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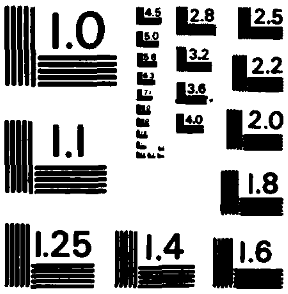

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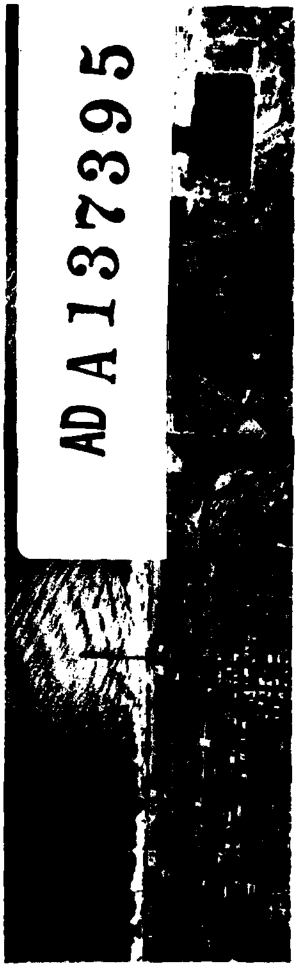

MISCELLANEOUS PAPER CERC-83-7

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SEDIMENT BUDGET CALCULATIONS OCEANSIDE, CALIFORNIA

by

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A sediment budget was constructed for the Oceanside, California, area to predict the effect on adjacent beaches of each of two alternative solutions--groins and nearshore breakwaters--to the Oceanside erosion problem. The pre-project sediment budget was modified and assumptions made about the performance of each proposed project.

The report discusses briefly each of the sources of data used in the budget, sets up the sediment balance equations, solves the equations under

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20. ABSTRACT (Concluded)

several sets of assumptions for conditions prevailing in the 1950-1972 time period, and then uses this pre-project sediment budget to evaluate the possible effects of the of the groin field and nearshore breakwater projects on adjacent beaches.

PREFACE

This report was prepared by the U. S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC) for the U. S. Army Engineer District, Los Angeles, to support their study of and evaluate alternative solutions to the erosion problem at Oceanside, California. Dr. J. Richard Weggel, former Chief, Coastal Structures and Evaluation Branch (CSEB), CERC, and Gene R. Clark, presently of CSEB, wrote the report under the general supervision of Neill E. Parker, former Chief, Engineering Development Division, and Thomas W. Richardson, present Chief, CSEB.

On 1 July 1983, CERC became part of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Dr. Robert W. Whalin.

Commander and Director of WES upon publication of this report was COL Tilford C. Creel, CE; Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per foot per year	0.0929029	cubic meters per meter per year
cubic feet per second	0.02831685	cubic meters per second
cubic yards per day	0.7645549	cubic meters per day
cubic yards per year	0.7645549	cubic meters per year
cubic yards per foot per year	2.5083822	cubic meters per meter per year
feet	0.3048	meters
miles (U. S. statute)	1.609347	kilometers

INTRODUCTION

The City of Oceanside beaches south of the Oceanside Harbor, California, have experienced severe erosion. The Corps of Engineers is investigating the possibility of abating the erosion by building erosion control structures such as groins or nearshore breakwaters in conjunction with beach fill and periodic nourishment. To better understand the coastal processes of the area and to assess the effect of any proposed structural solution on adjacent beaches, a sediment budget analysis has been made and is presented herein.

The sediment budget was constructed for the 22 year time period from October 1950 to February 1972 using beach survey data obtained by the Los Angeles District of the Corps of Engineers, a wave and longshore transport climate prepared by the Waterways Experiment Station of the Corps of Engineers, and streamflow-sediment discharge information developed by the U.S Geological Survey and the State of California. The sediment budget consists of a series of sediment balance equations for several littoral sub-cells within the overall Oceanside littoral cell which extends from Dana Point to La Jolla, California. Sediment gains and losses for each sub-cell are balanced against beach profile volume changes. Each sub-cell is coupled with adjacent sub-cells through the longshore transport; thus, the longshore sediment loss from one sub-cell becomes a sediment gain for an adjacent sub-cell. The accuracy of the sediment budget obviously depends on the quality of the data used to construct it and whether or not all important sediment gains and losses have been identified and considered. The budget presented here is thought to be an approximate description of the disposition of sediments in the Oceanside area for the 1950-1972 time period; however, a number of assumptions had to be made to solve the sediment balance equations. The assumptions made are believed to be reasonable; however, other justifiable assumptions could also have been made. The answer is, therefore, not the only answer that could be obtained.

One purpose of constructing the Oceanside sediment budget was to predict the effect on adjacent beaches of each of the two alternative solutions to the Oceanside erosion problem, groins and nearshore breakwaters. To do this, the pre-project sediment budget was modified and assumptions about the performance of each proposed project were made. In all, 16 sets of conditions involving different assumptions were investigated for both the groin field and nearshore breakwaters alternative. Again, other assumptions could have been made and other beach responses would have been predicted. The sediment budget should not be viewed as providing an absolute answer to what will happen, but rather as a tool to evaluate what might happen under various sets of assumptions.

