A SEDIMENT BUDGET ANALYSIS AND MANAGEMENT STRATEGY FOR FORT PIERCE INLET, FL

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ABSTRACT

Understanding the sediment transport processes in the vicinity of Fort Pierce Inlet, Florida and the effect of longshore sediment interruption due to the presence of the inlet are essential for better management and sustainability of this coastal system. In order to establish the sediment transport processes in this area and the influence of the inlet, a sediment budget analysis has been carried out. The sediment budget analysis is based on available survey data, nourishment and dredging records extending from 1972 to 2002. Available survey data encompass shoreline distances approximately 32,000 ft north and 81,000 ft south of Fort Pierce Inlet. Three periods were examined in this study: 1972 to 1987, 1987 to 1997, and 1997 to 2002. Average annual sediment volume and shoreline changes derived from the profile data collected during these three periods were analyzed. A substantial variability of sediment transport into and out of the system was found for these three periods of study. Application of general sediment budget principles established that for the total period 1972 to 2002 there was an annual deficit of approximately 16,300 yd^3/year. The general sediment budget suggests that 116,000 yd^3/year enter the north boundary of Riomar Beach; 82,000 yd^3/year enter the north boundary of St. Lucie County and 57,000 yd^3/year leave the south boundary of St. Lucie County. Application of numerical modeling to develop an understanding and predictability of the performance of beach nourishment south of the inlet was carried out as a supporting method to better understand the littoral processes in the area. Recommendations to improve the sediment management practices including sand bypassing to restore balance to the south beaches are presented.

INTRODUCTION

Recognizing the need to preserve a navigable inlet and a stable beach are inherent in this sediment budget assessment. The identification of quantities to be bypassed around the inlet or to be provided by nourishment are essential elements in the strategies to be implemented to reduce the inlet's impacts on the system.

Lack of sediment supply as a result of entrapment of sand by the jetties and the presence of the inlet acting as a sink are the main causes of the downdrift erosion. Since the inception of Fort Pierce Beach Erosion District in 1957 various alternatives to mitigate erosion were proposed by local interests including a series of beach nourishments as part of this mitigation measure which have been implemented to remediate the sediment deficiency on the south beach.

The objective of this study is to develop and apply an updated sediment budget for Fort Pierce Inlet and the adjacent beaches. Available survey data obtained for this study correspond to St. Lucie County coastal boundaries and partially include Indian River County data. Available surveys from the area are the basis for developing the sediment budget. The sediment budget concentrates on volume and shoreline changes with a major emphasis on volume changes.

Site Description and Recent History

The coastal system of concern in this study encompasses the Department of Natural Resources (DNR) monuments R-1 through R-115 situated in St. Lucie County, shown in Figure 1. The extent of the shoreline covers a total distance of approximately 21.5 miles. Like many of the inlets on the east coast of Florida, Fort Pierce Inlet is a tidal system which contains a flood shoal and a small ebb shoal.

Site Description

Fort Pierce Inlet is a manmade inlet that connects Indian River with the Atlantic Ocean located between monument R-33 and R-34 in St. Lucie County. Two jetties located 900 feet apart stabilize the inlet. The north jetty is 1,800 feet in length while the south jetty is 1,200 feet long. The north jetty is permeable (visually inspected by Taylor Engineering, 2001) and the south jetty is topped with a paved walkway. In 1997, a spur jetty of 200 feet was attached to the south jetty to prevent sand bypassing from the south into the inlet. The spur jetty is located approximately 450 feet west of the jetty tip. Figure 2 shows the characteristics of the inlet.

Figure 1 Location of St. Lucie County, Florida.

Figure 2 Fort Pierce Inlet. Looking West, 2004.

Recent History

A preceding natural inlet also known as Indian River Inlet existed approximately 2.85 miles to the north of the present Fort Pierce Inlet. The inlet channel shifted regularly remaining navigable for small boats (Walton, 1974). After 1892 when St. Lucie Inlet was opened, Indian River Inlet became unusable due to shoaling. The development of the deepwater port of Fort Pierce started with the dredging in 1921 of a channel and an artificial inlet through the land barrier separating the Atlantic Ocean from Indian River east of the town of Fort Pierce, Florida.

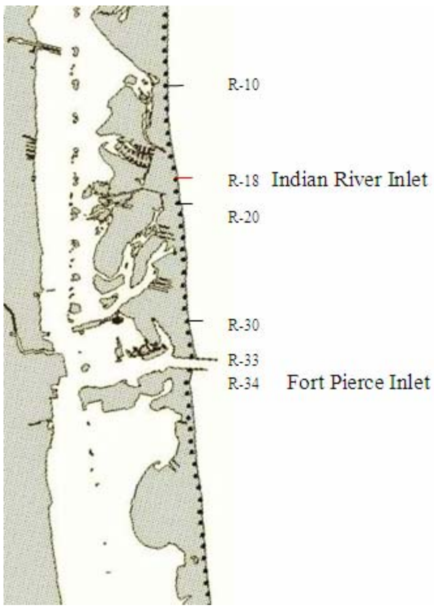

Figure 3 Fort Pierce Inlet and Approximate Location of Indian River Inlet in St. Lucie County, Florida.

Excavation through the barrier island was initiated in 1920 and was completed in 1921. The channel was originally 3.9 feet deep and 100 feet wide and protected by rock jetties of native coquina rock.

Fort Pierce Beach Remedial Measures

The first nourishment of the downdrift beaches was conducted in 1971 with the placement of 718,000 yd^3 of sand. As a result of the continuous erosion experienced on the beaches south of Fort Pierce Inlet, periodic nourishments over a 1.3 mile beach segment were recommended. A second nourishment occurred in 1980 with a placement of 346,000 yd^3 of sand and a third nourishment of 870,000 yd^3 took place in 1999.

Erosional spots have occurred regardless of the placement of sand downdrift of the jetties. In 1994, three geotextile erosion control tubes were placed perpendicular to the shoreline within 1,000 feet of the south jetty to stabilize a small emergency fill of 54,400 yd^3 and intermittent sand placement from dredging events are programmed as part of the mitigation measures.

