned and analyzed based upon evident changes in the physical parameters of the sediment with depth in the core.

One set of surface sediment samples obtained in the August 1974 tracer study was analyzed for size frequency only. Certainly, more intervals of sampling would have been desirable. The core samples do, however, represent depositional changes through time. From the cores obtained in May 1974 from the "adjusted" 1973 beach fill and the August 1974 surface samples, consistent results were obtained. Thus, we believe the sampling program provided data upon which evaluation of the behavior of the artificial beach fill at Jupiter Island could be made.

III. DATA ANALYSIS AND RESULTS

(1) The Hydrographic Surveys

The hydrographic surveys were analyzed to yield information on the total sand volume in the nourished area and its gradual depletion with time. Figure 3 shows a summary of the total sand volumes in the study area during the different stages of construction and post construction periods. It is surprising to see no net loss of sand after one year following completion of the first stage. This was not expected since it is believed that a net littoral transport towards the south prevailed in this area of the shoreline, see reference [7].

Although unexpected at the outset the above result is easily explained by the fact that both the shoreline and the offshore profile advanced following restoration. The latter produced a groin effect at the northern extremity ofthe fill. The shoreline alignment with respect to breaking waves is altered and induces a net decrease in the longshore current at the north end of the restored section. The nourished area therefore received sand from the then prevailing littoral system at its north end. The gain is evidently equal to the loss from the central and southern segments of the fill during the first year. The analysis of the hydrographic surveys indicated a small net gain during this first year.

The distribution of volumetric changes along the study area is shown in Figure 4(a). As indicated before, the shore area at the public beach was left unrestored to satisfy biological concerns for a reef offshore. Both sides of the public beach were restored, however. It is evident from Figure 4(a), that large quantities of sand were transported by littoral drift from the nourished area north of the public beach to the void in front of the public beach. This is shown in Figure 4(a) as erosion north of the public beach and accretion at the public beach. The groin effect discussed previously is also evident by the accretion pattern at the north end of the fill. The central region of the fill (south of the public beach) shows minor erosion as expected because of prevailing southerly longshore drift. Near the south end of the fill a net accretion occurred. This is probably due to the wave refraction pattern generated in the vicinity of a recessed shoreline.

Figure 4(a) shows that erosion patterns can not be determined by observing changes in the shoreline profile alone. Two shoreline contours obtained from the November 1973 and May 1974 surveys are drawn with respect to the reference prefill shoreline of June 1973. Near the north end of the fill the shoreline is receding while a net volumetric gain is computed due to the groin effect discussed before. A similar pattern is observed near the southern end of the fill. In the central