This report discusses briefly each of the sources of data used in the budget, sets up the sediment balance equations, solves the equations under several sets of assumptions for conditions prevailing in the 1950-1972 time period, and then uses this pre-project sediment budget to evaluate the possible effect of the groin field and nearshore breakwater projects on adjacent beaches.

LONGSHORE TRANSPORT

The analysis of potential longshore transport made by Hales (1978) was used as the basis for estimating transport rates in the present study. Hales estimated the annual net and gross transports at three sites in the vicinity of Oceanside, California. The northernmost site was at Las Flores Creek, about 8 miles* northwest of Oceanside. The second site was at Oceanside itself, and the third site was at Encinitas, about 12 miles southeast of Oceanside. The gross transport rate at Las Flores was estimated to be 794,000 cu yd/yr of which 336,000 cu yd/yr (42.3%) were northward and 459,000 cu yd/yr (57.8%) were southward. At Oceanside the gross rate increased to 1,184,000 cu yd/yr with 541,000 cu yd/yr (45.7%) northward and 643,000 cu yd/yr (54.3%) southward. At Encinitas, Hales estimated the gross transport at 1,877,000 cu yd/yr. Of this, 856,000 cu yd/yr (45.6%) were northward and 1,021,000 cu yd/yr (54.4%) were southward. These transport estimates were made from hindcast wave data assuming that the constant of proportionality between the longshore component of wave energy flux and the potential longshore sand transport rate, k, is equal to about 0.39 if significant wave heights are used. This is equivalent to what is suggested in the "Shore Protection Manual" (U.S. Army Corps of Engineers, 1977). The relationship between wave parameters and longshore sand transport is given by,

$$I = 0.0088 k \rho_f g^{3/2} H_b^{5/2} \sin 2\alpha_b \qquad (1)$$

where I = potential submerged-weight longshore sand transport rate,
H_b = breaking wave height,
g = acceleration of gravity,
ρ_f = fluid density,
α_b = angle the breaking wave crest makes with the local shoreline, and

* A table for converting inch-pound units of measure to metric (SI) units is presented on page vi.

k = constant of proportionality between the submerged weight transport and the longshore component of wave energy flux.

Since the transport rate is needed in terms of the volume rate, the relationship,

$$Q = I/(\rho_s - \rho_f)ga \qquad (2)$$

is used, where ρ_f and g are as defined above, and

a = the fraction of solids of the in-situ bulk volume (1-porosity), and

ρ_s = the mass density of the sand.

If all these factors are substituted back into the preceding equation, equation (3) below results in which the specified dimensions of the various terms must be observed since the coefficient is no longer dimensionless. (Note that equations (1) and (2) are valid for any consistent system of units.)

$$Q = 7500\ (32.1)\ H_b{}^{5/2} \sin 2\alpha_b \qquad (3)$$

where Q is given in cu yd/yr and H_b is the significant wave height in feet.

For the present study, transport rates were also needed at points between Las Flores Creek and Encinitas. To estimate these values, an interpolation scheme was devised. The gross transport was assumed to vary with distance along the shoreline. This assumption can be rationalized by recognizing that the sheltering caused by the Channel Islands varies along the coast affording more protection to the more northerly coastal locations. A graph showing how the gross transport rate was assumed to vary with location is shown in figure 1 where the gross transport rate is given as a function of shoreline distance in miles measured southward from Las Flores Creek. The intermediate point is for Oceanside which is about 8.15 miles south of Las Flores Creek. The variation is approximately linear.

The proportioning of gross transport between northward and southward transport was assumed to depend on the local shoreline orientation. The shoreline orientation (measured in degrees west of north) was determined for the three sites for which Hales (1978) had determined transport rates. These shoreline orientations were then compared with the relative amounts of northward and southward transport expressed as a percentage of gross transport. These relationships are shown in figure 2. The figure shows little variation of the relative proportion of northward or southward transport with shoreline orientation. A 30 degree change in shoreline alignment results in only a 2% change in the amount of northward or southward transport. Shore-

