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SEDIMENTS IMPOUNDED BY AN OFFSHORE BREAKWATER, (U)  
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SEDIMENTS IMPOUNDED BY AN OFFSHORE BREAKWATER

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ABSTRACT

The breakwater and entrance jetties for the Channel Islands Harbor in California form a total littoral barrier to longshore sand transport. The sand impounded by these structures was monitored by repetitive bathymetric surveys and systematic surface sand sampling. This paper discusses patterns of sediment deposition behind an offshore breakwater. Data collected were studied to determine if the deposition observed agrees with that predicted prior to construction. Both the geometry and size distribution of the deposition sediment are examined.

Three dimensional computer plots are used to illustrate filling patterns. Sediment size and sorting distribution which occur during filling are investigated. Analyzed data allows an evaluation of predicted verses actual filling patterns. Sediment distribution in the impoundment area was evaluated.

BACKGROUND

At Channel Islands Harbor in Southern California, entrance jetties and an offshore breakwater are used to provide a solution to a downcoast beach erosion problem and to provide a small craft harbor. This harbor is located about 60 miles (100 km) northwest of Los Angeles and 1 mile (1.6 km) upcoast of Port Hueneme (Figure 1). The harbor was constructed for the dual purposes of beach erosion control and small craft harbor. Prior to Channel Islands Harbor construction a serious erosion problem existed downcoast of Port Hueneme, which was attributed to diversion of littoral sands into the Hueneme Canyon by

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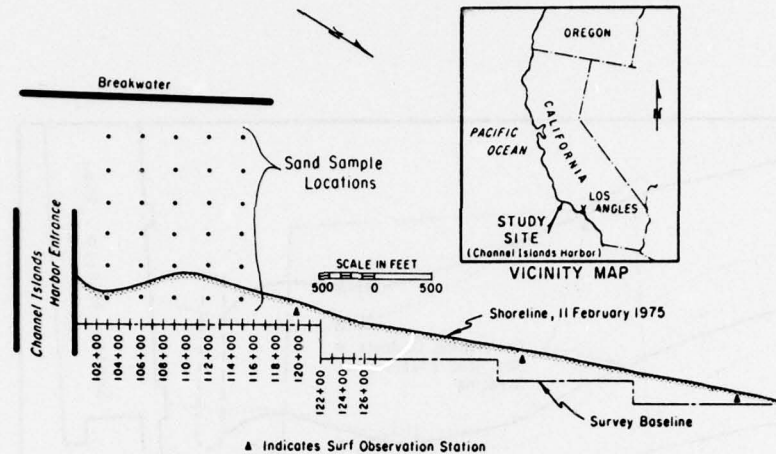


Figure 1. Study Area

the Port Hueneme north jetty. Presently, sands trapped at Channel Islands Harbor are bypassed to the south of Port Hueneme by periodic dredging.

The offshore breakwater is located at a depth of 30 feet (9 m); it is 2300 feet (700 m) long, about 2000 feet (600 m) from shore, and trends roughly parallel to the shore. The design of the sand trap was developed empirically by considering the configuration of the Santa Monica, California breakwater fillet and by developing diffraction patterns for generally prevailing waves (Corps of Engineers, 1948; Herron and Harris, 1966). Figure 2 shows the predicted fillet developed for design of the sand trap and offshore breakwater. During the period from April 1974 to September 1975, between sand trap dredgings, repetitive hydrographic and topographic surveys were conducted and surface sediment samples were taken. Surveys were made by measuring elevations along 22 shore-normal profile lines spaced at 100 foot (30 m) intervals (Bruno and Gable, 1976). These profiles covered the full extent of the trap and beyond the dredge area. Sand samples were taken on a grid of 30 points with a spacing of 300 feet (90 m) (Figure 1).