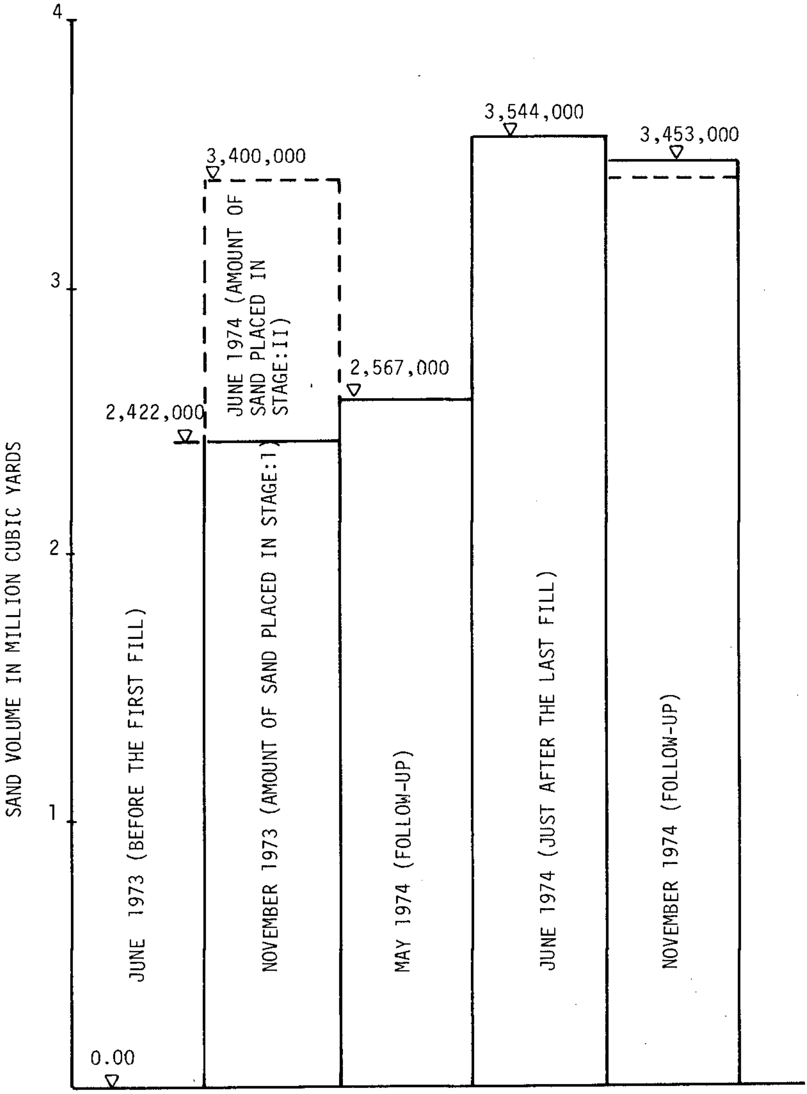
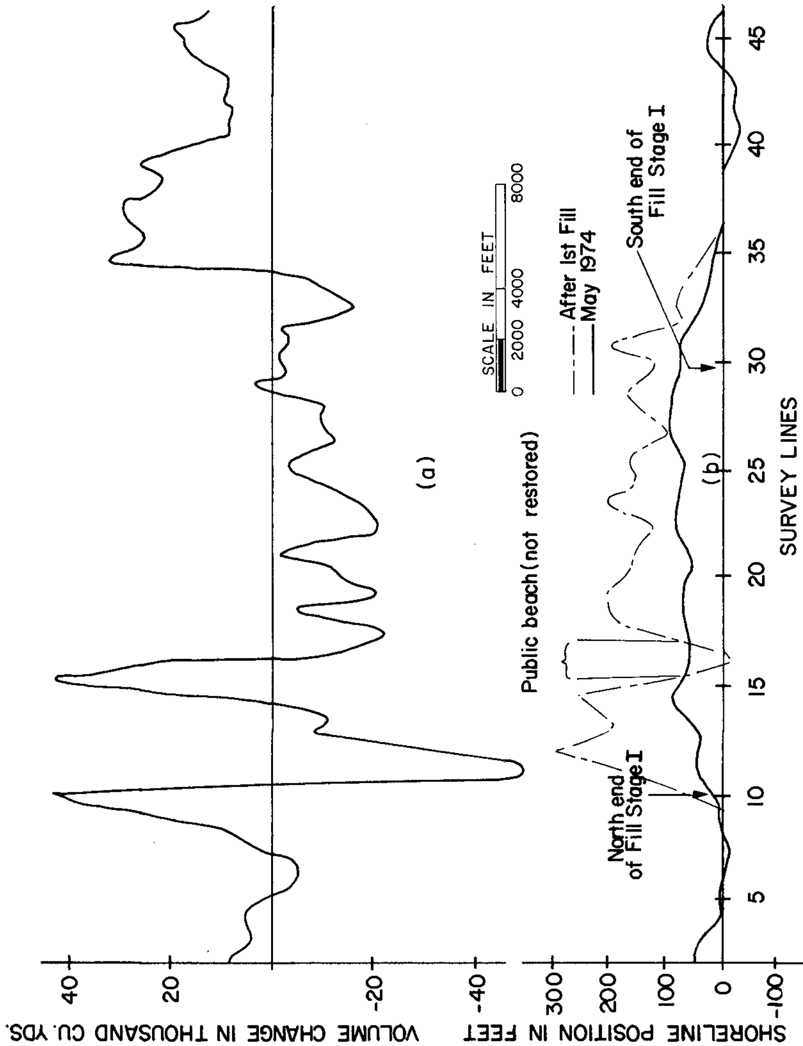


Figure 3: Summary of volume calculations obtained from hydrographic surveys.



