Quantification of Longshore Sand Transport and Sand Bypassing at South Lake Worth Inlet Palm Beach County, Florida

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1.0 INTRODUCTION

1.1 Abstract

The intent of this paper is to express the quantities of sand bypassed by a sand transfer facility and transported in the littoral drift at the South Lake Worth Inlet, Palm Beach County, Florida. Discussion on littoral transport volumes will include estimates of the annual average drift from 1948 to 1987, and discussions of sand bypassing quantities will include improvements in the estimation of pumping rates.

1.2 History

The South Lake Worth Inlet District was established by the Florida Legislature in 1915 (Ref. 1), for the purpose of creating an Inlet flushing canal from the Atlantic Ocean to help alleviate serious pollution in freshwater (slightly brackish) Lake Worth, resulting from rapid development of the area after the turn of the century.

The United States Army Corps of Engineers (COE) issued a permit in April of 1924, authorizing the District to construct and maintain the Inlet, including stone jetties on each side of the Inlet and allowing for the construction of a fixed bridge across the Inlet (Ref. 2). The Inlet was completed in July 1927.

Substantial improvements resulted from a 1964 model study by the University of Florida (Ref. 3). These included a new Inlet configuration with curved north and south jetties extended from their original lengths and a widening of the Inlet by removing a bridge abutment. Also, a training wall was constructed west of the bridge to improve the flow and self-maintenance of the Inlet channel and to redirect the suspended sediment flow into a sand trap area. The Sand Transfer Facility was relocated approximately 100 feet seaward of the MHW line on the north jetty (Fig.1).

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Fig. 1 Aerial Photo of South Lake Worth Inlet (photo circa 1984)

The STF's function is to transfer the sand as it reaches the north side of the north jetty to the downdrift beaches. Sand not transferred, generally flows around the Inlet in the ebb tidal shoal, acting as a conveyor belt, and is deposited on the downdrift beach to the south (Fig. 2).

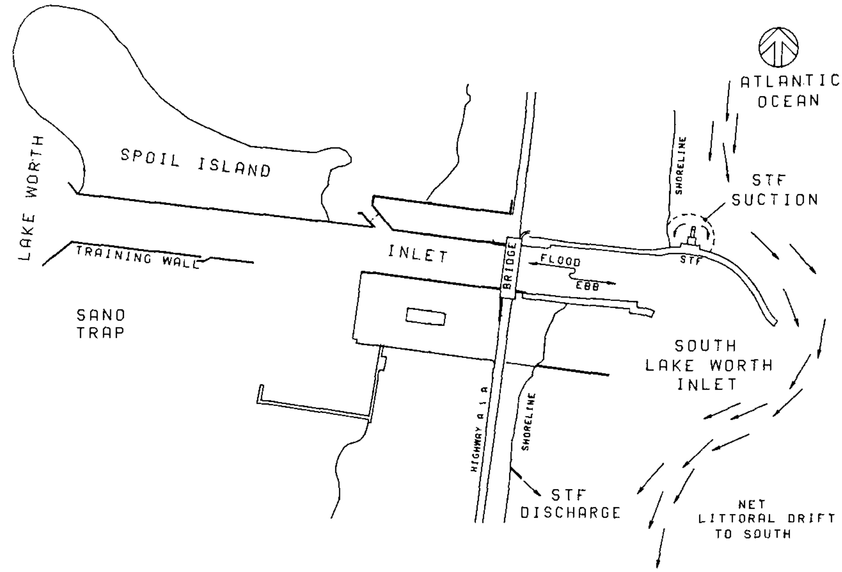

Fig. 2 Present Configuration of South Lake Worth Inlet, Palm Beach County, Florida

2.0 QUANTIFICATION OF LITTORAL TRANSPORT

2.1 Littoral Environment Observations

In October 1984, monitoring of the littoral environment was initiated utilizing the (COE) Littoral Environment Observation (LEO) Data Collection Program (Ref. 4). The LEO beach monitoring site is located about 1,000 feet north of the South Lake Worth Inlet. The LEO Program was developed by the Coastal Engineering Research Center (CERC) branch of COE. The purpose of the LEO Program is to record visual observations of breaker conditions (height, angle of approach, and tides), local winds, longshore currents, rip currents and beach geometry on a daily basis for at least one year or more (Ref. 5). The reliability and credibility of the LEO observation results and analysis depend on the number of observations taken and the availability of trained observers.