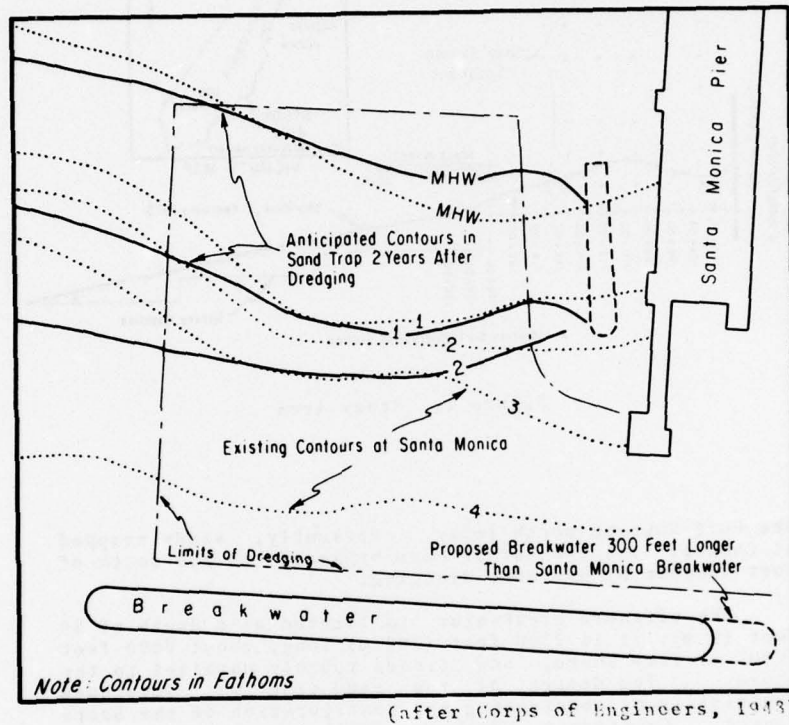


Figure 2. Design of Channel Islands Harbor Sand Trap

## NEARSHORE ENVIRONMENT

Figure 1 shows the sites where twice daily nearshore data were collected using procedures developed under the Coastal Engineering Research Center's (CERC) Littoral Environment Observation (LEO) program (Bruno and Hiipakka, 1973; Berg, 1968). These data include observations of surf conditions, local winds and littoral currents.

By looking at the plot of monthly averages on breaker height, period and direction (Figure 3), two seasons can be identified. These can be considered as the general summer and winter conditions. From November to May storms with larger breakers (7-10 feet, 2-3 m) and breaker angles greater than 92 degrees are observed. However, from June through October summer conditions persist. These are smaller breakers (2-4 feet, 1 m), and monthly average wave directions are less than 92 degrees.

## DEPOSITION GEOMETRY

The geometry of sand fillet formed behind the offshore breakwater is illustrated with the use of three dimensional computer plots. For each geometry two plots were drawn, first a perspective view of all profile lines, then shore parallel grid lines were added to give the appearance of a surface. Figure 4 shows the post dredge configuration in April 1974. The many irregularities in this surface are the result of dredging. The dredged area covered stations 102+00 to 118+00. Dredge cuts were terminated about 1100 feet (350 m) from the baseline thus leaving a shore parallel ridge at 1150 feet (360 m) from the baseline.

By February 1975 the trap area shows significant filling and smoothing (Figure 5). The fill is occurring along the shore as the beach builds seaward. Also fill can be seen forming a pronounced offshore bar/plateau at a depth of about 10 feet (3 m). The presence of the ridge at 1150 feet (360 m) offshore is still evident.

The September 1975 survey of the fillet is shown in Figure 6. The only remnant of the dredge hole can be seen on stations 103+00 and 104+00. The ridge at 1150 feet (360 m) has now lost its identity. The shore has prograded in a bulge with its apex at station 103+00. At the 10 foot (3 m) depth contour a plateau can be seen seaward of this bulge.

