CHAPTER 19

APPLICATION OF FLUORESCENT COATED SAND IN LITTORAL DRIFT AND INLET STUDIES

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ABSTRACT

The use of fluorescent coated sand in tracing the sand movement along beaches and around inlets is an important tool in the field of Coastal Engineering. As a part of an extensive beach erosion study along the shore of West Palm Beach, Florida, four areas were subjected to such a "tracer study." Each area represented a particular beach configuration either with or without erosion protective structures. In this paper the procedure and results for one area is described.

As a second application of sand tracers, the results of a study concerned with the sand migration in and around South Lake Worth Inlet is discussed.

LITTORAL DRIFT STUDY ALONG A BEACH

Injection

Figure 1 shows the methods of injection and sampling of the fluorescent tracers. The tracer sand, whose properties have to be exactly the same as the properties of the sand of the test beach, is injected during low water. It is spread out on the dry beach from approximately the high water line to the low water line over a width of 50 feet and is mixed with the beach sand by raking. In this way the tracer material is wet before it is subjected to the wave action. Experience has shown that this is a particularly important step in the injection procedure for if the tracer material is not "wetted" it will float on top of the water due to surface tension and may result in misleading information. Water soluble bags were used for tracer injection from the low water line to approximately the MSL -3 foot line. These bags often being placed under water dissolve within ten to fifteen seconds releasing the tracer material.

Sampling Procedure

The sampling of beach material is started at the first low tide after injection. The tides along Florida's east coast are semi-diurnal. The time intervals between sampling are generally taken as the period between

two low tides. The low tide during the daytime is most convenient for working on the beach. The distances between sampling points generally depend on the nature of the study. If only a small area is to be studied in detail, the distances between sampling points may be as small as 100 feet; whereas a littoral drift study along a relatively uniform beach does not require such small distances. In the discussed littoral drift study, the distances between sampling points was chosen at 500 feet. In the offshore direction, three samples were taken, at the high water line, the low water line, and the MSL -3 foot line, respectively. Although, in general, there exists no rule for the number of samples to be taken, the accuracy of information obtained by the sand tracing method improves proportionally to the number of samples taken. However, the time required for analysis of each sample sets a practical limit to the total number of samples to be collected during each survey.

Sample Analysis

The sand samples are collected in small labeled bags, dried, and examined for tracer content. For reasons of comparison, one-hundred grams of the well-mixed sample are analyzed. This analysis is carried out for all of the samples taken.

The results for a particular set of sampling give a concentration distribution of tracer as a function of distance from the injection point. The least square method was applied to fit a third-degree polynomial curve to the "raw" field data (Figure 2). If this is done for each consecutive survey, a family of concentration curves as a function of time can be formed as shown in Figure 3. Since samples have been taken at three water lines, three sets of curves are obtained.

From Figure 3 it can be seen that, in general, the concentration decreases for each subsequent survey and that the maximum of the concentration curve shifts. The decrease of tracer concentration is due to dispersion as well as burial of part of the tracer material. If one assumed uniform erosion or accretion, the absolute maximum of the concentration would be affected; but the location of the tracer concentration maximum would remain the same. If the distance, Δs, between two successive concentration maxima is divided by the according time interval, Δt, the average migration speed, $\bar{v}$, of the tracer material is obtained. Since the tracer material is identically the same as the beach material, the speed of the littoral drift is known for the time, Δt, between two surveys. Figure 4 shows $\bar{v}$ as a function of time for the high water line, low water line, and MSL -3 foot line. Since the test beach has a north-south orientation, the drift is found to change from north to south.

As a next step, it has been tried to correlate the speed of littoral drift with the longshore component of the wave energy. The Coastal Engineering Research Center, U.S. Army Corps of Engineers kindly allowed the Department of Coastal and Oceanographic Engineering to obtain the daily records of a step-gauge wave recorder located at the end of the 1,000 foot long public pier at Lake Worth, Florida. The analysis of the records showed that 85 per cent of the wave periods ranged from 3 to 6 seconds and that the remaining 15 per cent of the waves were in the range of 6 to 11 seconds. Accepting an average period of 5 and 9 seconds for the two categories,

respectively, refraction diagrams were calculated for these two periods and for wave directions from the northeast, east, and southeast. Diagrams were calculated for each study area in addition to a small area around the wave recorder. Knowing the wave energy E_R and the width between adjacent rays b_R at the recorder, the energy E_s in each consecutive ray in the study area could be extrapolated from

$$E_s = \frac{b_R}{b_s} E_R$$

The longshore component of the wave energy is represented by

$$E_L = E_s \cos \alpha = \frac{b_R}{b_s} E_R \cos \alpha$$

where α is the angle between the normal to the beach and the wave crest.