Dredging Events

Required navigation depths in Fort Pierce Inlet and harbor are maintained through dredging of sand from the entrance channel and turning basin. Sand that accumulates in navigation channels as a result of protective works has been placed either offshore or, in some cases, on downdrift beaches to help restore the sand budget of the littoral system. Cumulative maintenance dredging volumes dating from 1974 to 1998 are shown in Figure 4. The upper curve shows total cumulative volumes dredged from the channel and turning basin and the lower curve shows total volumes dredged that were placed on the beaches south of the inlet.

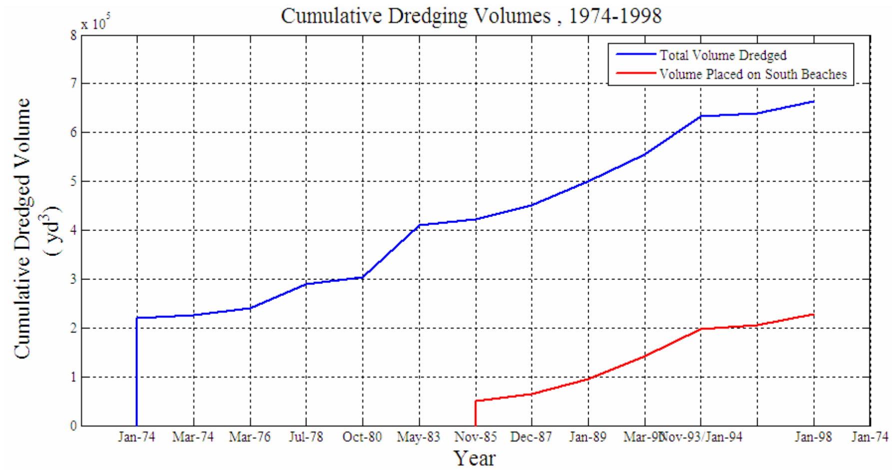

Figure 4 Cumulative Dredging Volumes for the Period 1974-1998.

Longshore Sediment Transport

Table 1 is a summary of several of the longshore transport rates previously developed for this study area.

Table 1 Littoral Drift

Source	North (yd^3/year)	South (yd^3/year)	Net Drift (yd^3/year)
USACE 1962			200,000 – 250,000
Walton 1979	245,000 – 281,000	260,000 –387,000	15,000 – 106,000
WES 1955-1975	170,000	185,000	15,000
CP&E 1997			106,000
USACE 1998			53,000
Brown 2002			500,000

Influences of Regional Scale Longshore Transport

Effects of Riomar on Sediment Transport at Fort Pierce

Analyses of processes at Fort Pierce Inlet also include to a greater scale the processes having effects on the adjacent stretches of shoreline. It is pertinent to include here the variable amounts of sediments flowing into St Lucie County which can diminish or increase depending on the mechanisms occurring in the 29 miles stretch of shoreline between Sebastian Inlet and Fort Pierce Inlet.

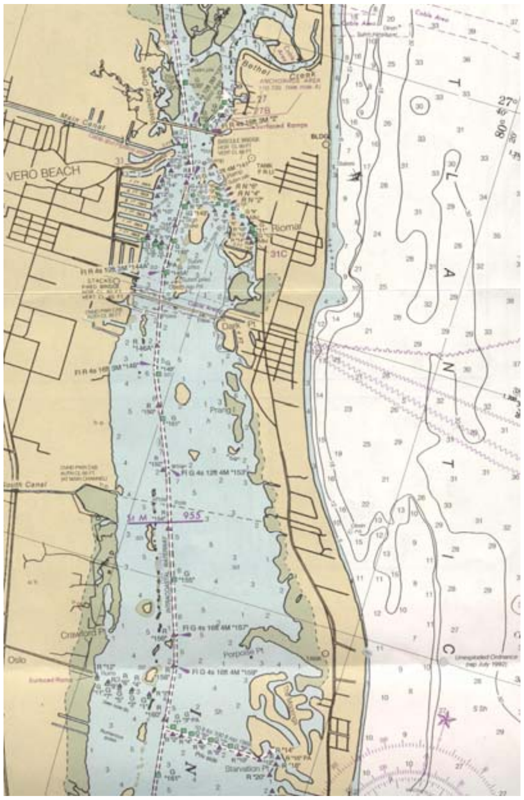

Figure 5. Riomar Crenulate Bay Feature. Nautical Chart (NOAA, 1997)

The presence of a crenulate bay at Riomar Beach, located approximately 11 miles north of Fort Pierce Inlet between approximately Monuments R-87 and R-103 is considered to have a direct effect on the longshore sediment transport rate south of this feature. The rationale is that for the period 1887-2002 the shoreline at Riomar moved seaward a maximum of approximately 650 feet. This advancement is believed to be a consequence of the infilling of the bay. The explanation for the infilling of the bay is a result of either the augmentation in sediment supply, change in the dominant wave direction or both mechanisms (Hays, 2001). Figure 5 shows a detail of the Riomar crenulate bay.

Further analyses of volume changes over a 30 year period (1972-2002) suggest that an average of 34,000 yd^3/yr is being stored in the Riomar Beach embayment. Additional results will be shown later.

Profile Data

The beach profile data analyzed were obtained from the Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems. The data set included 4 surveys; the horizontal datum for the surveys selected is North American Datum NAD 27.

The total distance covered is approximately 21.7 miles, which is the shoreline length in St. Lucie County. The north and south jetties at Fort Pierce Inlet are located at 6.25 and 6.42 miles south of Monument R-1. Table 2 presents the survey dates and beach profile availability for the data acquired.