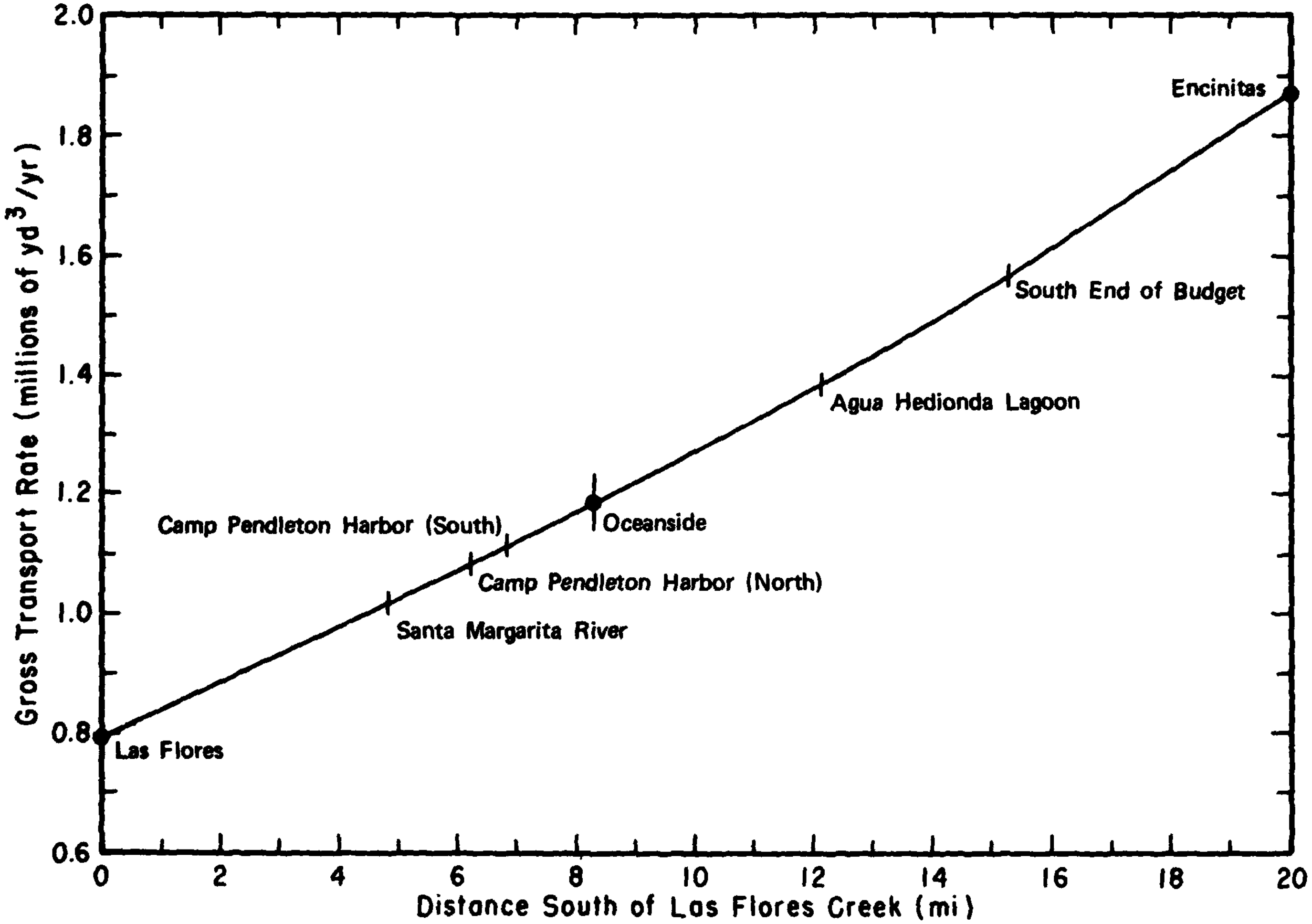


Figure 1 Assumed Variation of Gross Longshore Transport as a Function of Distance Along Shore

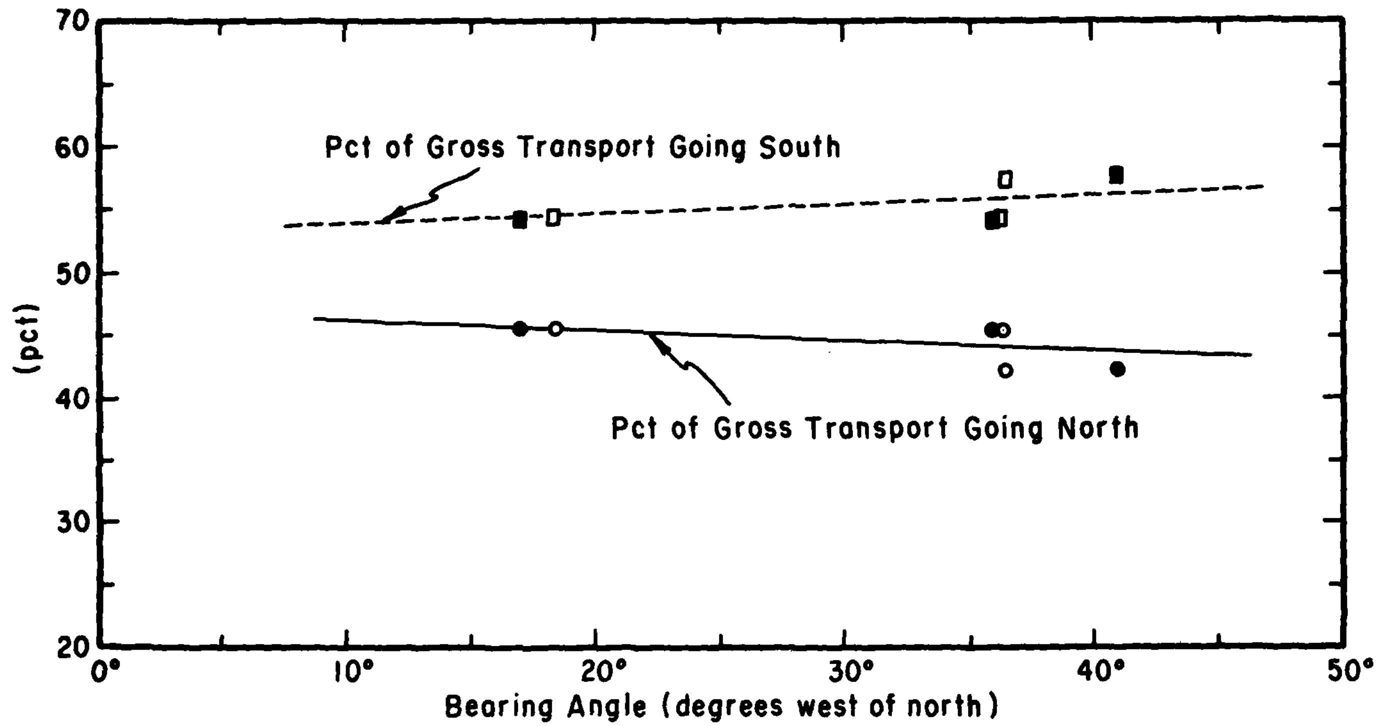


Figure 2 Distribution of Gross Longshore Transport Between Northward Transport and Southward Transport

line alignment is thus a minor factor in the relative transport rates in the Oceanside area.