The application of the LEO data at the South Lake Worth Inlet is for the purpose of predicting longshore sand transport rates utilizing observed waves breaking at a recorded angle to the shoreline. The quantities of sand transported along the shore are a result of waves creating a longshore current and the breaking wave turbulence that suspends the sediment. Empirical equations in the Shore Protection Manual (Ref. 6) utilize LEO data in the empirical relationship to relate the longshore transport to wave conditions. Using a second method in 1980, Todd L. Walton Jr. (Ref. 5) applied LEO current observations to compute the longshore transport. The annual summary of

LEO data by CERC uses these two separate, although not completely independent, methods for determination of sediment transport rates.

The data summary in Table 1 presents two years of LEO longshore transport estimates. Review of the annual estimated littoral transport rates clearly show the net movement of sand is to south, but a true determination of the annual rate will need more years of data collection and observations. The LEO estimates for 1987 have been deleted due to data collection errors resulting in inaccurate transport rates.

TABLE 1

A. CERC LEO estimated annual net southerly sediment transport volumes (Jan-Dec.)

	Method 1	Method 2
1985	379,731 cy	110,987 cy
1987	385,168 cy	126,996 cy

B. South Lake Worth Inlet average annual estimated sand bypassing volumes (dredge years 1968-B7)

Based on 100 CY per hr of pump operation	50,140 CY
Based on 125 CY per hr of pump operation	62,675 CY
Based on 160 CY per hr of pump operation	80,224 CY
Based on 200 CY per hr of pump operation	100,280 CY

C. South Lake Worth Inlet average annual measured sand bypassing volumes (1985-88) 74,409 CY

2.2 Annual Average Drift

There have been many estimates of the annual average drift for the purpose of determining the net littoral drift to the south (Table 2). In 1948, the COE did a study which concluded that during the fourteen (14) year period immediately following completion of the Inlet and the jetties, material was impounded at a rate averaging 150,000 to 225,000 cubic yards (CY) per year (Ref. 7). In a 1953 study by the COE, an estimate of 200,000 CY per year was used as the "southward drift at the South Lake Worth Inlet to the 27 ft. depth" (Ref. 8). In 1964, the University of Florida Coastal Engineering Department. by con-tract for the South Lake Worth Inlet District, used an es-timate of 200,000 CY as the net drift to the south (Ref.3).

In 1966, Per Bruun's book entitled "Inlets and Littoral Drift" (Ref. 9), credited the COE, Jacksonville District for its determination of the predominant drift at the South Lake Worth Inlet as being 150,000 to 200,000 CY per year. In a later report dated July 21, 1965, Per Bruun, assumed that the normal rate of drift at the Inlet is 225,000 CY per year (Ref. 10).

TABLE 2
Estimates of Annual Average Drift

Year	Agency/Individual	Rate (Net to South)
1948	U.S. Army Corps of Engineers (COE)	150,000 to 225,000 cy/yr. Drift to south at area of South Lake Worth Inlet
1953	COE	200,000 cy/yr.
1964	University of Florida	200,000 cy/yr.
1965	Per Bruun	225,000 cy/yr.
1966	Per Brunn	150,000 to 200,000 cy/yr.
1985	COE/WES	270,000 cy/yr. based on wave data collected in Atlantic Wave Information Study (1956-1975)
1987	Olsen	270,000 cy/yr.

The COE Waterway and Experiment Station (WES) in Vicksburg, Mississippi utilized twenty (20) years of wave hindcast data (1956 to 1975) to determine the potential average annual net southerly littoral transport rate of 270,000 CY in the area of South Lake Worth Inlet, which was later reported in the 1985 General Design Memorandum for Beach Erosion Control Projects in Palm Beach County (Ref. 11). The wave data utilized in the determination was supplied by the 1976 Atlantic Ocean Wave Information Study (Ref. 12). In 1987, Olsen & Associates prepared a report for Palm Beach County entitled "Guidelines for the Review and Consideration of Coastal Permits" and utilized the same 1985 WES estimate (Ref. 13).