Table 2. St. Lucie County Survey Data Analyzed

Filename	***Survey Date(s)***	***Offshore Profile Availability***
STL72AA.CCC	February to March 1972	Every third monument
STL87AA.CCC	November 1986, January and February 1987	Every third monument
STL97AA.CON	June, July and August 1997	Every monument
STL02AA.CON	July 2002	Every monument

Figure 6 illustrates the profile variability at Monument R-12. Depths beyond 16 ft, or farther than 900 ft, exemplify uncertain closure of the profile due to the presence of hard bottom. Figure 7 shows profiles for monument R-33, including features which represent reefs in the bottom and the proximity to the navigational channel. This profile is immediately north of Fort Pierce Inlet.

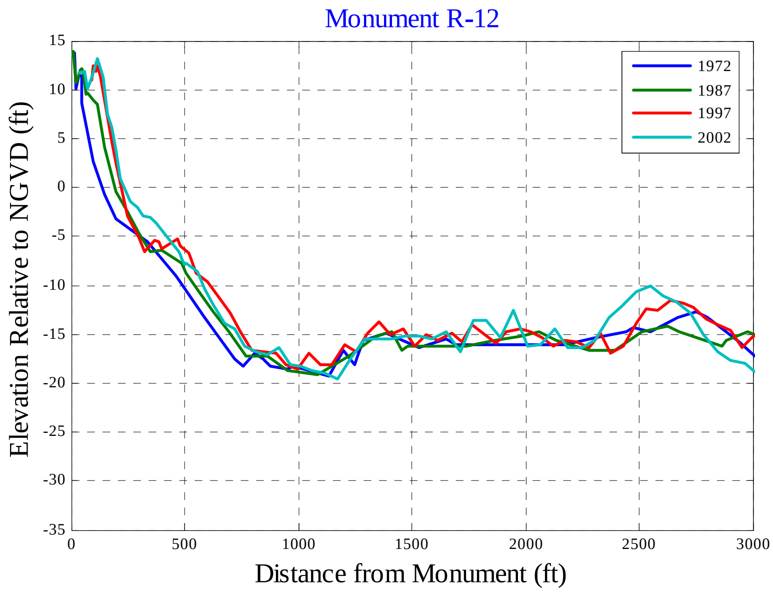

Figure 6 Beach Profile for Monument R-12 in St. Lucie County.

A shoreline advancement of nearly 108 feet from year 1972 to 2002 is observed in Monument R-12 which indicates that the inlet is still influencing the shoreline, to a distance of 3.9 miles north of the inlet.

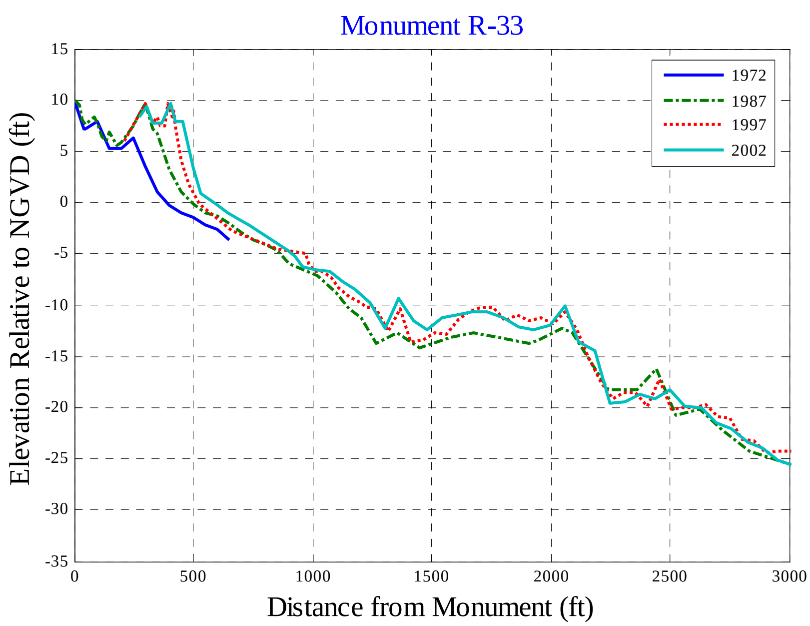

Figure 7 Beach Profile for Monument R-33 in St. Lucie County.

A 270 feet advancement of the beach for the 30-year period is observed in Monument R-33. The north jetty extends to a depth of approximately -10 feet NGVD. The steep slope at the end of the profile extending to a depth of 27 feet is due to the presence of the navigational channel.

Data Limitations and Uncertainties in Records

Attempts to Correct Survey Data for Non-Closure

Profile data were reviewed to determine possible errors, especially those measurement errors observed in the early 1970's surveys. The method used was intended to correct the outer portions of these profiles taking as a datum the latest survey data, and presumably the most accurate survey.

The outer portions of profiles such as R-9, R-18, R-45, R-48, R-57, and R-96 among others showed features including lack of closure suggesting survey errors. Profile data were inspected and later, volumes were calculated with corrected and uncorrected profiles. Results of corrected volumes did not pose any credible basis to continue the analysis with corrected profiles. For this reason, volume changes calculated with the correction method are not included in the sediment budget analysis, rather uncorrected volume calculations are used.

Offshore profile surveys show depth variability making it difficult to quantify a depth of closure. A typical depth of closure of 16 feet for the vicinity of the inlet as suggested for practical purposes by Dean and Grant (1989) is not applicable for all profiles. The uncorrected method finally adopted consisted of selecting a depth, less than 20 feet, where potential errors are likely to be minimal. Associated with the selection of a new "closure depth", a maximum offshore calculation distance was selected, here referred to as the 'cut' distance. Identification of rock outcropping, where present, assisted in selecting the offshore distance to which the profiles were analyzed. This latter method allows the calculation of cross-shore volume changes for each profile while minimizing potential errors that can adversely affect the sediment budget.