Using the results of figures 1 and 2, Table 1 was developed for the transport rates at selected intermediate points between Las Flores Creek and Encinitas.

TABLE 1
Longshore Transport Rates at Various Points Between Las Flores Creek and Encinitas

Location	Distance from Las Flores (miles)	Shoreline Orient. (degrees W of N)	Gross Transp. (1000 cy/yr)	Northward Transport (1000 cy/yr)	Southward Transport (1000 cy/yr)
Las Flores	0	36.5	794.0	349.4	444.6(56.0%)
Santa Margarita R.	4.81	35.0	1015.0	448.6	566.4(55.8%)
Oceanside Harbor N	6.21	23.75	1080.0	486.0	594.0(55.0%)
Oceanside Harbor S	6.84	40.25	1110.0	487.3	622.7(56.1%)
Oceanside Beach	8.32	36.25	1184.0	522.1	661.9(55.9%)
Agua Hedionda N	12.13	30.50	1380.0	615.5	764.5(55.4%)
Agua Hedionda S	12.13	34.5	1380.0	610.0	770.0(55.8%)
Encinitas	20.08	18.5	1877.0	854.0	1023.0(54.5%)

OFFSHORE LOSSES

Sediment losses to the offshore were assumed to be the result of a relative rise of the sea level in the Oceanside area. The rate of sea level rise at La Jolla, California, presented by Hicks (1973) was assumed to apply to Oceanside as well. In recent years, this rate has been 0.0056 ft/yr.

Bruun's (1962) method was used to convert this rate of relative sea level rise to shoreline retreat rates and to volumes of sediment lost to the offshore. A number of profile lines were used to determine the closure depth. The estimated closure depth determined from these profile lines was about 40.0 ft. below MLLW. The resulting shoreline retreat rates were about 0.50 ft/yr and the rate of sediment loss to the offshore was estimated at about 27.0 cu ft/ft yr or about 1 cubic yard of sediment per foot of beach each year. The methodology used to establish these rates is presented in Weggel (1979). An example semi-logarithmic plot of the beach profile is shown in figure 3. For this example, the closure depth is at about -37.0 ft MLLW. The offshore loss rate of 1 cu yd/ft yr was assumed to apply to the entire shoreline reach between Las Flores Creek and Encinitas. Obviously this offshore loss rate is an estimate and will be affected by a number of things such as the distance of the closure depth contour from shore and any local variations in the relative change in sea level. If sea level data were available for a site closer to Oceanside, the 1 cu yd/ft yr figure might need to be revised; however, it is believed to be a reasonable estimate. This offshore loss is a small quantity when compared with the sediment quantities in transport alongshore; therefore, it does not significantly influence the outcome of the sediment budget.

WIND LOSSES AND GAINS

No attempt was made to estimate the amount of sediment gained or lost from the littoral zone by wind action. The configuration of much of the shoreline is such that wind will not remove sand from the beaches. In the northern reaches of the study area the beaches are backed by high bluffs which make removal of sediment by wind almost impossible. In addition, some of the beaches, particularly in the Oceanside area, are armored by cobbles. Wind losses and gains were, therefore, deemed negligible.

CONTRIBUTIONS BY RIVERS AND STREAMS

The contribution of sediment to the littoral zone by streams and rivers is a significant process in Southern California. The only important riverine sources of sediment for the California coast between Las Flores Creek and Encinitas between 1950 and 1972 were the Santa Margarita and San Luis Rey Rivers. Sediment contributions from other streams were assumed negligible. Streams that pass through large lagoons before discharging into the ocean contribute little sediment to the beaches since most of the sediment