(a) OBSERVED VOLUME CHANGES ALONG THE SHORELINE FROM NOVEMBER 1973 TO MAY 1974. (+ ACCRETION; - EROSION); (b) SHORELINE POSITIONS AS REFERENCED TO 1973 PREFILL SHORELINE

Figure 4

region (south of the public beach) on the other hand, the shoreline contour is advancing towards offshore while the volumetric curve shows a net erosion. This can only be explained by the shoreward retreat of the offshore profile.

Further insight on the advance of the offshore profile and the simultaneous retreat of the shoreline contour is presented in Figure 5. In the top portion 11 foot depth contours are depicted to show the advance of the offshore profile. During the same period a general recession in the shoreline contour occurs and is shown in Figure 5(b). Figures 4 and 5 clearly demonstrate the role the offshore profile; the central conclusion being that shoreline advances and recessions are poor indicators of accretion or erosion in a nourished area.

The borrow area and the locations of borrow holes also produce substantial variations in the offshore profile. These are shown in Figure 6. Five foot contours are drawn to show variation of the offshore bar during the period of the study. This depth is typical of the near shore bar. The May 1974 contour shows the beginning of a cyclic variation which has correspondence to the offshore borrow holes. The variation is accentuated in the November 1974 contour following the October 6-7, 1974 storm. The borrow holes induce nearshore concentration of energy by uneven refraction of wave rays in the vicinity of borrow holes. The refraction calculations were not carried out due to lack of hydrographic data in the vicinity of borrow holes.

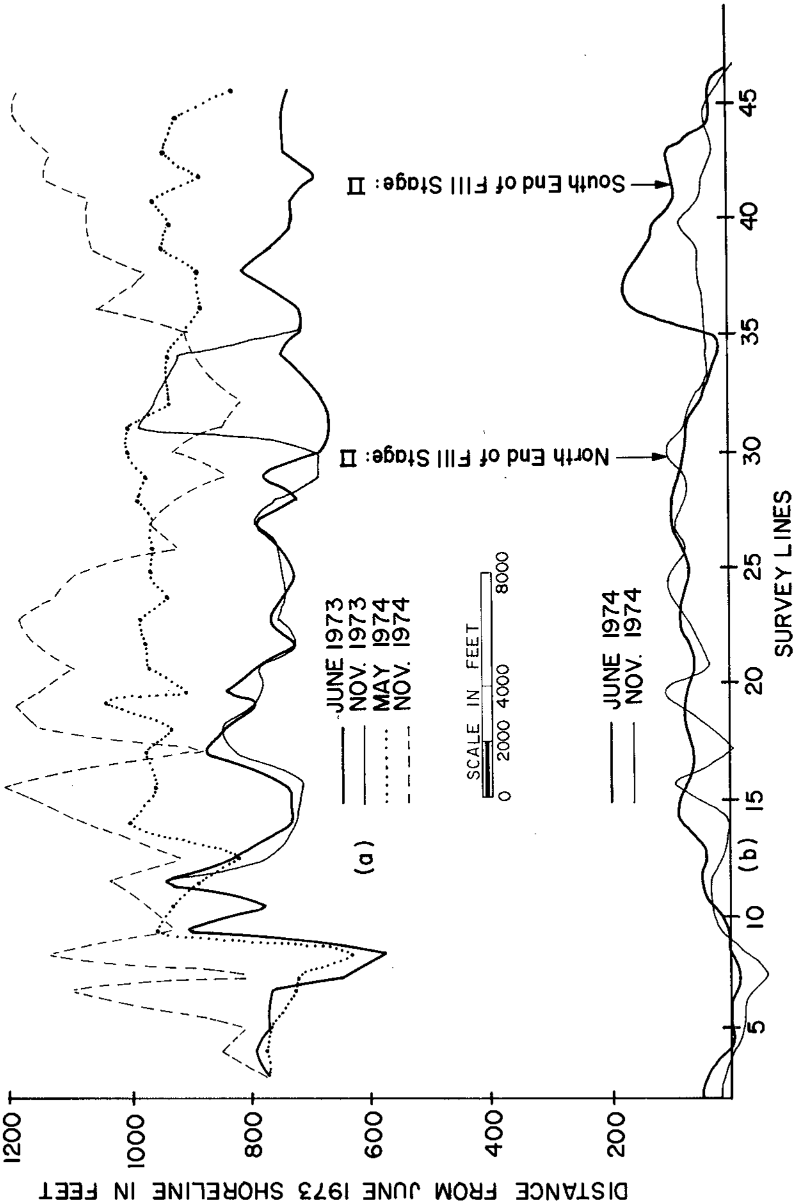
(2) The Wave Climate and Longshore Transport