The divergence between the seaward portions of earlier and more recent profiles is probably attributable to early surveying techniques. The alignment for profile surveys was determined using range poles located approximately perpendicular to the shoreline or a surveyor would keep the surveyors on line with a theodolite. The offshore portion is generally obtained using a survey vessel equipped with a fathometer and positioning system so the location of the boat can be correlated with the depth measurements. The boat is kept on the profile line by visual profile markers, by radio, or by electronic distance measuring equipments (Dean, 2001). Errors in the earlier survey data often originate in sounding depths which are relative to water levels obtained from a tide gauge. If the survey area was near a standard tide gage on the outer coast, there was no further requirement to determine the water level. Temporary tide gages were often placed on "supports of convenience" which included bridge piers, docks, or other existing structures which not be representative of water levels on the outer coast. Vertical depth changes associated with horizontal errors can also be detected in some of the profiles. Uncertainties in volume changes due to the latter explanation may occur in individual profiles; however it is believed that this type of error is generally small.

Correction for monument relocation

Several monuments along the coastline were relocated after 1972. In those cases, the horizontal survey distances were adjusted and included a shift in the origin and a projection onto the azimuth of the original profile line.

Leakage through the North Jetty

There are uncertainties in the quantity of sediment passing though the jetty. The profiles immediately north of the north jetty contain indications of leakage into the inlet. It was estimated that approximately 15 to 20% of the volume stored north of the north jetty leaks through the north jetty into the inlet (USACE, 1963).

Shoreline and Volume Changes

Shoreline and volume changes were calculated for each portion of the beach where data were available. DNRBS model was used to validate the extent of the inlet influence on the adjacent shorelines and also to compare the results given by the theoretical model and the volume changes obtained based on the data analysis.

NGVD Shoreline and Volume Calculation

The volume and NGVD shoreline position differences were calculated for each of the following intersurvey periods: 1972-1987, 1987-1997, and 1997-2002.

Historical Shoreline Changes

Shoreline change rates for historical periods (1860 to 1928) for Indian River and St. Lucie Counties are shown in Figure 8 and later period (1928 to 1970) changes are shown in Figure 9. The old inlet shown in Figure 8, also known as Indian River Inlet, was located approximately near monument R-18 of St. Lucie County. The rapid growth in the shoreline at that point and to the south is a result of the closing and infilling of the old inlet. Accretion on the order of 4.3 ft/year is observed at Riomar for this earlier period and strong erosive signals are observed in the south of the south jetty located at Monument R-34. The steady erosional feature between monuments R-50 to R-115 for the earlier period in St. Lucie County is anomalous and not well understood.

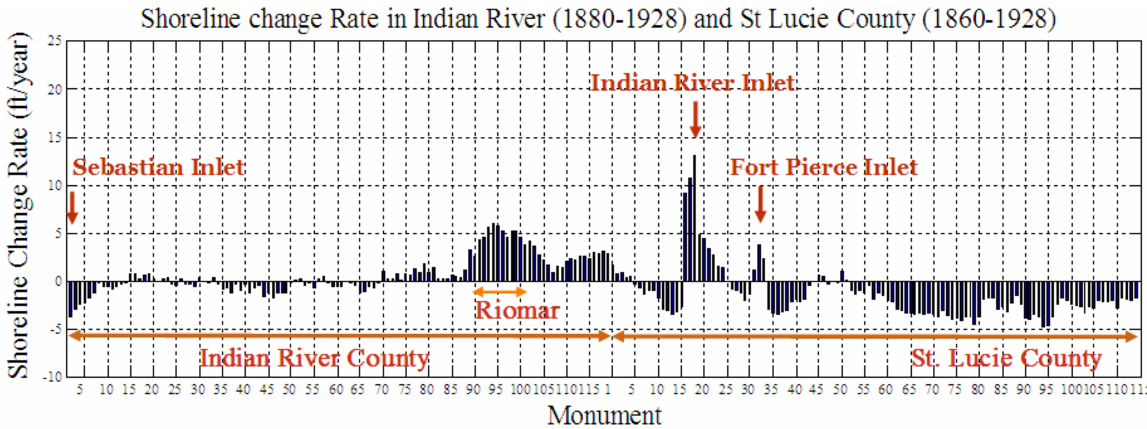

Figure 8 MHW Shoreline Change Rates along the Coastline of Indian River and St. Lucie County for the early period 1860-1928.

Recalling that the parallel jetties were reconstructed between 1921 and 1927, the period 1928-1970 reflects shoreline changes after the jetties were placed and before the nourishment on the southern beaches. Shoreline changes are shown in Figure 9. A comprehensive way to view the influence of the current inlet is by analyzing the accreted and advanced and receded planform areas north and south of the inlet, respectively. The strongest indicators are located between Monuments R-24 through R-33 on the north side and R-34 through R-65 on the south side. The presence of an inlet in a coastal system will influence greater shoreline distances with time. Accretion on the north side of the inlet extends to approximately Monument R-9 located 24,000 feet north of the inlet.

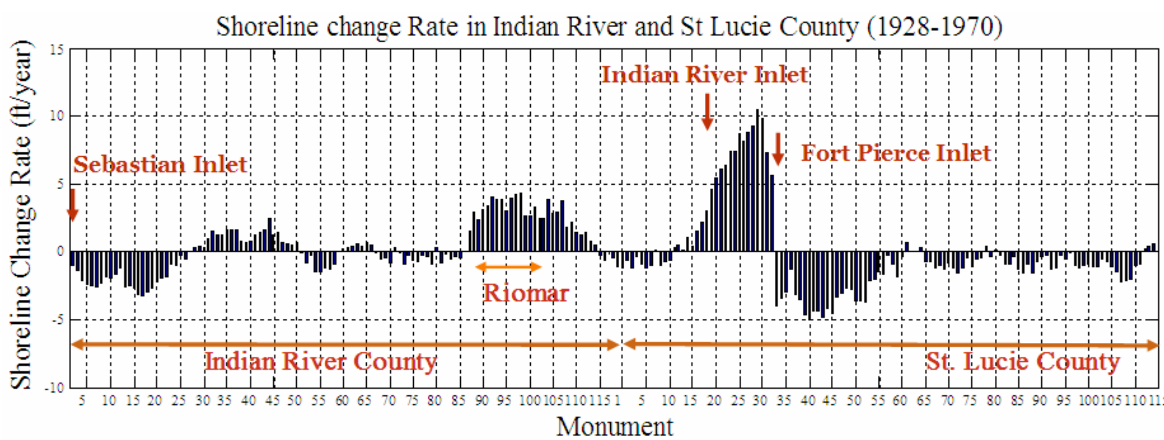

Figure 9 MHW Long-Term Shoreline Change Rates along the Coastline of Indian River and St. Lucie County for the period 1928-1970.