Discussion of Results

The result of a long and tedious analysis is comprised in Figure 4. The figure shows the speed of sand migration as a function of time in one study area and is correlated with the longshore wave energy of that area. The figure shows the change in direction of the longshore energy component to agree fairly well with the change in direction of littoral drift. It also indicates an increase in speed of littoral drift with an increase in longshore energy. There seems to be a tendency for the littoral drift to slightly lag the longshore energy component. A very significant feature of the figure is the sensitivity of the high water area to the wave energy, indicated by the maximum amplitudes of the solid line. A remarkable fact is that the transport in the MSL -3 foot area is also very pronounced. Less movement is observed in the low water region. This generally has been observed in the analysis of the other three areas. The latter results are not shown to avoid repetition.

It has to be stated that the accuracy and the correlation are not perfect. Particularly, the representation of the speed of sand movement as a function of time does not generate the desired confidence; although, a pattern of similarity in the modes of transport for the high water line, low water line and MSL -3 foot line can be unmistakably defined. It is believed that the indicated approach for obtaining information concerning littoral drift can be made very useful especially for calculating and comparing the speed of littoral drift for a wide variety of beach configurations found in nature.

From the results of this study it is evident that the sampling methods need to be improved. As a first step, it seems to be necessary to take more than one sample at each sampling point and to determine the tracer concentration at this point from the analysis of three or four samples. Another step could be to reduce the distance between the sampling points.

As stated before, this may not be possible from a practical point of view.

SOUTH LAKE WORTH SAND TRACING STUDY

General

A very effective use of sand tracers can be made in the study of sand migration in-and-around inlets. Figure 5 shows the South Lake Worth Inlet connecting the Intracoastal Waterway with the Atlantic Ocean. The width of the inlet channel is 130 feet, and the length measured from the easternmost jetty tip to the Intracoastal Waterway is 1900 feet. The average depth is 14 feet below MSL. The channel bottom has a rocky composition with some patches of sand, particularly in the bridge area. The channel is confined between vertical steel sheet piling over its entire length. A serious problem, dating back to the time the inlet was dredged in 1927, is the sand drain into the inlet. This results in a substantial loss of sand from the surrounding Atlantic beaches. This problem has been partially solved by installing a permanent dredge on the north side of the inlet to artificially transfer sand by a 10-inch pipeline to the south side of the inlet. Qualitative determinations of natural and artificial bypassing as well as the transport of sand into the inlet have been made by using four different colors of tracer material.

Locations of Injection and Sampling

Green tracer in the amount of 2000 pounds was placed on the beach 600 feet north of the inlet; 2000 pounds of red tracer material was injected at the same location on a bar at a distance of approximately 100 feet offshore. This bar extended southward and terminated due east of the inlet entrance. Another 2000 pounds of yellow tracer material was injected 500 feet to the south of the inlet between the high water line and the MSL -3 foot line. Finally, 2000 pounds of rose-violet tracer material was injected in the inlet on the Intracoastal Waterway side. Figure 6 shows all the locations of injections.

The samples on the north side of the inlet were taken at 100 foot intervals from Station 0 + 00N through Station 5 + 00N. The sampling points on the south side of the inlet also had a spacing of 100 feet between each station from Station 0 + 00S through 10 + 00S and were spaced 500 feet apart from here on through Stations 25 + 00S.

In the inlet channel, bedload and suspended load samplers were installed from which samples could be remotely drawn (See Figures 5 and 6). A small hand dredge was used to obtain samples from the Intracoastal Waterway bottom in the immediate vicinity of the inlet and the area adjacent to the jetty.

Current and Wave Measurements

Current measurements employing a Price current meter were made in the inlet channel in order to obtain a correlation of the mode and speed of sediment transport to the prevailing currents during the test. The velocities were measured in the middle of the channel and 40 feet to the north

and south of the middle at a distance of approximately 150 feet east of the bridge crossing the inlet (See Figure 5). This location coincides with the location of the samplers. Table I shows the current velocities during the peak of the flood tide.

TABLE I

CURRENT VELOCITIES IN INLET CHANNEL

Average Current Velocity (ft/sec)			
Date of Measurement	North of Middle	Middle	South of Middle
12-6-1967	5.8	5.2	2.8
12-7-1967	5.6	5.0	2.7

The current velocity distribution is highly asymmetric about the channel centerline. Figure 5 shows how the current even reverses direction in a region south of the middle. The location of the trap was such that it was not affected by this negative current. In addition to the skewed current pattern, the flow was highly turbulent. To record the current pattern, use was made of dye packages attached to anchored floats. The dissolved dye created clearly distinguishable streaks in the water which were recorded by aerial photography.

The wave heights and wave periods were measured visually. Table II shows that during the test the direction of wave approach was at about 15 degrees north of the normal to the beach with wave heights of 3 to 5 feet and periods of 4 to 5 seconds. This produced a relatively strong longshore current flowing south.

Discussion of the Results

Natural and artificial bypassing

Figure 5 shows the concentration curves for the green tracer material between the north jetty and Station 5 + 00N for eleven consecutive surveys. The migration of the maxima of the curves to the south indicates the speed of sediment movement which appears to be slow. Of particular interest is the zero concentration for survey 1 through 5. This most likely was caused by stagnancy of the water in a strip directly north of the jetty. This feature is evidenced by the fact that during the first and second day the samples taken from the artificially bypassed sand show almost negligible amounts of green tracer material. (P indicates location of permanent dredge, and the arrow at Station 10 + 00S indicates discharge of bypassed effluent.)