The analysis of the wave data was aimed at determining the monthly averages of the long shore current (and sand transport) at different stations along the restored beach. The in situ measurements were supplemented by available wave statistics corresponding to the period of study from NOAA, Surface Marine Observations, National Climatic Center. This data was found to be especially useful in filling in situ measurement gaps. The measured wind speeds and directions were found helpful in producing correlations between different wave data sets. Hydrographic information was obtained from monitoring surveys and USGS boat charts.

The analysis procedure consisted of generating equivalent deep water wave heights and directions from nearshore point measurements of wave height, period and breaking angle. A modified Dobson [8], refraction program was utilized with a nested grid system. A nearshore fine grid network was used to relate the measured breaker angle to a mean wave direction at the wave measuring station. Then using a large grid the measured wave heights and the derived wave directions were used to yield deep water wave heights, and directions.

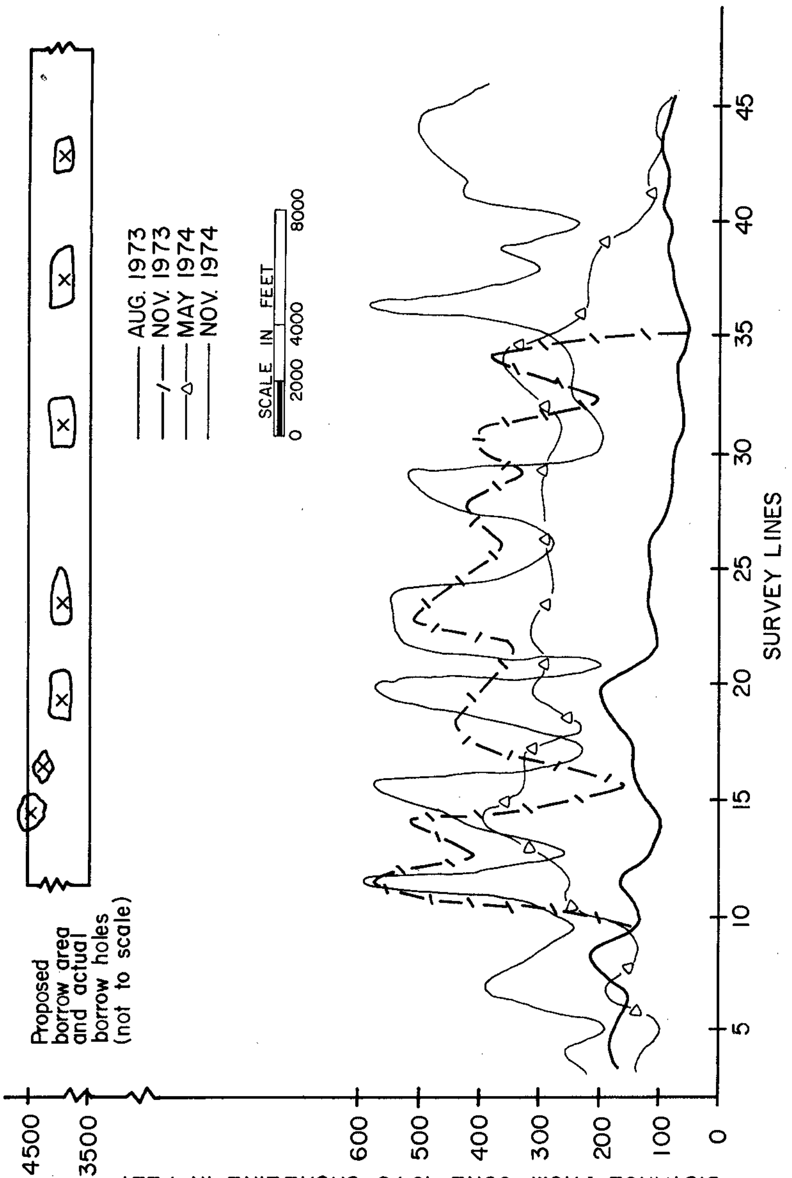
The surface Marine Observations of NOAA were calibrated by correlating the derived deep water wave heights and directions during the periods when both data sets were available. Calibration constants were derived to make the ship observations compatible with in situ measurements.