Shoreline changes in St. Lucie and Indian River Counties from 1970-2002 are shown in Figure 10. A steady erosional stretch of nearly 4.0 ft/year is observed between monuments R-33 to R-40. Monuments R-41 through R-115 have variable accretional and erosional trends.

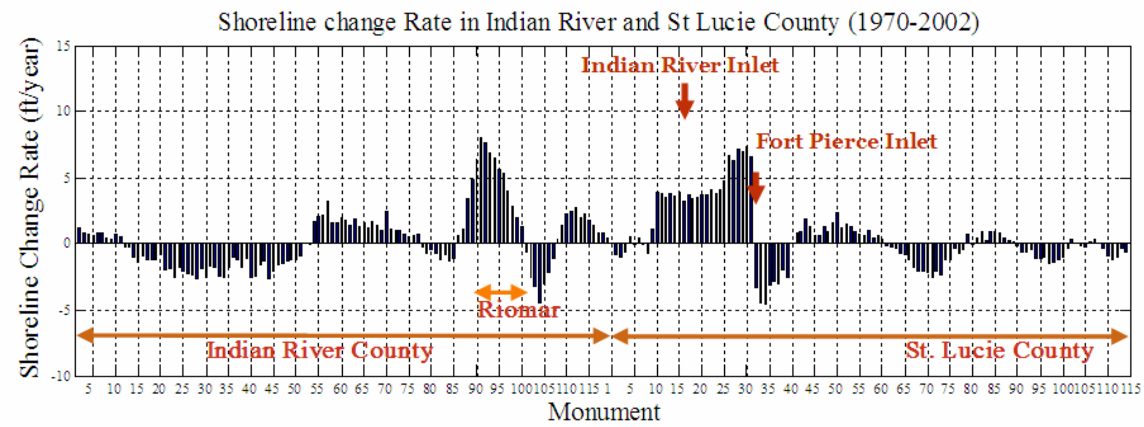

Figure 10 MHW Long-Term Shoreline Change Rates along the Coastline of Indian River and St. Lucie County for the period 1970-2002.

Recent Shoreline Changes

Shoreline changes for the period 1972-2002

An average increase in the shoreline of 4.3 ft/year is observed for this 30-year period. The first 1.1 miles south of the inlet is considered the erosional hot spot of the area. An average shoreline retreat of 3.3 feet/year is observed. The shoreline advancement of up to 3 ft/year from 5,000 ft to 20,000 ft south of the inlet is interpreted as due to the nourishment projects. The presence of sand waves due to the periodic nourishment south of the inlet can explain some of the variability observed along the southern beaches.

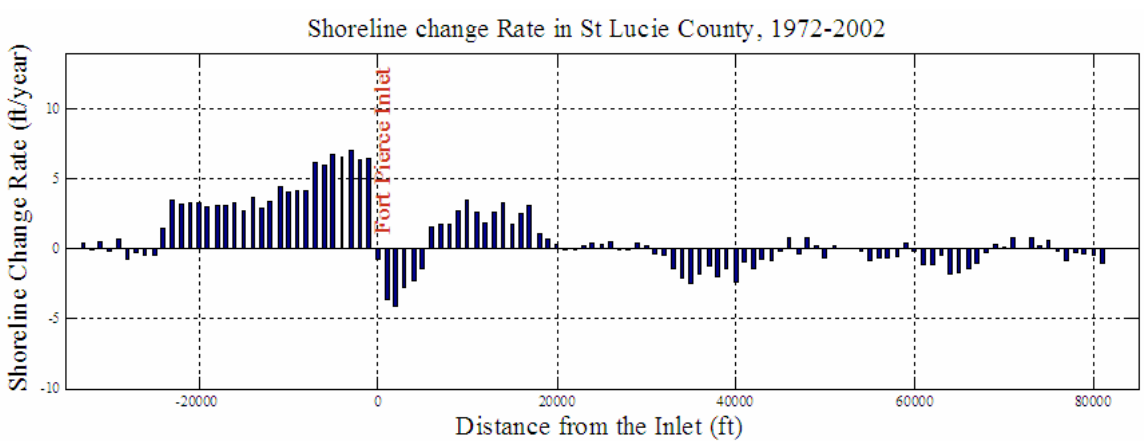

Figure 11 Shoreline Change Rate in St. Lucie County for the period 1972-2002.

Figure 11, for the 30-year period 1972-2002, is similar to Figure 10 and shows an accumulated planform area of 97,200 ft^2/year in the 6.2 miles north of the inlet and an accumulated planform area of –12,900 ft^2/year in the 15.5 mile segment south of the inlet. An average of 40,530 yd^3/year had been placed in the 1.3 mile stretch of beach adjacent to the south jetty.