TABLE II

WAVE HEIGHT, WAVE PERIOD AND WAVE DIRECTION DURING TESTING PERIOD

Date	Survey No.	Wave Height in Ft.	Wave Period in Seconds	Wave Direction
12-5-67	1	6.10	5.06	ENE
12-6-67	2	5.00	3.83	NE
12-7-67	3	3.88	3.60	NE
12-8-67	4	2.51	3.40	NE
12-9-67	5	2.15	3.48	ESE
12-10-67		4.10	3.73	SE
12-11-67	6	3.58	3.71	SE
12-12-67		1.66	3.13	E
12-13-67		1.65	2.95	E
12-14-67		2.18	4.48	E
12-15-67	7	No Waves		
12-16-67		No Waves		
12-17-67		1.80	6.00	E
12-18-67		2.08	4.20	E
12-19-67	8	2.56	5.20	E
12-20-67		3.78	4.75	SE
12-21-67		2.48	3.93	ENE
12-22-67	9	4.50	5.30	NE
12-23-67		4.15	4.26	NE
12-24-67		4.73	5.76	NE
12-25-67		2.35	4.73	NE
12-26-67	10	1.30	4.76	E
12-27-67		1.85	3.46	E
12-28-67	11	3.80	3.66	E
12-29-67		0.96	4.14	E
12-30-67		1.18	3.63	E
12-31-67		2.05	3.56	SE

The notation "green 1/100" refers to the presence of one green tracer grain in a sample of 100 grams. Only at the point where waves rushed up on the beach and then hit the jetty was a substantial amount of green tracer observed.

Due to the prevailing rough weather only a few samples could be collected from the bar. However, the few bar samples taken show high amounts of red tracer indicating a considerable sediment transport along the bar. The high concentrations of red tracer sampled from the artificial bypassed effluent show that the feeding of the bypassing plant occurred predominantly by the sediment migrating along the bar. Evidence of considerable natural bypassing is given by the relatively high concentration of red tracer found on the beach to the south of the inlet (See Figure 5, curves in the right top corner).

Looking at the concentration curves for the yellow tracer, which initially had been injected on the south side of the inlet, it appears that for survey Nos. 2, 3, and 4 there is substantial transport to the south. This is in agreement with the wave information of Table II. For the next three days, the waves were from the southeast shifting the maxima of the concentration curves Nos. 5 and 6 back, indicating a transport to the north. For the remaining surveys, Nos. 7 through 11, the waves were from the east or northeast which, in combination with the orientation of the shoreline, should result in a littoral transport to the south. This is substantiated in the curves between Station 10 + 00S and Station 20 + 00S by the drop in tracer concentration. However, north of Station 10 + 00S there is a tendency for the tracer concentration to increase, indicating that sand is transported toward the inlet from the south and, as will be shown later, moves into the inlet. This tendency also appears in the concentration curves of the naturally bypassed red tracer material.

The explanation for this behavior can be found in the analysis of the dye patterns. They showed that, for waves approaching from southeasterly directions, the longshore current was directed toward the north and transported the sand into the inlet. For wave conditions from the northeast, as prevailed during the two days of measurements on which Figure 6 has been based, there existed a large eddy on the leeside of the north jetty rotating in a clockwise direction (See Figure 5). Dye packages released in the surf zone at various locations between Stations 0 + 00S and 10 + 00S produced south oriented streaks which reversed direction around Station 5 + 00S. The streaks north of Station 5 + 00S advanced to the easternmost tip of the south jetty giving rise to the idea that even under these conditions sand from an area extending approximately 500 feet to the south of the inlet is transported into the inlet.

Sediment transport into the inlet during flood

Bedload and suspended load samples were collected in the inlet channel. The suspended load was sampled for fifteen minutes by pumping the water-sand mixture through a fine sieve in a sample bag. The rate of pumping was such that continuity existed at the intake nozzle. The bedload was collected by means of bedload traps for thirty minute cycles. (Bedload traps are of the type described by Thornton (1968) in these Proceedings.) The qualitative results of this part of the test program are shown in Figure 6, I R, II R, I L, II L, III L, respectively. The figures represent the unsmoothed tracer

concentration curves for three consecutive days. The legend at the bottom of the figure only applies to these concentration curves.

The curves in I R and I L, representing the tracer concentrations two days after injection in the south and north bedload and suspended load sampler respectively, show that in the south side of the inlet the yellow tracer predominates, and the green tracer concentration is minor. On the north side of the inlet, green is dominant, and yellow is present in smaller quantities. II R and II L show the same tendency three days after injection. The yellow suspended tracer material is dominating on the south side, and the yellow bedload, green suspended load and green bedload occur in decreasing quantities. On the north side of the inlet, the appearance of red tracer in the bedload, as well as in the suspended load, indicates that the travel distance for the green tracer has been smaller than it was for the red tracer. This suggests a leakage in the north jetty. The tracer concentration of the red material also far exceeded the concentration in the bedload.