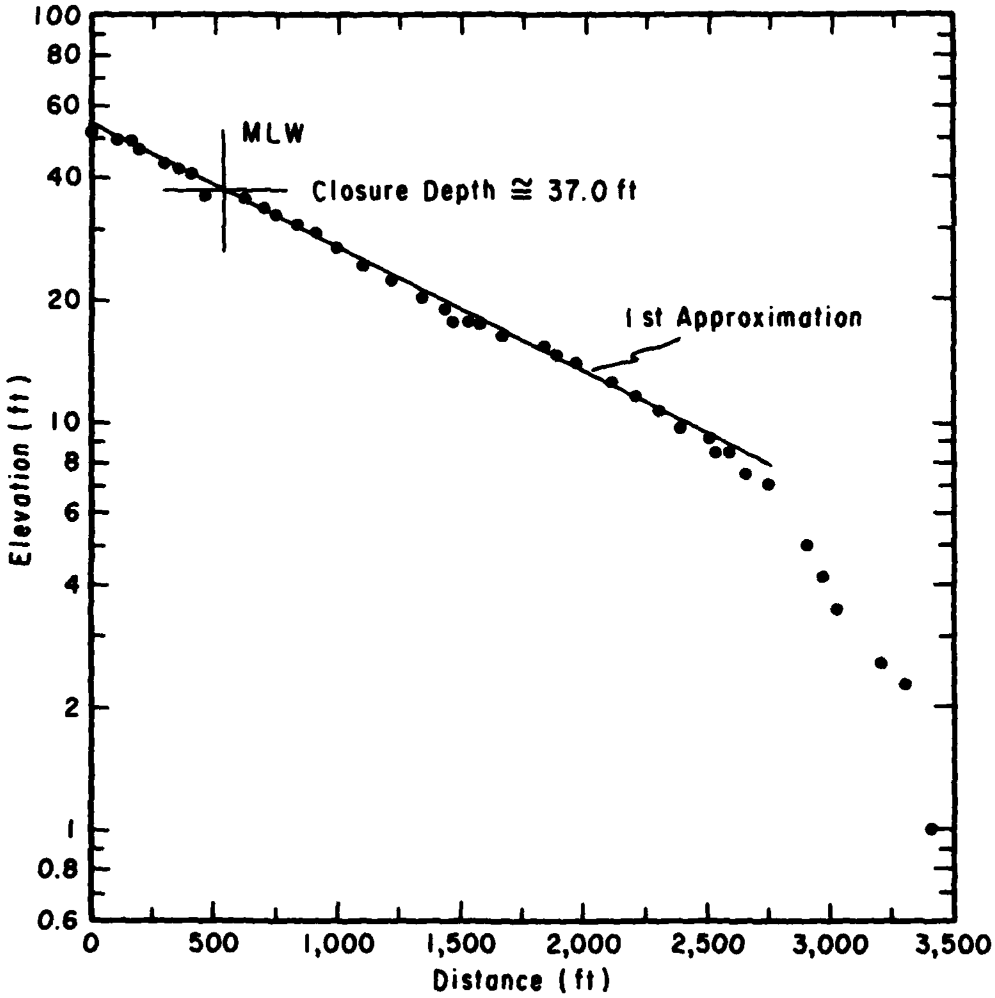


Figure 3 Example Semi-Logarithmic Plot of Oceanside Beach Profile

remains trapped in the lagoons. This was certainly the case during the 1950-1972 time period which was a particularly dry period. Streams such as Buena Vista Creek contributed little if any sediment during this period.

The quantity of sediment provided by the Santa Margarita and San Luis Rey Rivers was determined from daily streamflow data obtained by the U.S. Geological Survey and from a sediment discharge-streamflow rating curve presented by the State of California in a Department of Navigation and Ocean Development (DNOD) report (DNOD, 1977). The rating curves are shown in figure 4. Daily streamflow values were multiplied by the appropriate factor to determine sediment discharge. Annual sediment yields for each river are given in Table 2.

TABLE 2
Annual Sediment Yield
San Luis Rey and Santa Margarita Rivers

Year	San Luis Rey cu yd/yr	Santa Margarita cu yd/yr
1951	0	0
1952	1490	25230
1953	0	0
1954	0	103
1955	0	0
1956	0	0
1957	0	0
1958	8940	1170
1959	0	0
1960	0	0
1961	0	0
1962	0	0
1963	0	40
1964	0	0
1965	0	0
1966	228	1090
1967	35350	157
1968	65	0
1969	208890	62230
1970	1110	150
1971	0	0
1972(through Feb.)	4	0
Average Annual Yield	12000 cu yd/yr	4230 cu yd/yr