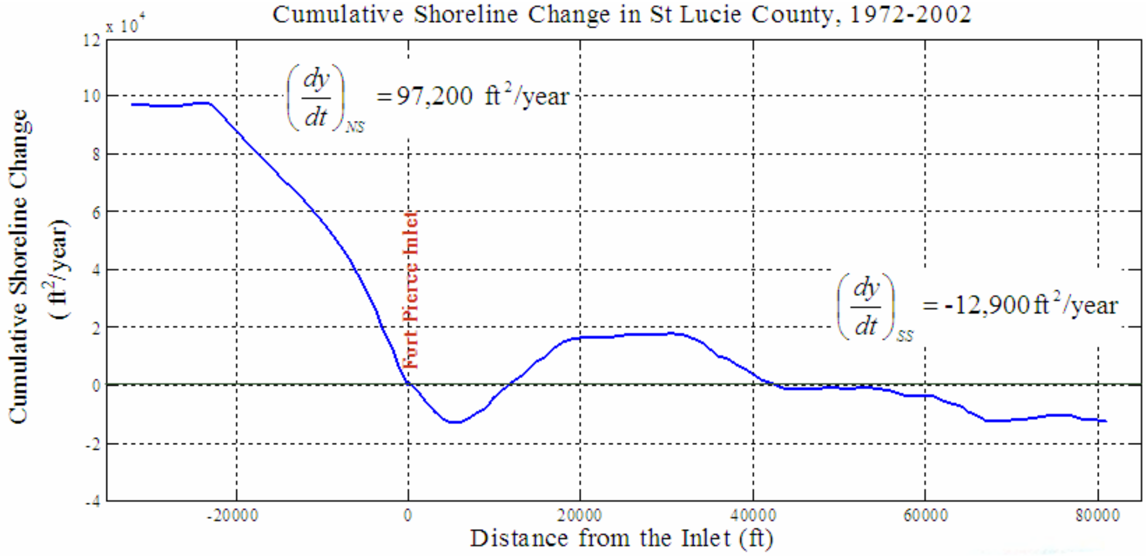

Figure 12 Cumulative Area Change Rate in St. Lucie County for the period 1972-2002.

Recent Volume Changes
Volume changes for the period 1972-2002

Volume per unit beach length changes are shown in Figure 13. This 30-year period is characterized by a strong average advancement of 2.8 yd^3 per linear feet in the first 4.35 miles north of the inlet. Shorelines south of the inlet are characterized by alternating values of positive and negative changes in the volume densities. A more general description is observed in the cumulative volume change plot shown in Figure 14. A total of 67,500 yd^3/year accumulated in the north and 5,100 yd^3/year accumulated in the southern portion of the segment of beach studied.

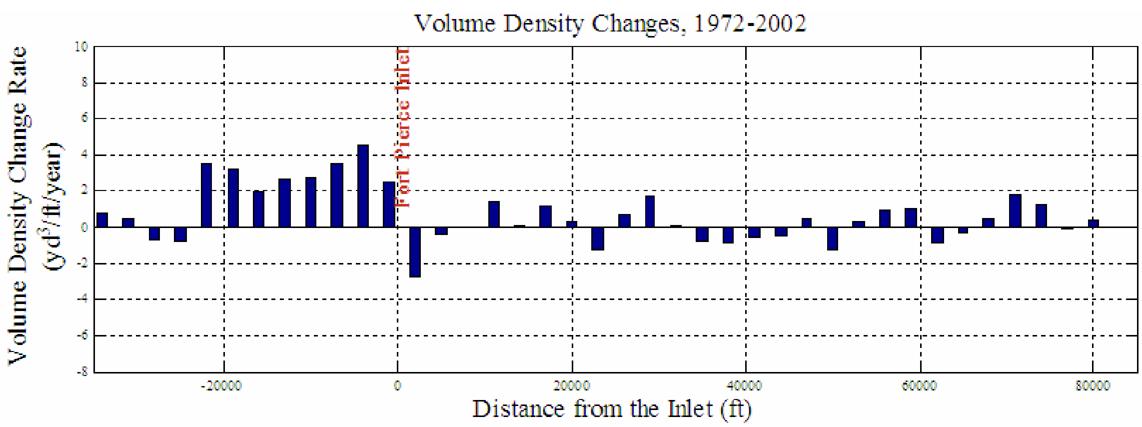

Figure 13 Volume Density Change Rate in St. Lucie County for the period 1972-2002.

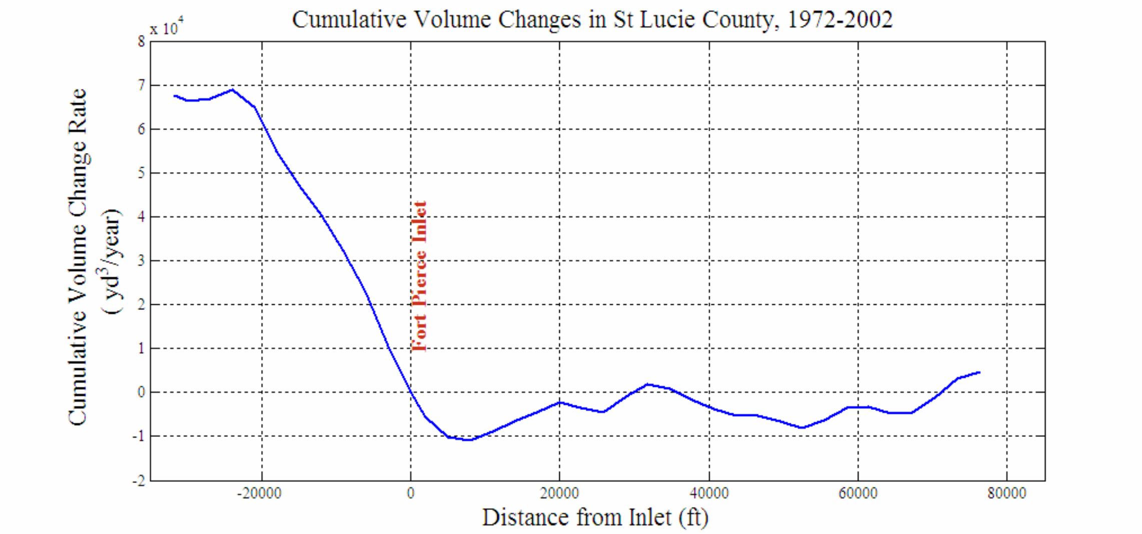

Figure 14 Cumulative Volume Density Change Rate in St. Lucie County for the Period 1972-2002.

Volume Changes at Riomar Crenulate Bay

Analyses of volume changes also over a 30 year period (1972-2002) suggest that 34,000 yd^3/year are being stored in the Riomar Beach indentation. Figure 14 presents the cumulative volume changes for the period 1972-2002. In addition to the plots, Table 3 summarizes the cumulative volume results obtained for different periods for this particular beach segment in Indian River County.