Figure 7 shows the grain size distribution curves for the beach samples north of the inlet and the samples taken north of the centerline in the inlet. Figure 8 shows the same set of curves for the south side. It is important to note that the difference between the grain size of the suspended sediment and the bedload material in the channel is insignificant. This can be explained by the high degree of turbulence in the inlet, causing intensive mixing of the sediment vertically. However, there is a substantial difference between the grain sizes of the sediment carried through the inlet on the north side and the sediment carried through the inlet on the south side, which is evidenced by the curves for the channel on Figures 7 and 8.

In general, there is always wave action on the north side of the north jetty entraining relatively coarse and heavy sediment. On the leeside of the north jetty, where there is little wave action, the only means of transporting the sediment towards the inlet is the eddy current generated in the lee of the north jetty. The current is so slow that only the light material is entrained. This explains the difference in coarseness of the material transported through the inlet.

Sediment Transport Outward During Ebb

Very small amounts of organic matter were collected in the suspended load trap as well as in the bedload trap during the outgoing tide. Of the rose-violet tracer, nothing was collected in the samplers either. Visual inspection of the injection area showed that the patches of rose-violet tracer material were still present indicating that no movement takes place in a region approximately 75 feet away from the inlet (See location of rose-violet injection in Figure 6). Both observations seem to imply that the transport out to the ocean is negligible.

Conclusions

The sharp decline in concentration of the green tracer in the immediate vicinity of the jetty very likely is caused by stagnancy of water next to the jetty. The lack of green tracer in the bypassed effluent and the presence of the same color tracer in the channel trap indicates a drain of sand through the north jetty occurring in the wave uprush zone, rather than being transported around the jetty. This has been confirmed by detailed tests at a later date. There appeared to be a rather pronounced transport along the

bar which even results in substantial natural bypassing of the inlet. This was evidenced by red tracer material collected on the south side of the inlet.

Concerning the artificial bypassing for the given situation, it can be concluded that most of the bypassed material originated from the bar region and not from the beach. This means that sediment not only is transported along the bar but also in substantial quantities across the bar.

Of great importance are the observations made in the inlet channel. They show that the sediment carried into the inlet is predominantly a suspended load. Of even more significance is the observed transport through the inlet from sediment originating from the south side (lee side) of the inlet for waves approaching from a northeasterly direction. Figure 6 shows that the order of magnitude of concentrations north and south of the channel center are approximately the same. This implies that, considering the low current velocity on the south side, the sand drain from the south is relatively high compared to the contributions from the north side.

The negligible amount of sediment transported outward to the ocean makes this inlet an extreme example of a sand drain causing a considerable loss of sand from the surrounding beaches as evidenced by these tracer studies.

Acknowledgements

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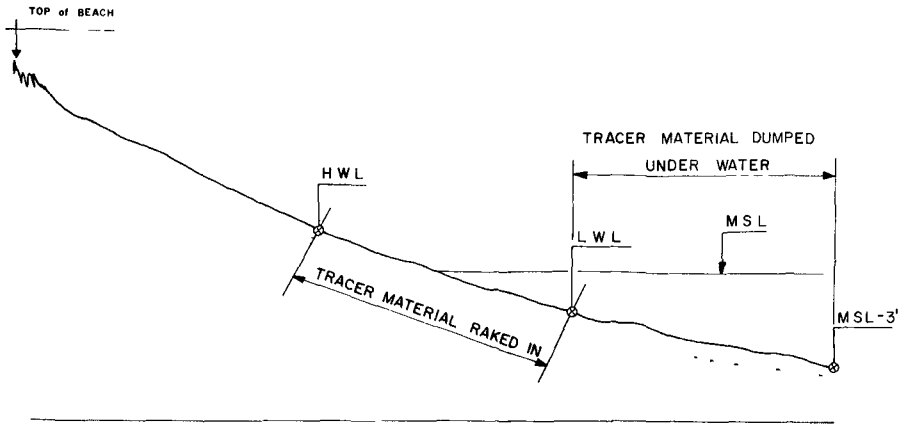
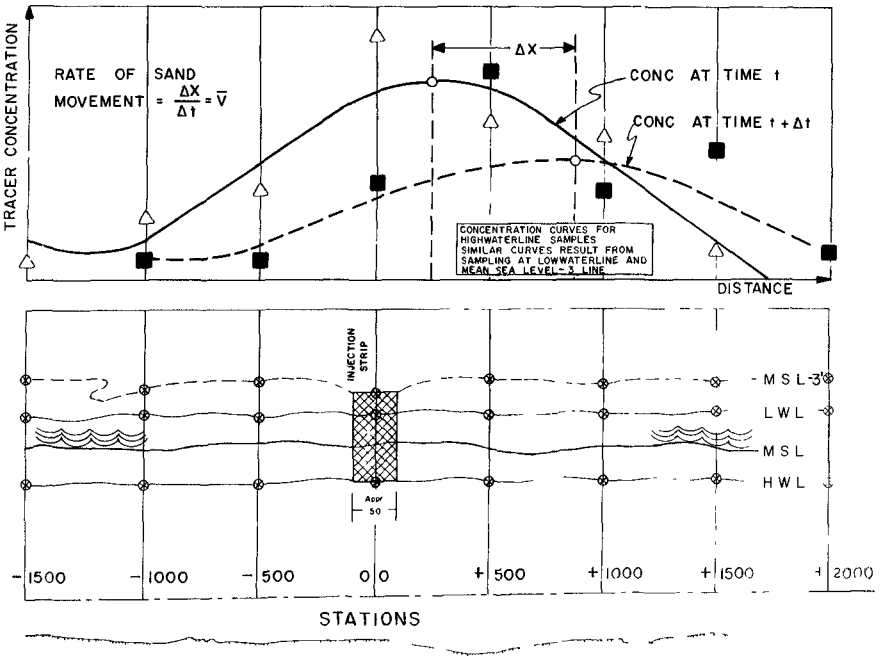