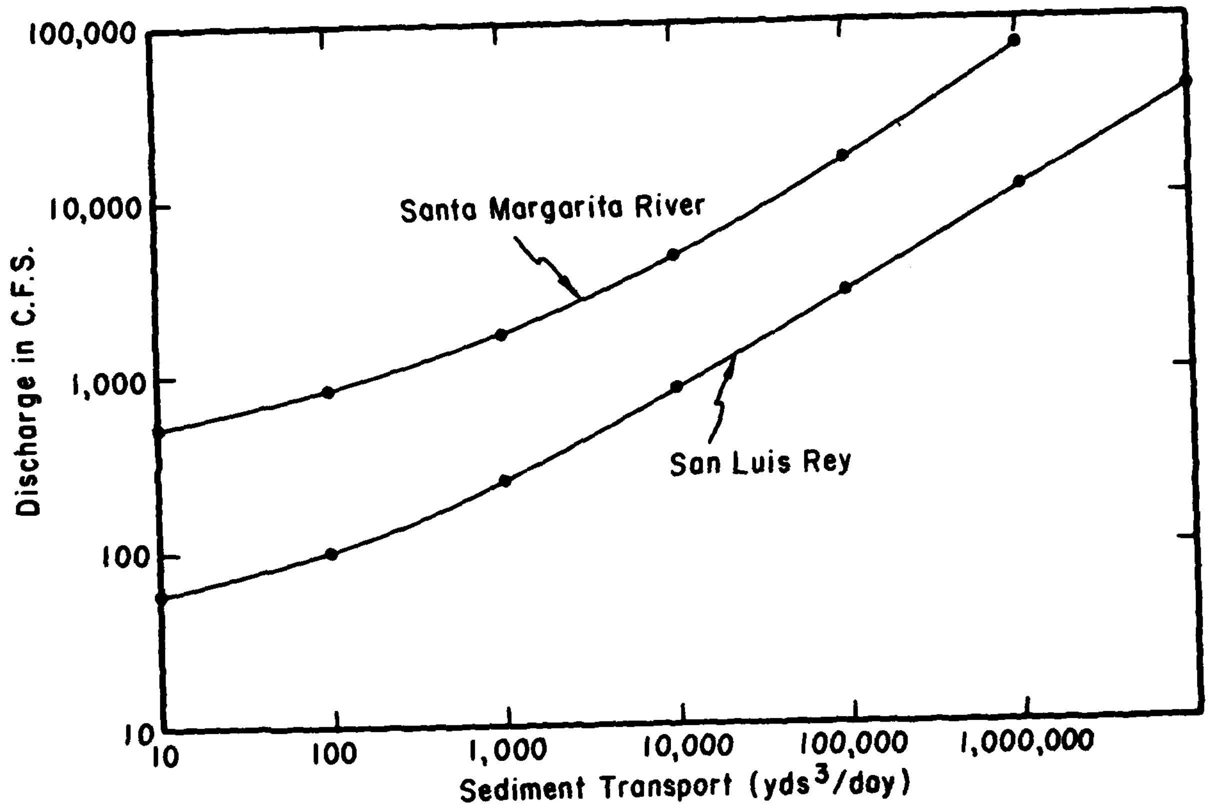


Figure 4 Sediment Yield vs. Discharge for Selected California Rivers and Creeks (State of California, 1977)

MAN-CAUSED CHANGES

Man's influence on the sediment budget of the Oceanside area is the result of dredging Ocanside Harbor and Agua Hedionda Lagoon and placing the dredged material on adjacent beaches. Primary sources for this data are the dredging records of the Los Angeles District for Oceanside Harbor and the records of the San Diego Gas and Electric Co. for Agua Hedionda Lagoon.

All of the sediment dredged from the Oceanside Harbor is placed on the beach at Oceanside. During the 1950 - 1972 time period, a total of 7,446,300 cu yd of material were removed from the harbor. Of this, 3,810,700 cu yd were from harbor expansion and 3,635,600 cu yd were maintenance dredging. The average annual beach nourishment was therefore 338,500 cu yd/yr while the annual rate at which the harbor traped or removed sediment from the littoral system was 165,300 cu yd/yr. This latter rate is based on the maintenance dredgeing while the former is based on the total amount of sand placed on the beach. The cumulative volume of sediment dredged from Oceanside is shown in figure 5.

The cumulative volume dredged from the Agua Hedionda Lagoon is shown in figure 6. Initially, 4,279,000 cu yd of sediment were dredged from the lagoon and distributed between the upcoast and downcoast beaches. Sediment was placed up to 3475 feet upcoast of the lagoon and 1970 feet downcoast. The volume distribution of sediment between the upcoast and downcoast beaches was assumed to be in proportion to the length of the beach over which it was distributed. Therefore, 2,732,000 cu yd of the initially dredged material were placed upcoast while 1,547,000 cu yd were placed downcoast. At present, most all of the maintenance dredging material taken from Agua Hedionda Lagoon is placed on the downdrift beach; however, in 1972 the maintenance dredging was split between the upcoast and downcoast beaches with roughly 95,000 cu yd being placed on each beach that year. In total, 2,827,000 cu yd of material were placed upcoast during the 1950 - 1972 time period and 3,339,000 cu yd were placed downcoast. The upcoast nourishment rate for the 21.33 years of the budget was, therefore, 132,540 cu yd/yr and the downcoast nourishment rate was 156,540 cu yd/yr.

EFFECTS OF STRUCTURES AND HARBORS

The influence of harbors on the movement of littoral materials is a major factor in the Oceanside sediment budget. It also represents that element of the sediment