2.3 Sediment Transport Rates

Most of the above annual littoral transport quantities are based on estimates rather than the observed data interpretation that the LEO Program attempts to correlate. The LEO Program allows for the variation in weather conditions (i.e., calm periods, when less sand will be moving, as opposed to the very active northeastern and hurricane periods, with the larger sand movement). It would be erroneous to expect any value of estimated net littoral drift to be constant year after year.

As stated in CETA 81-5 (Ref. 4) "the usefulness of the LEO program is best expressed in the statistical descriptions of the environment, often in areas where no other data exists, and in the inexpensive estimation of longshore transport rates."

2.4 Discussion

The estimates of net littoral transport have a common flaw in that there is an assumption of no interruption in the littoral transport system. The nearest interruption to the South Lake Worth Inlet littoral drift system is located fourteen (14) miles to the north at the Lake Worth Inlet. The Lake Worth Inlet, at its present location, was cut in the Barrier Island in 1917 and currently has a project depth of 35 ft. and channel width of 400 ft.

In a reference to maintenance dredging by Robert Dean (Ref. 14), it was suggested that the placement of sand in water deeper than 12 ft. does not allow for the sand to re-enter the longshore system by natural forces. This would mean that any sand naturally bypassed by the Lake Worth Inlet around the north jetty would have entered the wide channel where depths are greater than 12 ft., or deposited in the channel to be carried offshore with the ebb tide currents, or into the channel during the flood tide currents and deposited in the Intracoastal areas.

Therefore, since 1958 when the sand transfer plant was constructed on the north jetty of the Lake Worth Inlet, the only constant littoral drift across the Lake Worth Inlet was the approximately 70,000 CY per year pumped by the sand transfer plant.

All of the above information presented would make estimates of the net littoral drift at the South Lake Worth Inlet questionable. It would appear that the only way the South Lake Worth Inlet has been able to maintain the transferring, both artificially and naturally, of large quantities of sand is by tapping the supply between the two inlets. Therefore, there is a range of uncertainty in all of the above estimates.

3.0 QUANTIFICATION OF SAND BYPASSING

3.1 History

Prior to 1937, the South Lake Worth Inlet configuration with stone jetties extending perpendicular from the center line of Ocean Boulevard, approximately 350 ft. in length, allowed large quantities of sand to drift into Lake Worth through the Inlet (Ref. 15). In order to mitigate these sand losses, a sand transfer plant was constructed on the north jetty through a cooperative effort between the Inlet District and private property owners. This sand transfer plant is believed to have been the first of its kind in the United States.

Because of the fuel shortage during World War II, the plant did not operate between the years 1942 and 1945. Even though resumption of the plant operation following the war significantly restored the beaches to the south of the Inlet, it was found that a considerable amount of sand was still being trapped inside the Inlet in Lake Worth. Accordingly, the sand transfer plant was enlarged in 1948. This pump remained in operation until major renovations were made in 1967 in response to the physical model study and recommendations by the University of Florida, Coastal Engineering Lab (Ref.3) and previously discussed.

The primary purposes for these modifications were to prevent the loss of sand to the interior shoals of the Inlet, improve the sand transfer capabilities of the Inlet, and to make the Inlet channel self-flushing.

3.2 STF Quantities

The sand transfer facility today is a fixed hydraulic suction dredge with a rotating boom and 12 in. diameter suction intake line and 10 inch diameter discharge line. The dredge pump is driven by a 400 hp. diesel Caterpillar engine rated to pump 4,000 gpm with 20 percent solids in suspension. The discharge line extends west from the sand transfer facility to the road, then south across the bridge to the discharge location approximately 700 feet south of the south jetty.