BEACH CROSS SECTION

FIG 1



INJECTION AND SAMPLING LOCATIONS

FIG 2

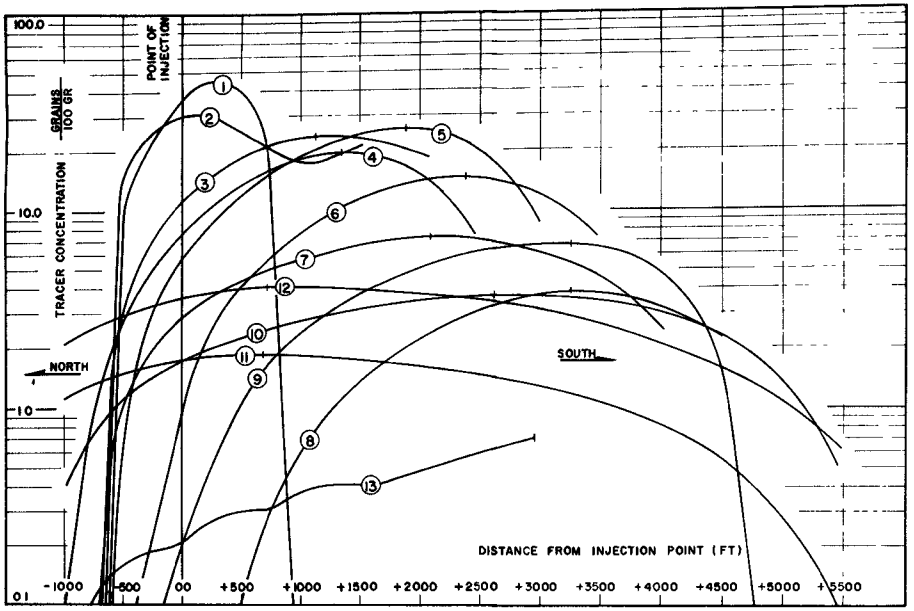


FIG 3 TRACER CONCENTRATION AS A FUNCTION OF DISTANCE FROM POINT OF INJECTION

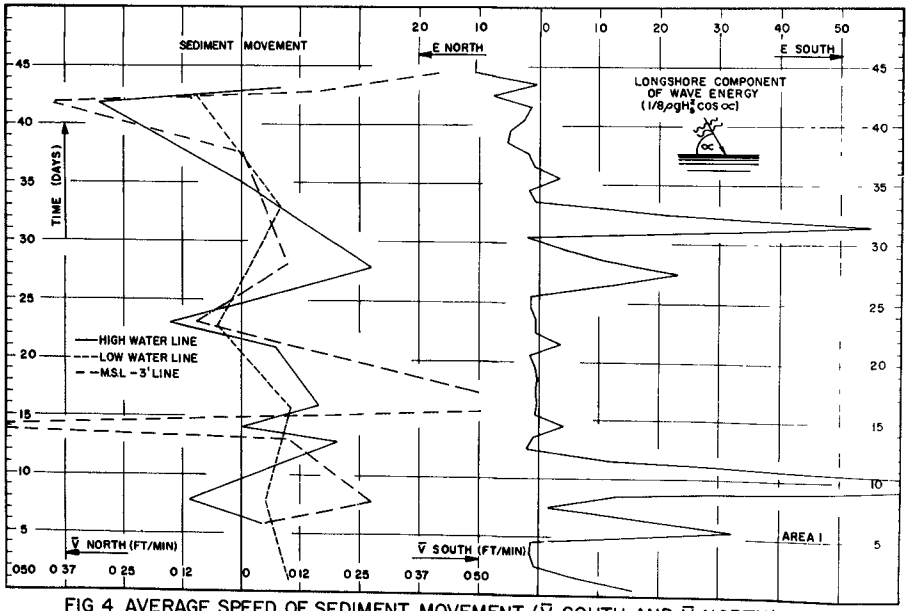


FIG 4 AVERAGE SPEED OF SEDIMENT MOVEMENT ($\bar{V}$ SOUTH AND $\bar{V}$ NORTH) COMPARED WITH THE LONGSHORE COMPONENT OF WAVE ENERGY