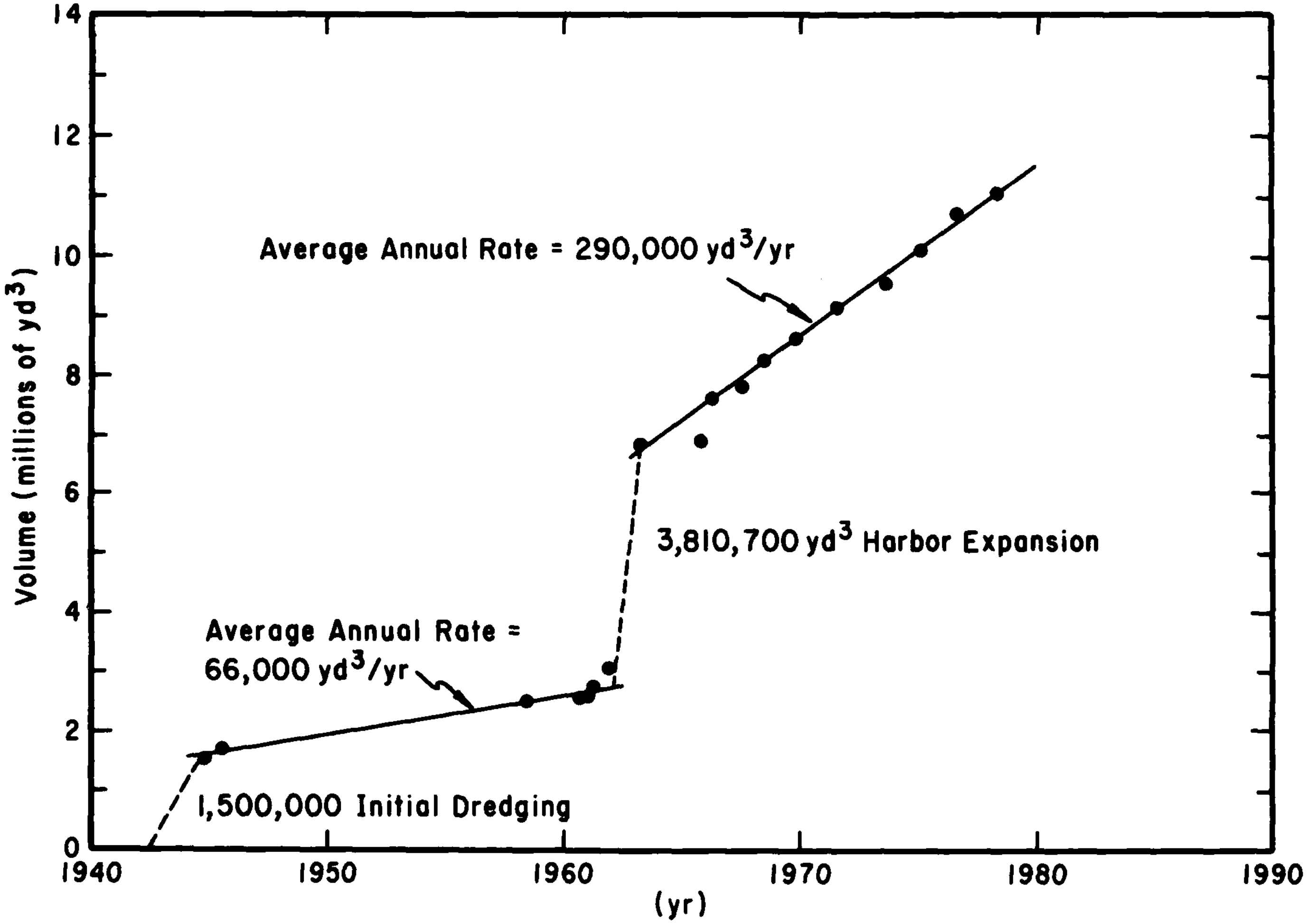


Figure 5 Cumulative Volume of Sediment Dredged from Oceanside Harbor vs. Time

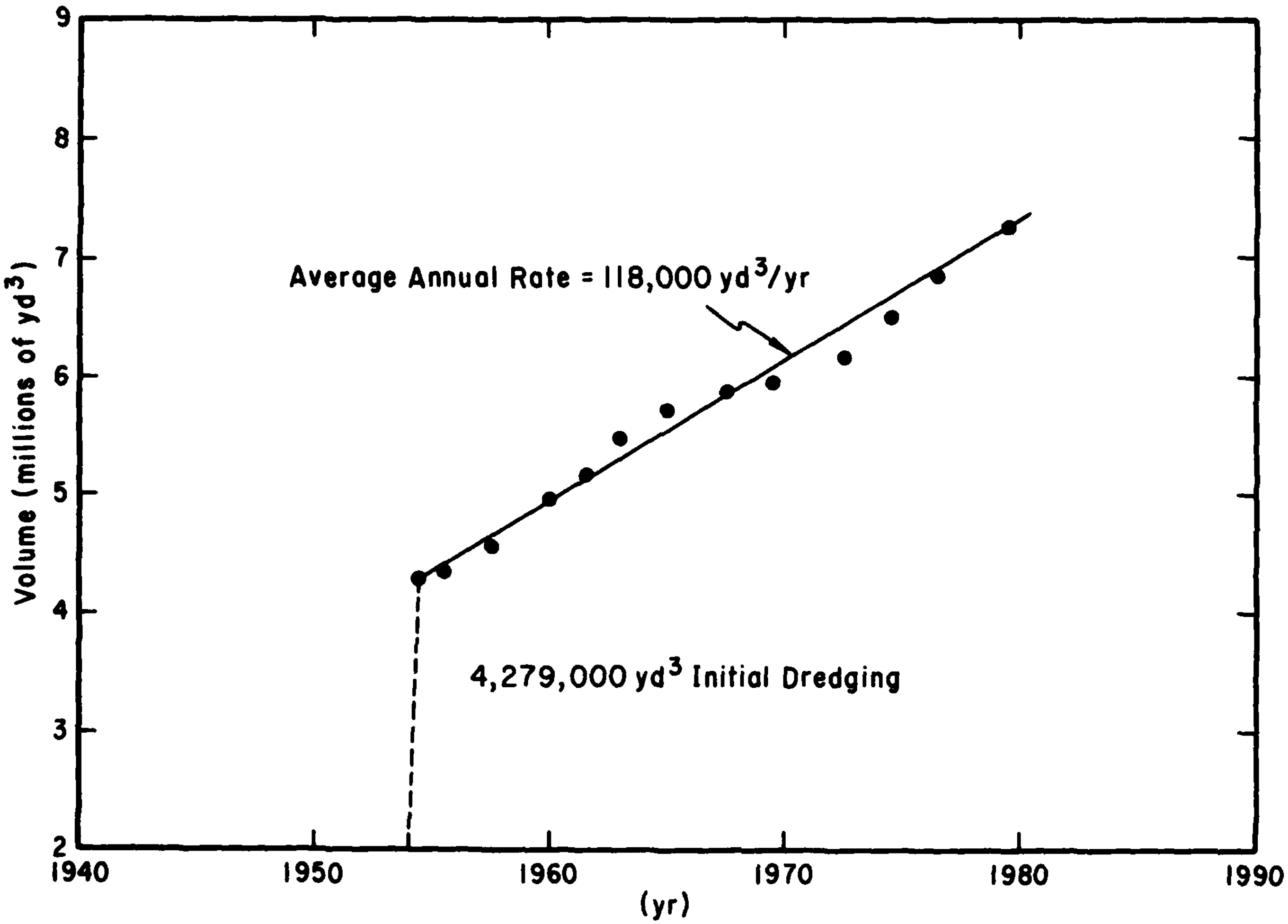


Figure 6 Cumulative Volume of Sediment Dredged from Agua Hedionda Lagoon vs. Time

budget about which the least is known. Data on sediment trapping is available from dredging records but little is known about the amount of sediment bypassing harbors. Bypassing quantities are therefore unknown quantities in the sediment budget equations and are sought in balancing the sediment budget. For example, sediment moving into a harbor from an adjacent beach is assumed driven by the longshore current and is, therefore, related to incident wave conditions; sediment moving from the harbor to an adjacent beach, however, is not only acted on by wave induced currents but by other hydraulic processes as well. Since these processes cannot be described in detail, their gross effect on the sediment transport process is determined by solving the sediment budget equations for the unknown bypassing quantities.

BEACH CHANGES

Beach changes within the Oceanside area were determined from data provided by the Los Angeles District. These data were obtained from beach profiles extending offshore to a water depth of approximately 50 feet. Profile lines extended from about 34,000 feet north of Oceanside Harbor to about 46,000 feet south of the harbor, covering about 15 miles of shoreline. These 15 miles constituted the region for which the sediment budget was constructed. The