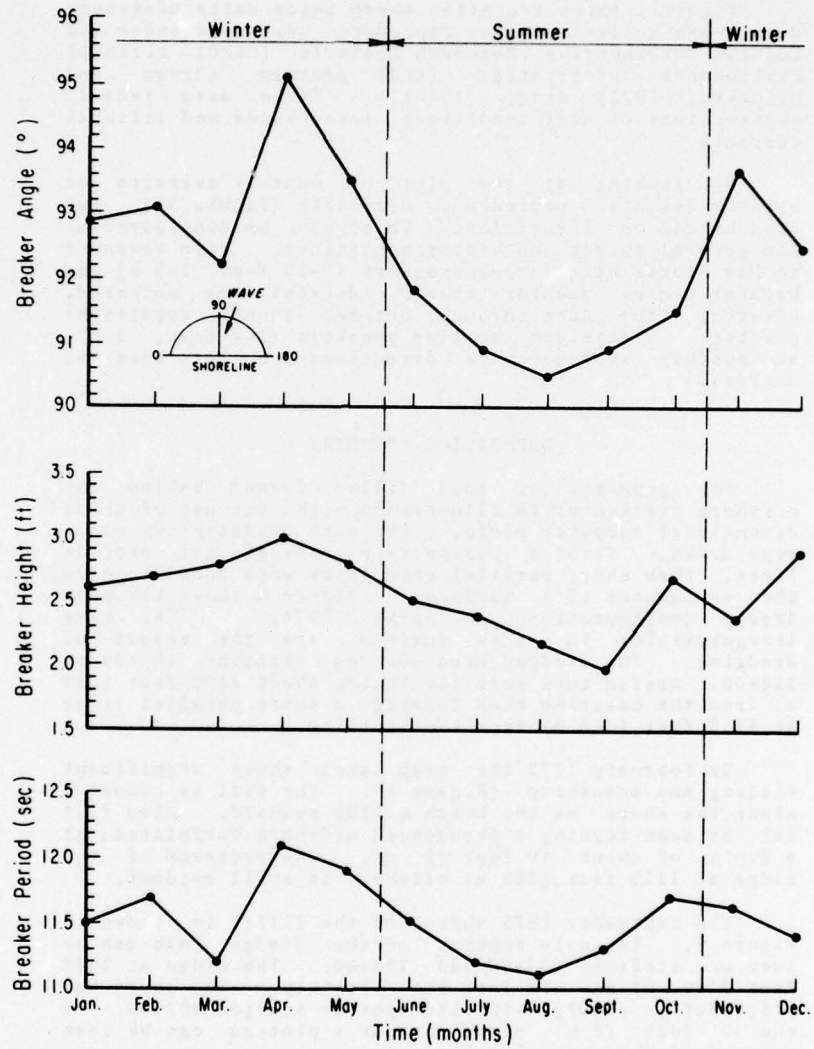


Figure 3. Monthly Average Littoral Observations

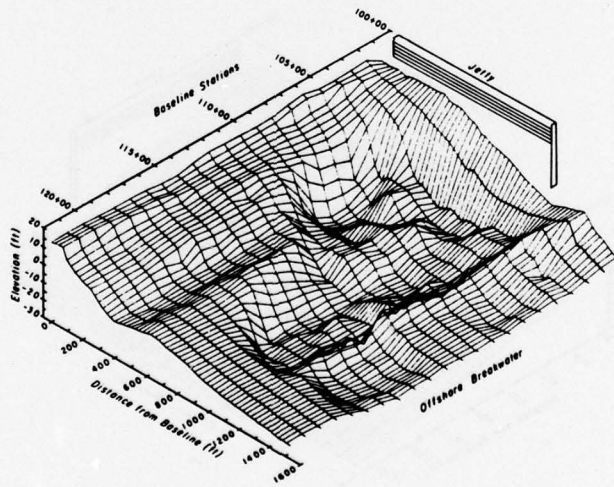
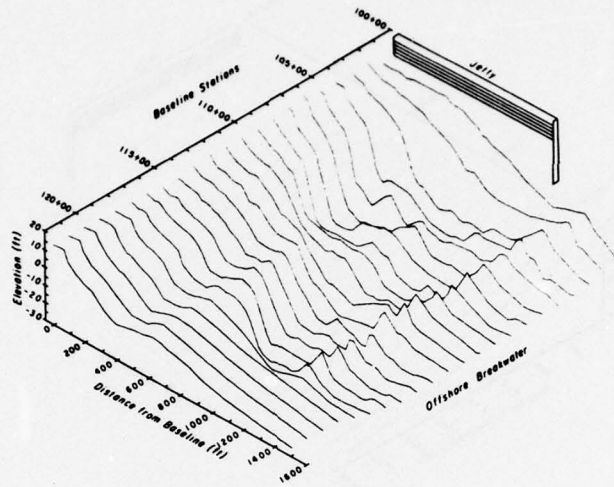