Records of the quantities of sand bypassed and dredged at the South Lake Worth Inlet date back to the 1960's. For this paper, the review of quantities of sand bypassed will be for periods following the 1967 renovations and newly constructed inlet configuration. The estimated quantities of sand bypassed by hydraulic dredge have been based on rates varying from 100 to 200 CY per hour of pump operation from dredge years 1968 to 1988 (Ref. 16). Current sand bypassing estimates of 125 CY per hour of pump operation were determined by comparing estimated quantities with the measured quantities from a nuclear density measuring unit and Doppler flow meter combination that comprises the production monitor unit at the South Lake Worth Inlet.

The production monitor is a liquid slurry density system developed by Kay-Ray Inc. Industrial Process Control Equipment. The unit was installed in late 1985 to work with the Taylor Disk Pressure Recording System installed in the pumphouse of the sand transfer facility. The measuring unit was placed inside the engine room on the 10 in. discharge line and linked to the recording and equipment panels located in the room above. The control panel and lever room are located in the upper level where a digitized readout for production monitor measured quantities can be recorded by the dredge operator. The system is calibrated to read out in cubic yards of dredged material discharged through the system.

3.3 Discussion

The production monitor data indicated that during peak pumping periods, typically September to March, a larger volume of sand was being bypassed than previously estimated. It was in October of 1986 that the conversion of sand bypassing estimated cubic yards per hour of operation was increased from 100 to 125. Data in Table 1 for measured quantities reflect adjusted totals to account for periods when the production monitor was not operating due to repairs.

Prior to the introduction of the production monitor, the method of determining the dredge volumes bypassed by the sand transfer facility were to assume a constant quantity per unit of time. Changes in the estimated cubic yard per hour totals for plant operation have varied from 100 to 200 cubic yards from 1968 to 1988.

The graph (Fig. 3) presents the data collected from the production monitor since 1985. The vertical axis of sand transfer operating hours per week and the horizontal axis of measured cubic yards per week from the production monitor system illustrates the variation of weekly available material for bypassing.

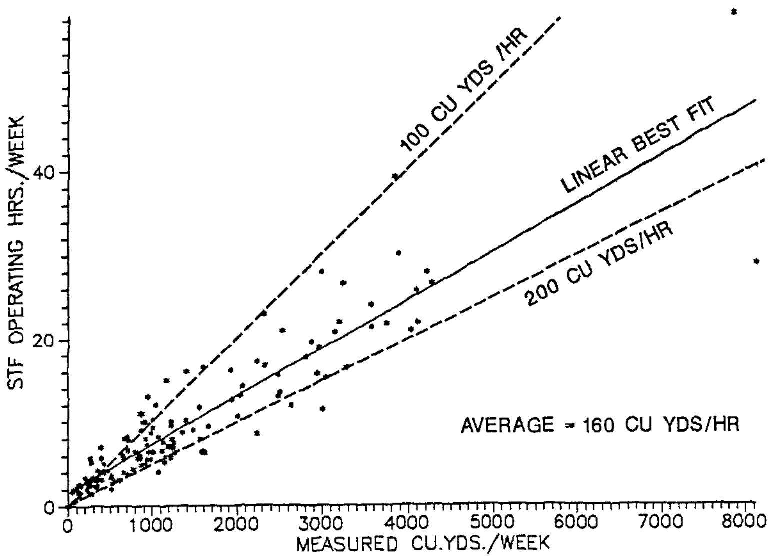

Fig. 3 Weekly Production Monitor Quantities (1984-1988)

During less active weather climates and operating conditions typical of summer and southeast winds and waves, the average measured bypassing totals are near an estimated 75 cubic yards per hour of plant operation. During active transport periods, with maximum sand availability, the plant has shown the capability to pump at a higher capacity for longer periods of time. Totals of measured bypassing in excess of 250 cubic yards per hour of plant operation have been recorded. The data in Table 3 lists the three peak periods of operation and the bypassing quantities measured during that dredge week from 1984-1988.