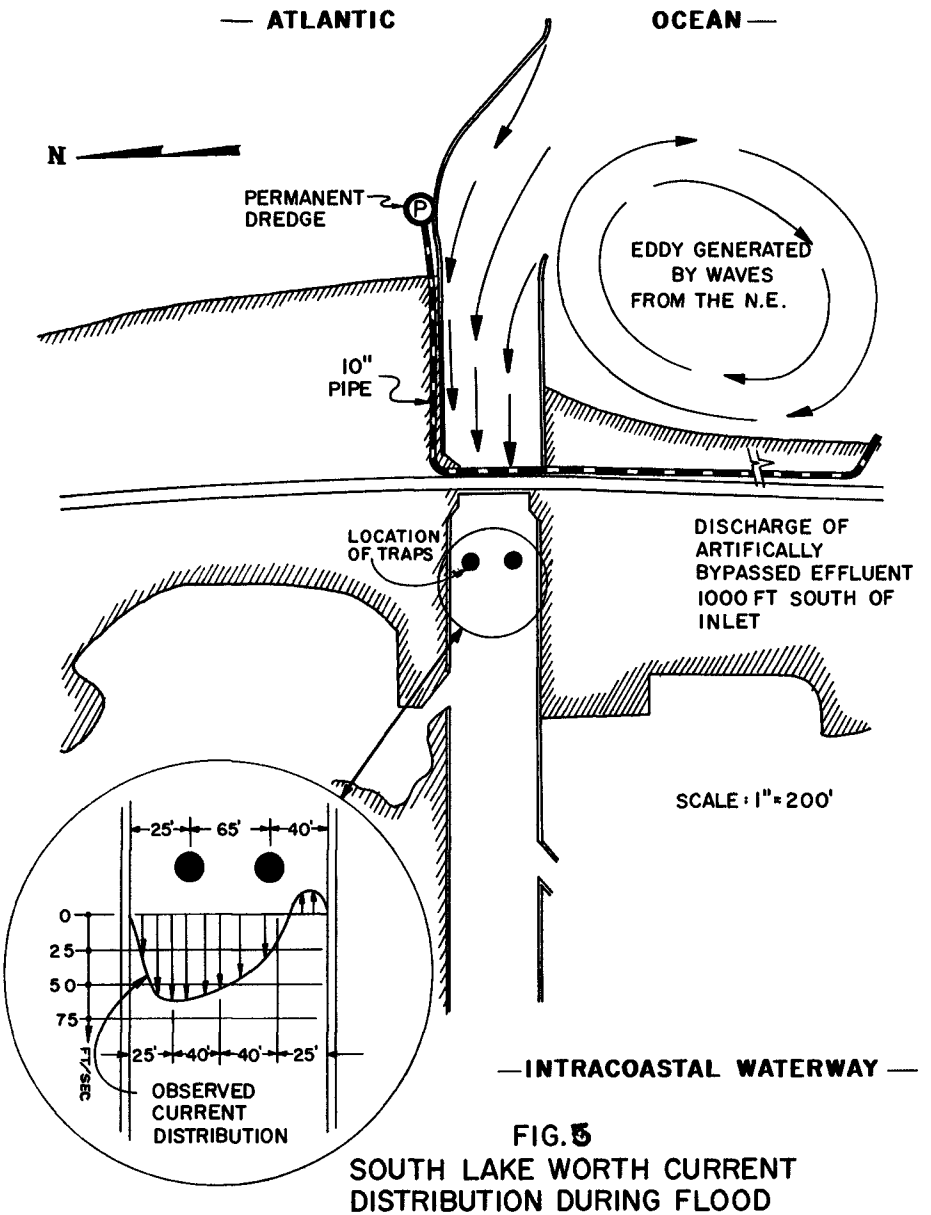
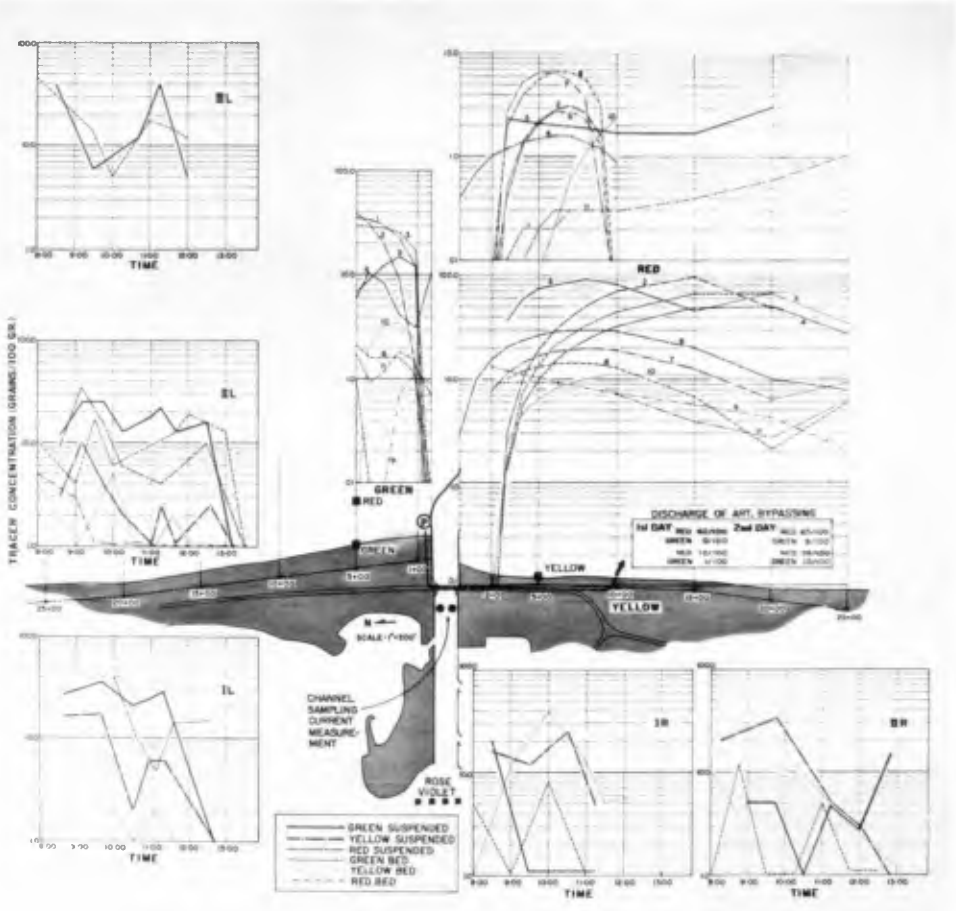