Figure 4. Sand Trap, 17 April 1974

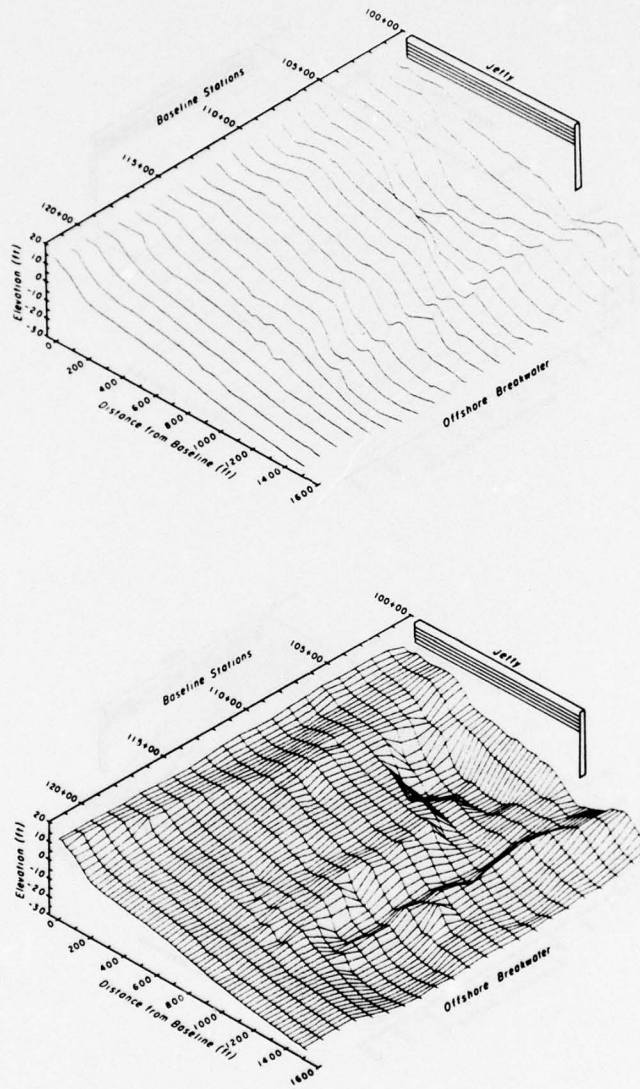


Figure 5. Sand Trap, 11 February 1975

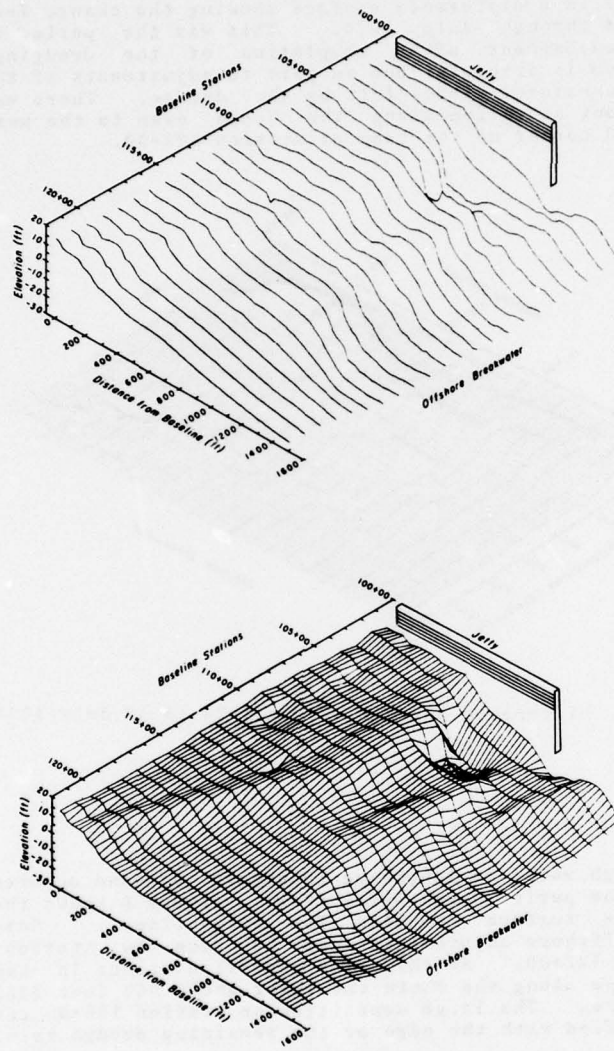


Figure 6. Sand Trap, 16 September 1975

Deposition can be examined by subtracting two surfaces and plotting the resulting difference surface. Figure 7 is a difference surface showing the change from May 1974 through July 1974. This was the period of initial adjustment after completion of the dredging. Deposition is irregular due in part to adjustments of the steep, unnatural slopes left by the dredge. There was significant accretion along the beach even to the most sheltered corner of the trap at station 103+00.

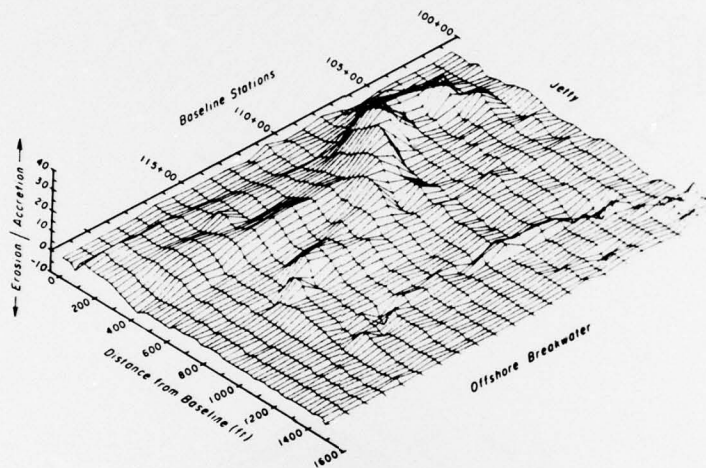


Figure 7. Difference Surface, 7 May 1974 to 30 July 1974

A high rate of longshore transport of sand occurred during the period March-April 1975. Figure 8 shows the difference surface computed for this time. Some onshore-offshore adjustments can be seen on stations 117+00 to 122+00. At this time accretion occurs in two bands, one along the shore the other about 900 feet (280 m) offshore. The large deposition on station 106+00 can be identified with the edge of the remaining dredge hole.

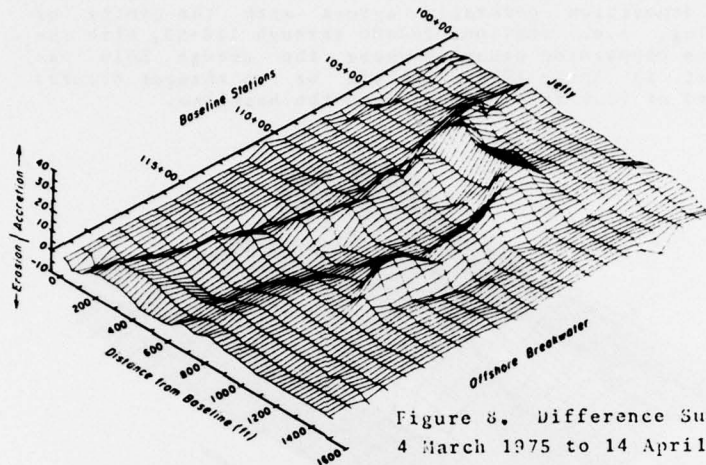


Figure 8. Difference Surface,  
4 March 1975 to 14 April 1975

In contrast, Figure 9 shows a period of low transport, August-September 1975. Here the only significant change occurred at the edge of the dredge hole on station 104+00. Part of this deposition is attributed to slumping into the hole as evident from adjacent erosion shown on station 105+00.