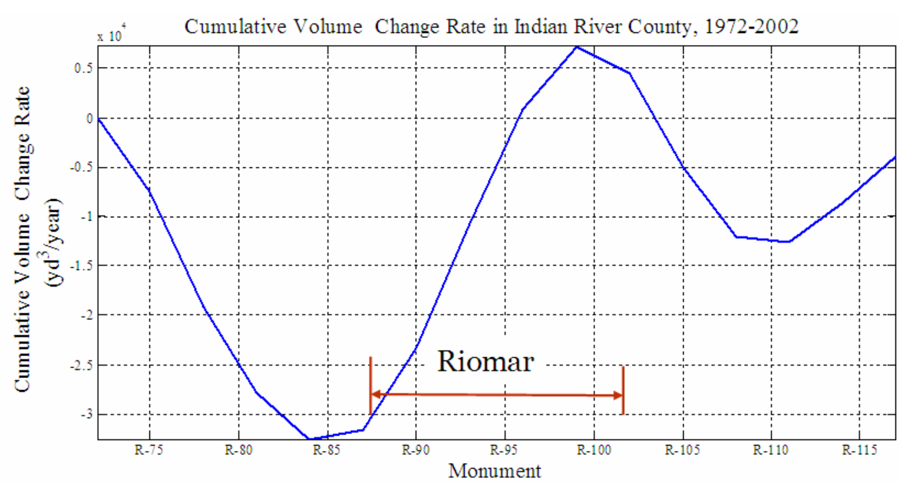

Figure 15 Cumulative Volume Change Rate at Riomar Beach for the period 1972-2002 between Monuments R-71 to R-119 in Indian River County.

Table 3 Cumulative Volume Changes at Riomar Crenulate Bay.

Year Period	Volume Accumulated (yd^3/yr)
1972 – 1986	35,600
1986 – 1997	33,700
1997 – 2002	29,100
Average 1972 – 2002	33,800

Application of DNRBS model

The computer model 'DNRBS' developed by Dean and Grant (1989) was employed to predict beach planform evolution and shoreline changes. A modified version of the original DNRBS which incorporates multiple nourishment events throughout the life of the project as well as multiple structure placements was used. The hydrodynamic conditions were represented by effective parameters. The initial shoreline was considered as straight and parallel and the sediment size representative of the project was taken as the mean grain size.

Applicability of DNRBS to Sediment Budget.

The numerical model calculates the planform evolution in the presence of a littoral barrier. The initial planform is specified in the input file. Volume changes on the beaches updrift and downdrift of the barrier are calculated and compared to the values of volume changes yielded by the profile changes method. Effective parameters are evaluated through a sensitivity test sequence in order to obtain volume, shoreline changes, and leaked volume through the barrier and lost to the channel. Volume changes updrift and downdrift of the barrier are calculated and compared to the actual values of volume changes yielded by the profile change method. User defined wave direction and profile "flattening" factors are used to evaluate which hydrodynamic conditions equate the volume of sediments yielded for the two approaches.

The width of the profile is determined in terms of the breaking distance to be $W_{break} = (h_{break}/A)^{3/2} = (H_o/kA)^{3/2}$ if an equilibrium profile is assumed. In this equation, k is the breaking index, A is the profile scale factor, h_{break} is the breaking depth and H_o is the effective wave height. A sand transport experiment made by Altman (2000) established that steeper slope beaches induce greater longshore as it is also shown in this model through the flattening assumptions. The flattening factor, V, modifies the transport rates downdrift of the inlet. This is done by multiplying the total transport in the downdrift cells by $W_{break} /(W_{break} – V.Y_{average})$ where $Y_{average}$ is unmodified. The target quantities are updrift and downdrift advancement and retreat respectively of 400 ft and 160 ft and a total transport in the north of 65,000 yd^3/year with 11% of the transport leaking through the jetty.

A wave height of 1.77 feet and a wave angle of 87.7°, where 90° would be shore normal waves. yield the results given below which are in reasonable agreement with the target values. For the run shown in Figure 15. The shoreline advanced 439 ft north of the inlet and in the presence of nourishments, the shoreline south of the inlet retracted 160 feet.

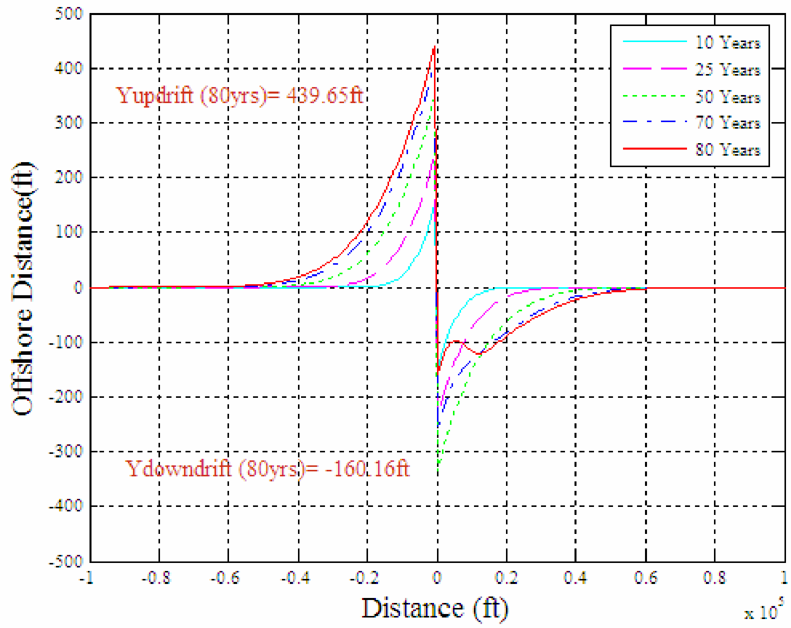

Figure 16 DNRBS shoreline evolution with time.

According to the modeling results, the inlet influences 9.5 miles of shoreline north of the inlet and 13.3 miles south of the inlet. The difference between updrift and downdrift influence distances is due to profile flattening on the downdrift side of the inlet.