The monthly averages of equivalent deep water wave parameters were computed and are shown in Table 2. The period covered is bounded by two hydrographic surveys. The intent was to predict the net erosion or deposition during this period by using the wave climate and the littoral drift formula and to compare with corresponding erosion or deposition patterns calculated directly from the hydrographic surveys.



(a) CHANGES IN 11 feet CONTOUR; (b) CHANGES IN SHORELINE, BOTH AS REFERENCED TO 1973 PREFILL SHORELINE

Figure 5



CHANGES IN 5 feet CONTOUR POSITION IN RELATION TO JUNE 1973 SHORELINE

Figure 6

Table 2. Deep Water Wave Climate.

Date	T (sec.)	H_o (ft.)	$_o$ (deg.)
March	8	1.0	109
April	8.5	1.48	110
May	7.4	1.04	119
June	7.7	0.84	120
July	8.2	0.96	98
August	9.1	0.99	110
September	7.9	0.99	106
October	8.9	2.6	69

The predicted volumetric changes using the littoral drift formula were found to be one order of magnitude larger than calculated values from hydrographic surveys. The discrepancy raises a number of questions regarding present technical capability to predict erosion and deposition patterns following a beach restoration construction. Two primary areas of concern are suggested:

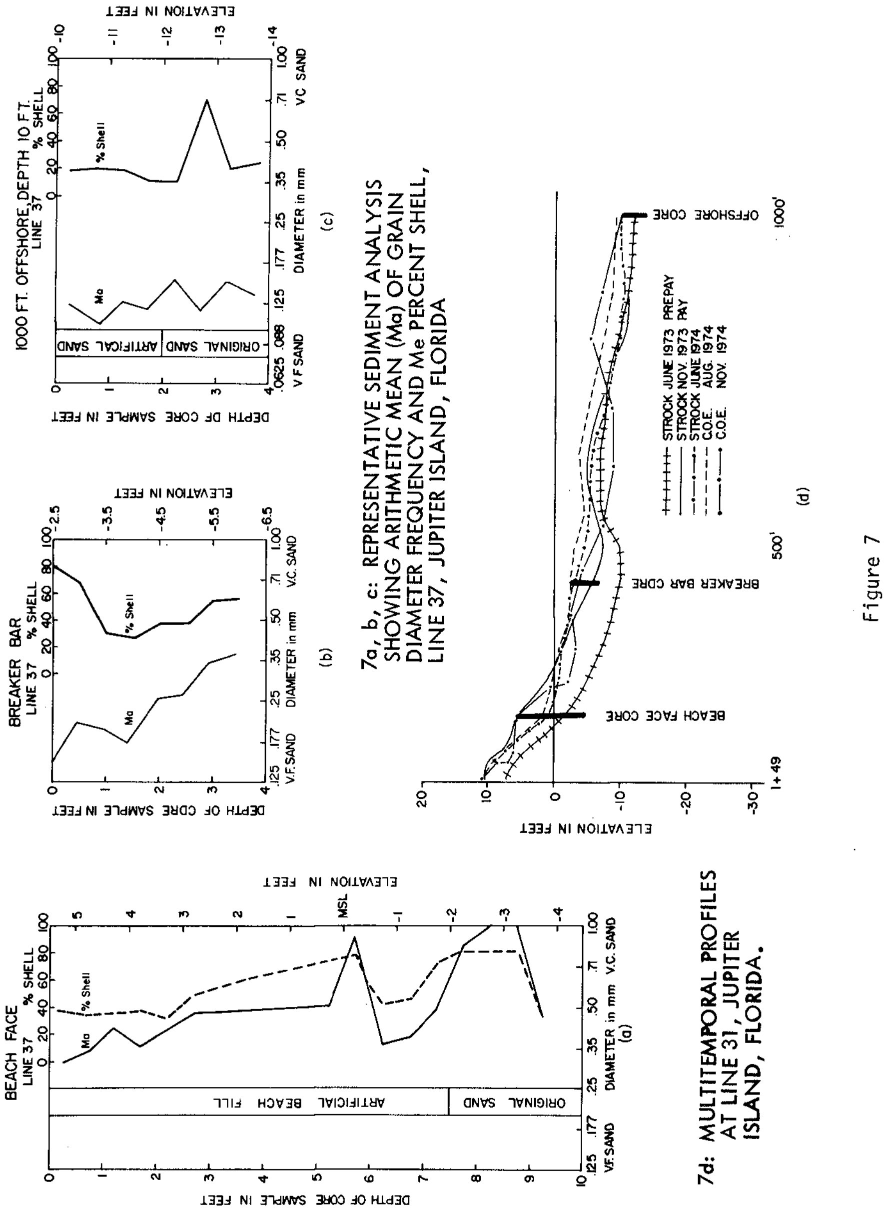
a) The littoral drift formula in present form is empirically derived from gross volumetric sand accumulation near littoral drift barriers. The formula is very useful for gross calculations but evidently less useful for more detailed changes along a shoreline with varying longshore wave activity. Research is needed to develop more detailed relationships for sand transport due to waves, current, wind, and grain size distribution.