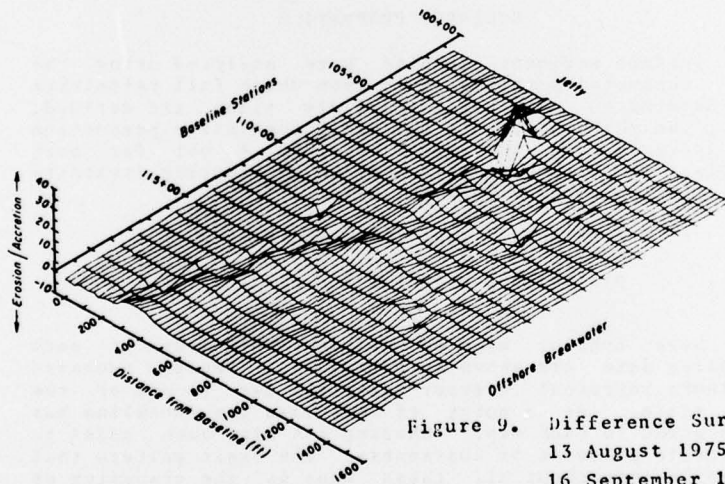


Figure 9. Difference Surface,  
13 August 1975 to  
16 September 1975

The total change experienced over the study period,

April 1974 to September 1975, is shown in Figure 10. This deposition generally agrees with the limits of dredging, i.e. stations 102+00 through 118+00, with the maximum deposition occurring where the dredge hole was deepest in April 1974. Little or no changes occurred seaward of 1200 feet (370 m) from the baseline.

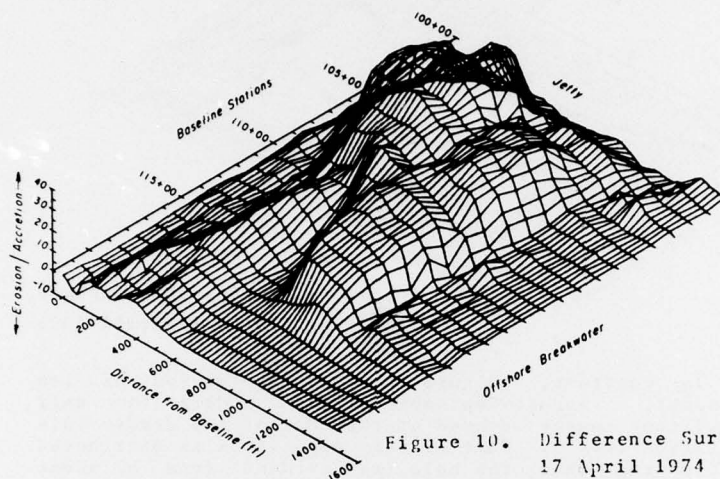


Figure 10. Difference Surface,  
17 April 1974 to  
16 September 1975

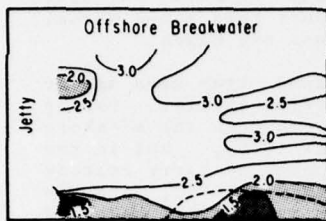
#### SEDIMENT PROPERTIES

Surface sediment samples were analyzed using the CERC automated settling tube from which fall velocities are determined and hence particle sizes are derived. Using the phi scale, a  $\frac{1}{2}$  phi class cumulative percentage is assigned over the range of -1 to 4 phi for each sample. From this analysis, means and sorting (standard deviation) are derived as follows:

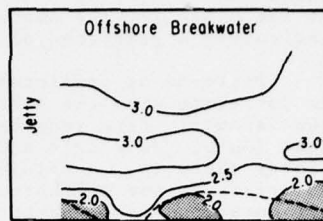
$$\text{phi mean} = (\text{phi } 16\% + \text{phi } 84\%)/2$$

$$\text{phi sorting} = (\text{phi } 84\% - \text{phi } 16\%)/2$$

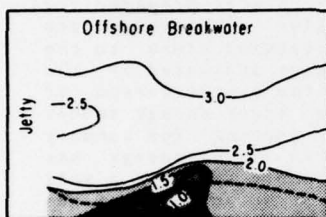
Seven contour maps of surface sample means at each sampling date are shown in Figure 11. Smaller numbered contours represent coarser materials due to use of the phi scale. As a point of reference the shoreline has been added to each map. Shading has also been added to delineate patterns of coarseness. The basic pattern that prevails throughout all these maps is the gradation of sediments from coarse onshore to fine offshore which is



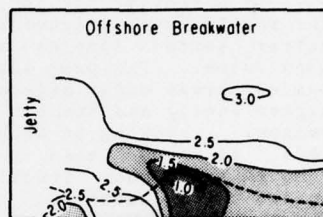
a. June 1974



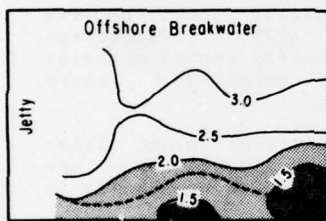
b. July 1974



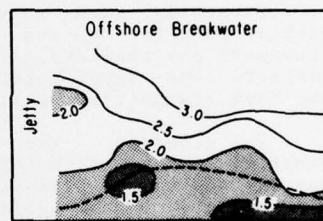
c. November 1974



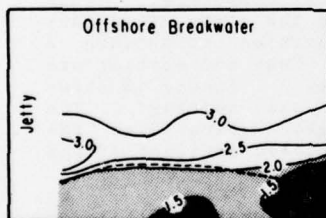
d. January 1975



e. March 1975



f. May 1975



g. September 1975

Notes:

Contours in Phi

Dashline denotes shoreline

Figure 11. Contours of Sample Means

typical of an open coastline. In the January 1975 map there is a deviation from this shore parallel pattern. At the bulge in the shore the contours turn shore normal indicating a gradation of sands across the beach.