FIG. 5
SOUTH LAKE WORTH CURRENT DISTRIBUTION DURING FLOOD



SOUTH LAKE WORTH SAND TRACING STUDY
FIG. 6

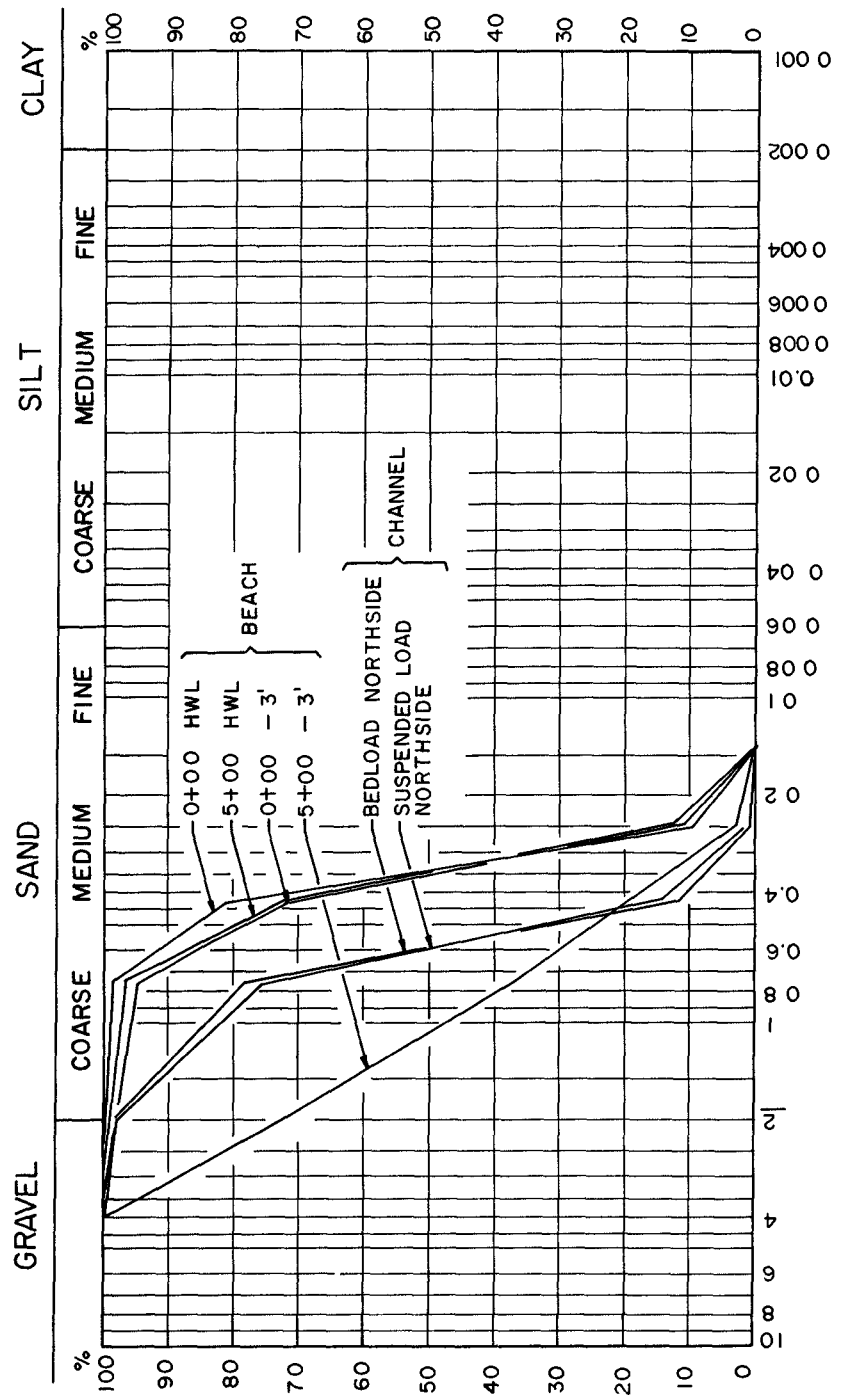


FIG 7 GRAINSIZE DISTRIBUTION OF THE BEACHSAND NORTH OF THE INLET AND OF THE SUSPENDED LOAD