Three survey periods were used to establish the longshore distributions of volume changes. The changes in shoreline positions and volumes are presented for the three intersurvey periods. In general, it is observed that for the three periods considered, updrift volume changes are positive. Nourishment quantities and volumes of sediment dredged and placed on the downdrift shoreline varies for the three periods under consideration. Table 4 summarizes the volume changes for the three intersurvey periods. Additionally dredged and nourishment quantities are presented for the three periods surveyed and the 30 year average values as well. For sediment budget purposes, a 30-year average period will be considered as a basis to estimate the required amount of additional sediment placement by nourishment. It can be observed that an average of 67,500 yd^3/year of sediments accumulated on the north side of the inlet and an average accumulation of 8,900 yd^3/year is present south of the inlet. In addition, an average of 663,100 yd^3 of sediment was dredged from the inlet and turning basin and 228,140 yd^3 was placed in the south beach from dredging events and 1,934,000 yd^3 from offshore sources over this 30-year period.

Table 4 Cumulative Volumes, dredged, Nourishment Events, and Additional Quantities

Year Period	$\left(\frac{dV}{dt}\right)_{NS}$ (yd^3/yr)	$\left(\frac{dV}{dt}\right)_{SS}$ (yd^3/yr)	$Q_{Dredged}$ Disposed on Beach (yd^3/yr)	$Q_{Dredged}$ Disposed Offshore (yd^3/yr)	$Q_{Nourishment}$ (yd^3/yr)	$Q_{additional}$ (yd^3/yr)
1972 – 1987	48,800	36,000	6,280	23,830	23,070	6,800
1987 – 1997	104,300	-63,700	14,050	7,750	0	87,900
1997 – 2002	50,000	73,000	4,650	0	174,000	-98,500
Average 1972 – 2002	*67,500*	*8,900*	*7,600*	14,500	*40,530*	16,300

The equations and results developed allowed the calculation of the required additional nourishment quantities to balance the volumetric changes north and south of Fort Pierce Inlet resulting in average additional values of 16,300 yd^3/year of nourishment downdrift of the inlet. This quantity is in addition to the nourishment quantities carried out. Additional requirements for all three periods examined are presented in Table 4.

The sediment budget is the result of the difference between sediment inflows and outflows from the region. The material dredged from the turning basin and channel which is disposed offshore may contain fine grain sediments mixed with 25% to 50% of good quality material. An initial estimate of littoral drift is made with the average values of additional nourishment, nourishment events, amount of sediments dredged and disposed on the beach and 25% to 50% of the amount dredged and deposited offshore. It was established that Riomar is trapping nearly 34,000 yd^3/year which indicates that the littoral drift north of Riomar is in the order of 112,000 yd^3/year to 116,000 yd^3/year.

Summary

The sediment budget calculated was based on the analysis of available survey data and nourishment and dredging records from 1972 to 2002. Survey data encompasses the entire shoreline of St. Lucie County. Three periods were examined in this study: 1972 to 1987, 1987 to 1997, and 1997 to 2002. Additional quantities of sediment necessary for placement on the south beaches were calculated considering that in the absence of the inlet and nourishment, volume changes on the north beach are expected to be the same as on the south beach over the same distance, regardless of the processes. A substantial variability of sediment transport into and out of the system was found for these three periods of study. However, it has been established that for the overall period 1972 to 2002, annual average values of approximately 82,000 yd^3 of littoral drift entered the area, and 57,000 yd^3 are transported to the south of the region considered.

The analysis of the Riomar crenulate bay reveals that an annual average of nearly 34,000 yd^3 is being trapped in this portion of the coast; thus leaving a total annual amount of 116,000 yd^3 to be transported southward towards Riomar Beach.

The sediment budget developed has established an average annual need for sand placement on the beaches south of Fort Pierce Inlet of 64,430 yd^3. Over the 30 year period examined (1972 to 2002), the average placement has been 40,530 yd^3/year, leaving an annual deficit of 16,300 yd^3/year. Thus, to reinstate the natural processes to the degree possible, it is necessary to place a total average of 64,430 yd^3/year of compatible sand on the south beaches. This amount could be placed through nourishment, bypassing or a combination of the two.

At present, the north jetty is leaky with an estimated 11,000 yd^3/year being carried into Fort Pierce Inlet. Some of this sand is intermixed with lesser quality material and deposited in the turning basin and is not suitable for placement on the beaches.

The average volume stored on the updrift (north) side of Fort Pierce Inlet was found to be 67,500 yd^3/year for the 30 year period examined. All or a portion of this sand is an attractive source of sand for bypassing to the south beaches.

Recommendations

Conduct an in-depth effort to design a sand bypassing plant at Fort Pierce Inlet. Construction of such a facility would require the concurrence of the Division of Recreation and Parks of the Florida Department of Environmental Protection. An advantage of bypassing rather than larger scale periodic nourishment as has been conducted in the past is that bypassing can better mimic the natural sand processes of a more or less continuous supply of sand. The design effort will require determination of the depth to rock and other characteristics of the system. Desired characteristics of the system should be provide to enough deposition capacity so as to not let the sand leak into the inlet and turning basin and also to providing adequate stability to the beaches updrift of the inlet.

Monitor, on a biennial basis, the beach profiles for a distance of 60,000 feet north and south of Fort Pierce Inlet. The profiles should be spaced at a nominal spacing of 1,000 feet on the DEP monuments. This monitoring will provide an improved basis for determining the nourishment/bypassing needs and effectiveness of these measures. The monitoring at this frequency should continue until an improved understanding of the variability in sediment transport and replenishment needs are better established and then the need for continued monitoring should be reassessed.

Different options to supply the deficit of sand are considered. The first is to use the sand transfer facility to supply the 64,430 yd^3/year needed. Over the long term, this will result in a significant decrease in the updrift fillet. The second option is a combination of bypassing and nourishment including continuation of the dredging program at the inlet and turning basin.

Beach Maintenance using an offshore source can complement the deficit on the south beaches. Borrow areas near the inlet, such as Capron Shoal, have been identified and could be used to mitigate the erosion problem

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