Patterns of coarseness in the sand trap area appear to correlate with the seasons identified earlier. During the summer, fine sediments may be found in the offshore zone (June, July 1974 and September 1975), but in the winter there is sufficient wave energy to carry coarser materials to the offshore area (January, 1975), and the offshore zone is composed of coarser material as compared to the summer season.

In a similar fashion, sorting maps were prepared for the sample dates (Figure 12). Smaller numbers indicate better sorted samples with sizes ranging close to the mean value. The poor sorting patterns indicated by the shaded areas occur offshore during the winter season of higher energy and inshore during the lower energy summer season. Looking at both mean and sorting for January 1975, it can be seen the available wave energy has removed the finer fraction from inshore and left a well sorted coarse material. Also this type environment has carried some coarser materials offshore producing a poorly sorted deposit with mean of 2.5 to 3.0 phi.

Extremely high values of sorting shown for the onshore zone for May and September 1975, indicate two transport environments. This very poorly sorted material reflects the superposition of sands deposited by waves and that transported by wind action.

In general, the sorting patterns trend shore parallel which is indicative of beach processes. Any sorting due to the presence of the offshore breakwater is not reflected in the surface samples.

The seven samples at each point taken over the study period can be combined to form a composite. This composite was produced by weighting the class frequency distribution by the amount of deposition to produce a composite frequency distribution. Mean and sorting are then calculated from this composite. Figure 13 shows composite weighted maps of mean and sorting. The composite sortings are generally higher values than the individual episode. This is an expected artifact of the mathematics.

The composite mean map shows the general pattern of coarseness inshore grading to fine offshore. The composite sorting map shows that the deepest dredge hole at the outset of the study contains the poorest sorted material. This indicates that all materials which were