b) The wave climate as determined from deep water wave measurements is only part of the total climate affecting littoral drift. The local wind, for example, plays an important role in a manner not completely understood yet. Definition of the total climatological factors in impacting sand movement and the consequent collection of pertinent data remains prerequisite to adequate prediction of sand movement following a restoration project.

(3) Sedimentological Results

At present, relatively little is known about the nature of onshore-offshore movement of sand in the surf zone. An indication of the onshore-offshore movement is found in the analysis of the sediment cores. As indicated these cores were taken at the beach face, the breaker bar and at distances 500 and 1000 feet offshore.

The mean diameter and shell content of the beach face core is shown in Figure 7 (a). Underlying the beach face there are layers representing different



7a, b, c: REPRESENTATIVE SEDIMENT ANALYSIS SHOWING ARITHMETIC MEAN (Ma) OF GRAIN DIAMETER FREQUENCY AND Me PERCENT SHELL, LINE 37, JUPITER ISLAND, FLORIDA

7d: MULTITEMPORAL PROFILES AT LINE 31, JUPITER ISLAND, FLORIDA.

Figure 7

energy conditions. There are even differences in the layers deposited during high and low tides. The beach face consists of medium to coarse sand with layers of shell.

The near-shore bar is composed of fine sand as shown in Figure 7(b); and very fine sand is found 100 feet offshore as shown in Figure 7(c). The shell content was found useful in distinguishing between the native sand and the new sand that moved towards offshore.