AND BEDLOAD NORTH OF THE CENTERLINE IN THE CHANNEL

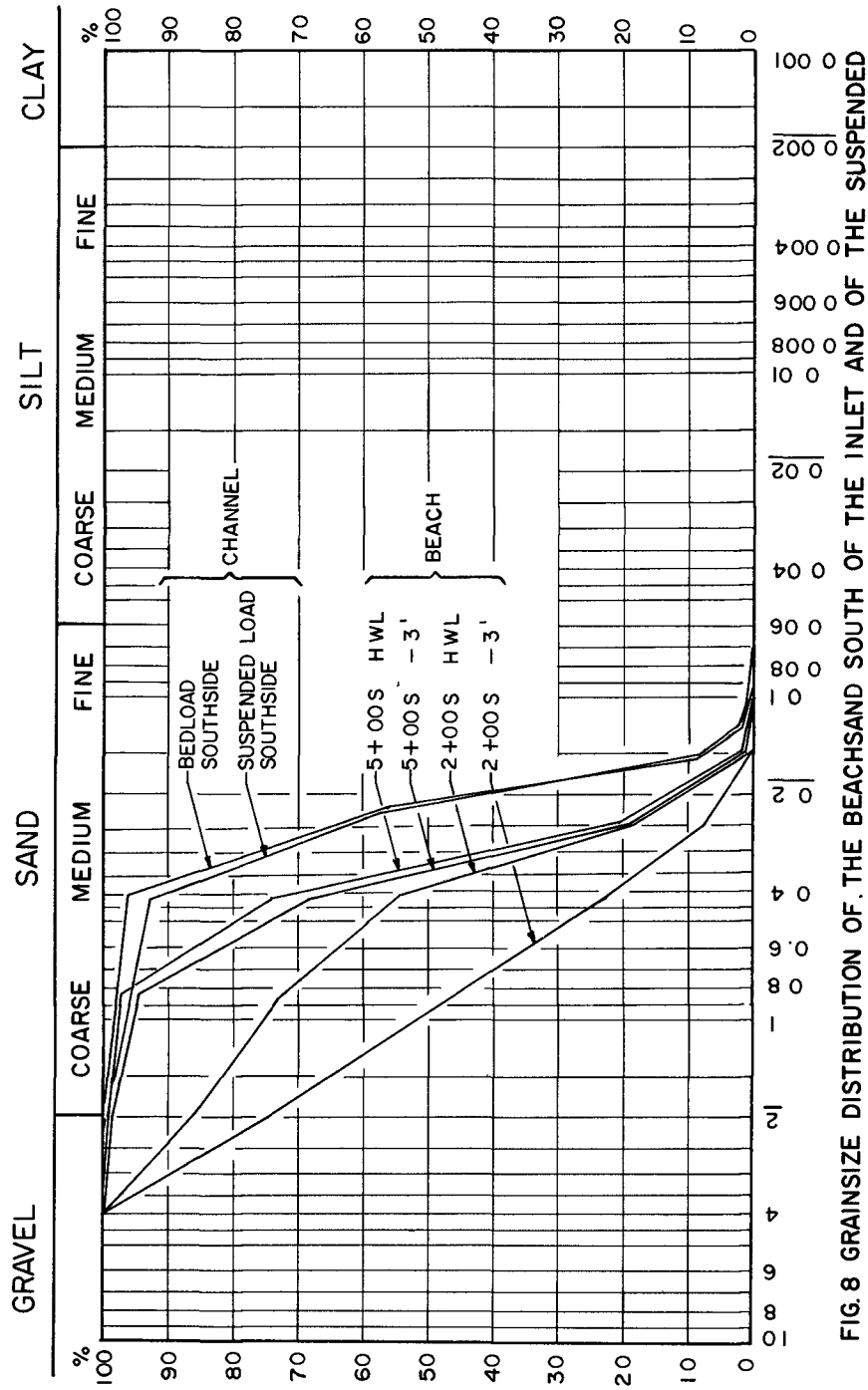


FIG. 8 GRAINSIZE DISTRIBUTION OF THE BEACHSAND SOUTH OF THE INLET AND OF THE SUSPENDED LOAD AND BEDLOAD SOUTH OF THE CENTERLINE IN THE CHANNEL