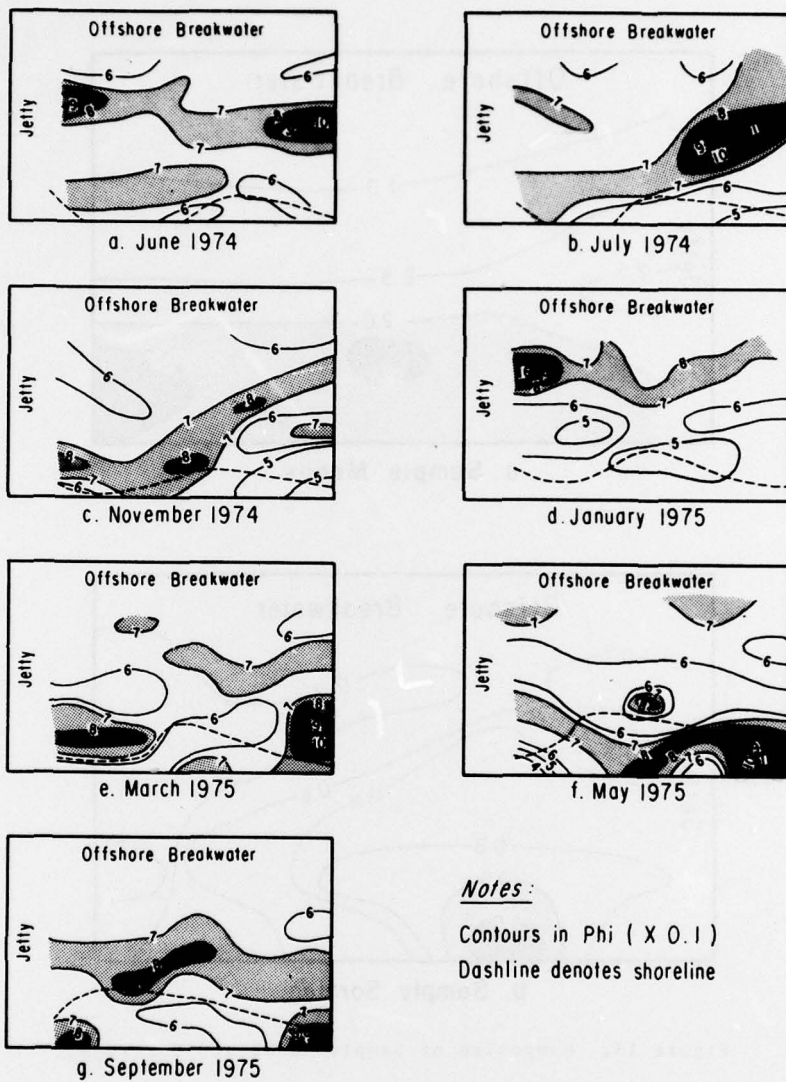


Figure 12. Contours of Sample Sortings

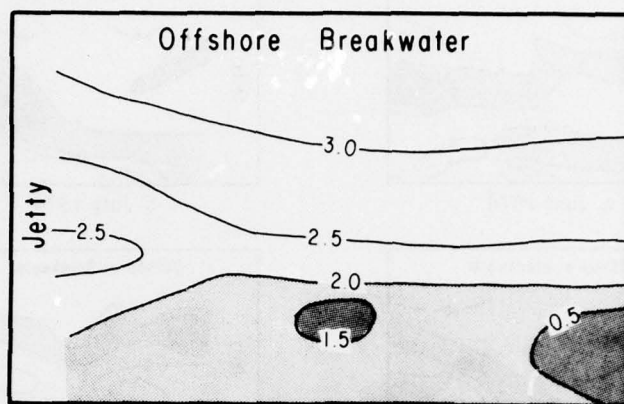
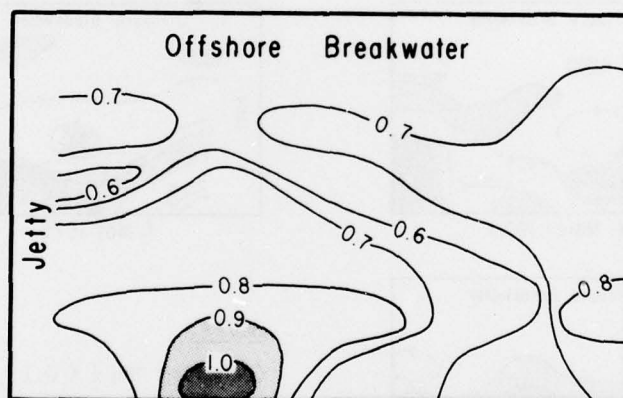
**a. Sample Means****b. Sample Sorting**

Figure 13. Composite of Sample Means and Sortings

brought to this point were deposited, whether they were fines brought in under low energy currents or coarse material transported by high energy waves.

In studying the composite mean values a linear trend is evident. Therefore, a best-fit linear surface was determined (83% sum of squares reduction) and is shown in Figure 14a. The residuals of this fit are shown in Figure 14b. This residual map indicates with negative values those areas where the material was coarser than the linear fit. The strong negative values shaded are indications that gradation is occurring across the trap as well as onshore-offshore.

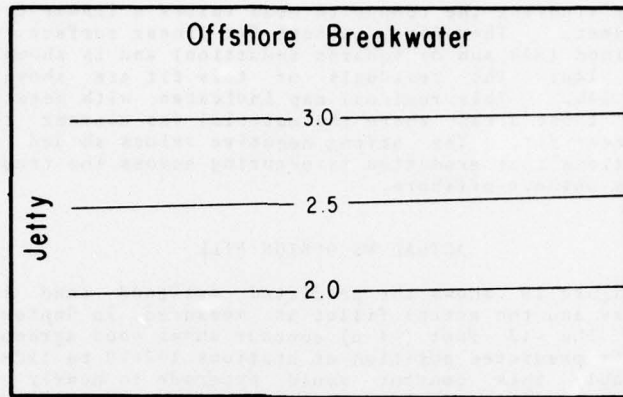
#### ACTUAL VS DESIGN FILL

Figure 15 shows the predicted designed sand trap geometry and the actual fillet as measured in September 1975. The -12 foot (-4 m) contour shows good agreement with its predicted position at stations 112+00 to 120+00. Presumably this contour would prograde to nearly the predicted position inside the trap as the trap continues to fill. The remnant of the dredge hole persists throughout the study and can be seen in the September 1975 contours, but was not predicted in the original design. As a result of this hole the -12 and -6 foot (-4 and -2 m) contours are closely spaced indicating a much steeper slope on the seaward side of the fillet.

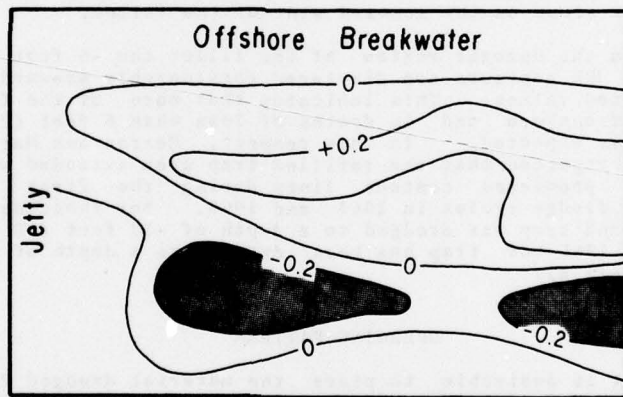
In the upcoast region of the fillet the -6 foot (-2 m) and MHW contours are displaced considerably seaward of predicted values. This indicates that more of the fill occurred onshore and in depths of less than 6 feet (2 m) than was expected. In this respect, Herron and Harris (1966) reported that the refilled trap area extended well beyond predicted contour lines during the first and second dredge cycles in 1963 and 1965. For those dates the sand trap was dredged to a depth of -30 feet (-9 m). Since 1965 the trap has been dredged to a depth of -35 feet (-11 m).