TABLE 3

Peak Measured Bypassing Volumes
(1984-1988)

Weekly Hours	Total Volume	Hourly Rate
39.2	3,832 CY	98.75 CY/Hr.Operation
58.6	7,816 CY	133.39 CY/Hr.Operation
28.9	8,113 CY	280.73 CY/Hr.Operation

Dashed lines on Fig. 3 represent the estimated rates of 100 and 200 cubic yards per hour to show the variation of measured bypassing rates around the upper and lower previously estimated rates of the sand transfer facility.

With a computerized linear best fit line, interpretation of the line was accomplished by averaging the data for operating periods of 10, 20 and 40 hours per week. The resulting average rate (based on these measured dredge rates) would be approximately 160 cubic yards of material per hour of plant operation.

The quantities of dredged material will vary depending upon the weather climate in the area of the South Lake Worth Inlet. As reported in an earlier paper, "Inlet Dredging Production as a Function of Sea State" (Ref. 17), a correlation was made between wave height and direction and the estimated quantities of material that could be dredged per hour of plant operation. It was determined that the problem was much more complex than simply averaging volumetric quantities for varying weather conditions.

In this paper, we also present the average annual estimates of sand bypassing volumes from 1968 to 1988 based on four (4) different estimates for bypassing: 100, 125, 160 and 200 CY per hour of pump operation (Table 1).

The graph (Fig. 4) shows that annual variations in the operating time for the sand transfer facility are apparent. The period of 1982-83 had 1,140 hours of operation and the period of 1971-72 had 231.5 hours of operation.

The graph shows a decrease in annual operating hours since 1982. This reflects a change in operation procedures and better efficiency in pumping as a result of the production monitor data (measured data) being available.

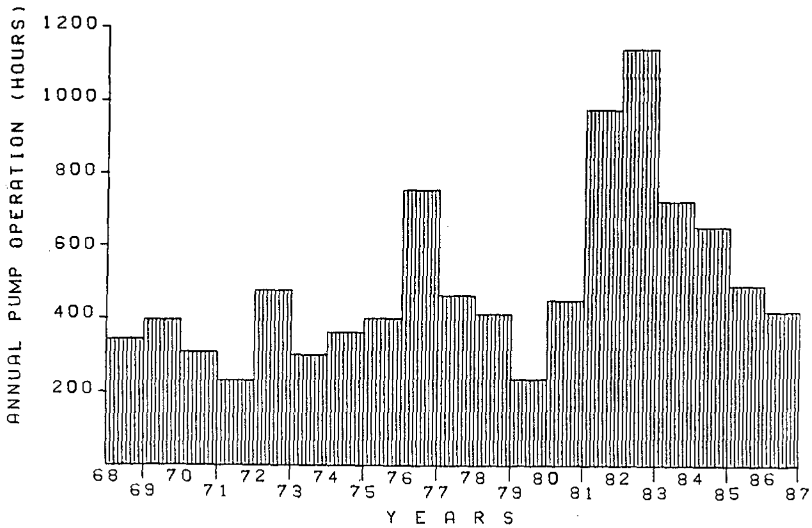

Fig. 4 Sand Transfer Facility Annual Operating Hours (1968-1987)

4.0 SUMMARY

4.1 Littoral Transport

Littoral transport is generally defined as the movement of sediments in the near shore zone by action of waves and currents. The Longshore Sand Transport component of the littoral transport is the volume of sand moving parallel to the shore. The review of the littoral drift and estimated sediment transport rates and associated volumes as presented in this paper were based on estimates, wave hindcast data, and LEO's two Shore Protection Manual methods.

The variations in the estimates of wave angle, surf zone width, and weighting of calm wave height observations in the littoral transport rate determination produce a wide range of estimated annual volume totals. As stated earlier, there is a range of uncertainty in all of the above estimates. The past estimates of littoral drift presented here documents the longshore transport rates variability.

4.2 Sand Bypassing

The sand bypassing operations at the sand transfer facility of the South Lake Worth Inlet show a great variability in the total annual volumes of material pumped from the north beach to the south beach. The combined presentation of the bypassing data and estimated LEO transport rates illustrates the variation in the dredge volumes due to the seasonal fluctuations of the wave and wind climate that create the transport events.

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