It is clear from these sedimentological results that the fine and very fine sand is moved offshore and is the main constituent for building the offshore profile. This sand is not totally lost to the system as volumetric computations such as those of Krumbein and James [9] would suggest. The beach face has been protected by coarser particles and the winnowed fine sand has contributed to energy dissipation through the buildup of the profile in the dynamic zone, especially the breaker bar.

The project engineer [8] stated the mean grain diameter in the proposed borrow area was 0.23 mm. whereas the native receding beach material had a mean grain size of 1.20 mm. When the size gradation, i.e. standard deviation, of these sand bodies are taken into consideration by utilization of the "critical ratio" formula of Krumbein and James [9], it is determined that 7.8 cubic yards of fill material would be required to yield one cubic yard of sand comparable to the original sand on the unstable beach. Fortunately, the project has developed better than preliminary statistics predicted. This is because a material with favorable parameters was placed on the beach.

IV. CONCLUSIONS

The conclusions derived from this monitoring study are the following:

(1) Beach Fills Have a Groin Effect - The placement of sand on a beach has the effect of extending the shoreline seaward and therefore inducing shoreline alignment changes at both extremities of the restored area. The restored beach consequently interferes with the previously prevailing littoral drift balance and induces a net deposition near the updrift end. The groin effect increases the half life of the restored beach.

(2) The Offshore Profile Serves an Important Role - Shoreline recessions do not reflect the true state of erosion or accretion following a beach restoration. The total sand volume contained in a restored area is critically dependent on the offshore profile. Shoreline recessions are normally accompanied by a buildup of the offshore profile.

(3) Borrow Holes Cause Energy Focusing on Shore - Local concentrations of wave energy at the shoreline are induced by wave refraction in the vicinity of borrow holes when they are located close to shore. Lateral variations in the shoreline contour and the offshore profile are induced by close to shore borrow holes.

(4) Prediction of Erosion or Accretion along a Restored Beach Is Not Possible by the Littoral Drift Formula - The presently used littoral transport formula does not give a reasonable prediction of erosion or deposition along a restored beach. The formula is derived empirically from gross transport rates and cannot be expected to provide accurate predictions for relatively detailed shoreline erosion following a restoration construction.

(5) The Need for Research in Nearshore Dynamics - This study points out the need for continued research on dynamical aspects of offshore-onshore and along-shore transport of sand. Relevant contributions were reported at the Hawaii conference; it will be instructive to apply the techniques proposed.

V. REFERENCES

1. House Document No. 765, 80th Congress, 2nd Session, "Jupiter Island," 1947.

2. Coastal and Oceanographic Engineering Laboratory, Tech. Prog. Rep. No. 5, "Coastal Engineering Investigation at Jupiter Island," University of Florida, Cainesville, 1957.

3. Dept. of the Army, Jacksonville District, Corps of Engineers Serial No. 54, "Beach Erosion Control Study on Martin County, Florida," 1968.

4. Coastal and Oceanographic Engineering Laboratory, "Cooperative Study at Jupiter Island, Florida," University of Florida, Cainesville, 1969.

5. Arthur V. Strock and Associates, Inc., "Town of Jupiter Island Beach Restoration Project," Deerfield Beach, 1973.

6. A. V. Strock, and A. D. Noble, "Artificial Nourishment Projects in Southeast Florida," M.T.S. Journal, Vol. 9, No. 3, 1975.

7. U. S. Army, Civil Engineering Research Center, "Shore Protection Manual, Vol. 1," Washington, D. C., 1973.

8. R. S. Dobson, "Some Applications of a Digital Computer to Hydraulic Engineering Problems," Tech. Rep. No. 80, Dept. of Civil Eng., Stanford, 1967.

9. W. C. Krumbein and W. R. James, "A Lognormal Size Distribution Model for Estimating Stability of Beach Fill Material," Tech. Mem. No. 16, U. S. Army Coastal Engineering Research Center, 1965.

10. W. N. Bascom, "The Relationship between Sand Size and Beach-Face Slope," Trans. Am. Ceophys. Union, Vol. 32, 1951.