#### DREDGING PATTERN

It is desirable to place the material dredged from the Channel Islands sand trap on the feeder beach downcoast of Port Hueneme where it has the same textural properties as that of the natural nearshore material upcoast of the Channel Islands Harbor trap. The data analysis presented shows that the material contained in the sand trap area tends to be coarser from onshore to offshore and from upcoast to downcoast. This coarse to fine distribution, however, is certainly not well defined



a. Trend Surface



b. Residuals

Figure 14. Trend Surface and Residuals of Composite Means

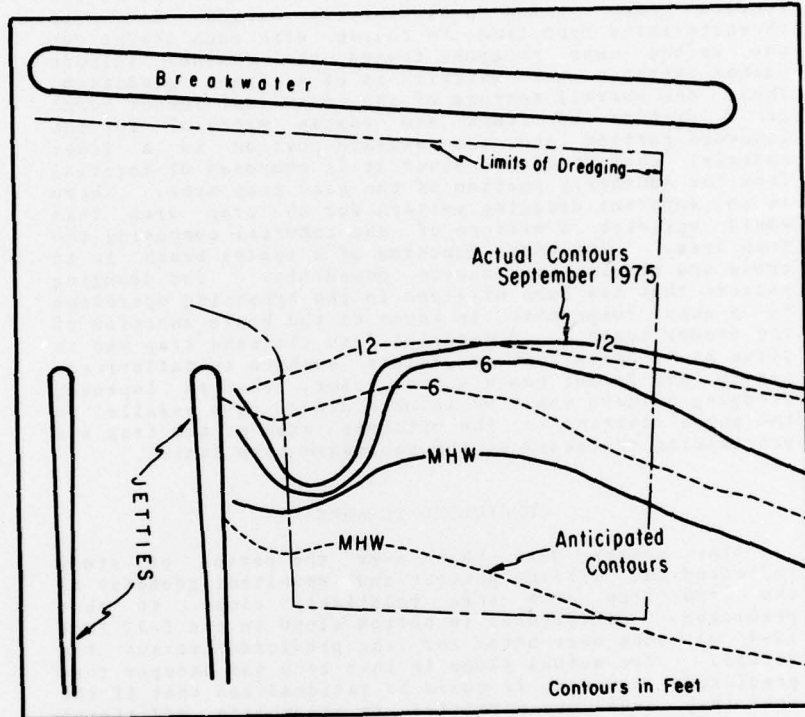


Figure 15. Actual and Predicted Sand Trap Fill

by the surface sand sample data. To achieve a well mixed bypass material for the feeder beach would require simultaneous dredging from the fine and coarse material areas. This, of course, is not possible with a single pipeline dredge. The pattern that has generally been utilized at the Channel Islands Harbor sand trap is to make a series of cuts normal to the shore with the cuts starting at the updrift side of the sand trap area. This dredging pattern results in placement of material in the feeder beach which progressively varies in size characteristic from fine to coarse with each dredge cut and as the cuts progress toward the Channel Islands Harbor entrance the material is of a finer gradation. Thus, the overall texture of the resultant feeder beach is a mixture of fines and coarse material for the landward portion and the seaward portion is a finer material characteristic since it is composed of material from the southerly portion of the sand trap area. There is no apparent dredging pattern for the trap area that would optimize a mixture of the material composing the trap area. The basic function of a feeder beach is to erode and nourish the shores downdrift. The dredging pattern that has been utilized in the bypassing operation is a good compromise in terms of the basic function of the feeder beach. If material from the sand trap was to serve as a beach fill to protect onshore installations, say in the feeder beach shore sector, then an improved dredging pattern would be to make dredge cuts parallel to the shore starting in the offshore area of the trap and progressing shoreward to the shoreward trap limits.

#### CONCLUDING REMARKS

The survey data taken over the period of study indicated the filling pattern and resultant geometry of the sand trap area were relatively close to that predicted. Differences in bottom slope in the 6-12 foot (2-4 m) zone were noted for the predicted versus the actual. The actual slope in this zone was steeper than predicted; however, it could be rationalized that if the sand trap area were permitted to accumulate additional material and adjust to the incident wave energies, the predicted and actual bottom slopes of the impoundment area would probably be in close agreement.

The design and physical features of the Channel Islands Harbor offshore breakwater and entrance jetty system would suggest that there should be a distinct pattern of coarse to fine composition for the littoral materials impounded in the trap area. The sand sample data do not clearly confirm this suggestion. The data indicates a trend of the pattern but the results were not as distinct as one would have predicted. One influencing

factor for this could be the high wave energy environment at the study site. Bottom cores are scheduled to be taken in the trap area prior to the next dredging (September, 1977) of the trap and these core data will be analyzed to further evaluate the material distribution pattern in the trap area.

## ACKNOWLEDGEMENTS

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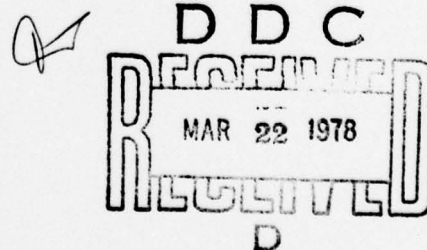
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