beach changes taking place within this area during the 1950 -1972 time frame are summarized in figures 7 and 8. Figure 7 is a mass curve presenting the cumulative volume change along the beach as one moves away from Oceanside Harbor (Station 0+00) either northward or southward. For the stations north of Station 0+00 a positive slope of the mass curve indicates erosion while a negative slope indicates accretion. Most of the area north of Oceanside Harbor shows accretion during the 1950 - 1972 time period. For the stations south of Station 0+00, negative slopes indicate erosion while positive slopes indicate accretion. With the exception of a small area in the vicinity of the south jetty at Oceanside, the beaches between Station 40+00 S and 280+00 S eroded between 1950 and 1972. The beaches between Stations 280+00 S and 500+00 S accreted during this period. The total amount of accretion or erosion occurring in a reach of shoreline is given by the difference in the ordinates of the mass curve at the end points of the reach.

Figure 8 shows the amount of erosion or accretion per unit length of beach occurring between 1950 and 1972. This curve is the slope of the preceding mass curve but corrected so that accretion is given as a positive value and erosion as a negative value. Large areas of accretion occurred near the north breakwater at Oceanside, near the

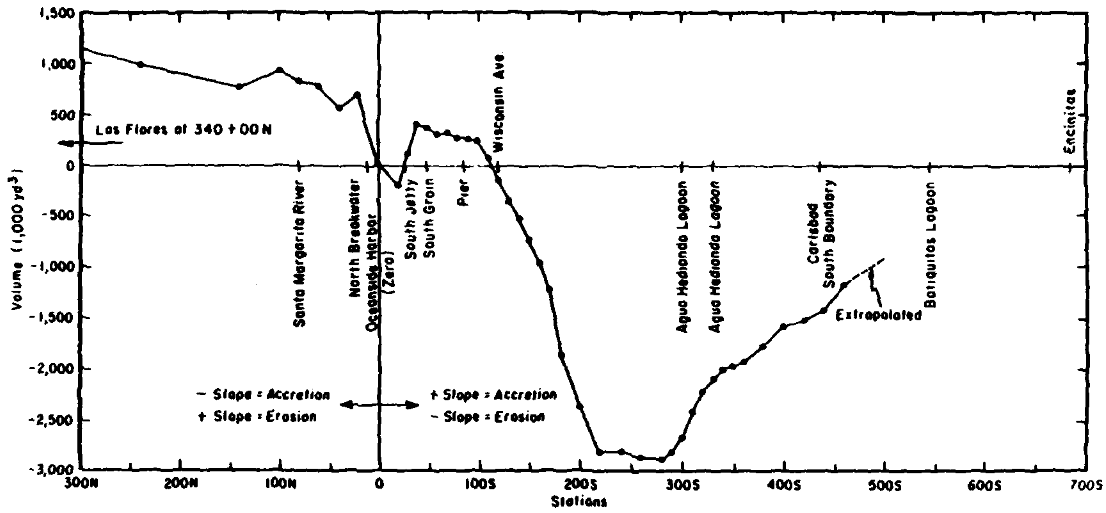


Figure 7 Cumulative Volume of Accretion or Erosion as a Function of Distance from Oceanside Harbor (mass curve)

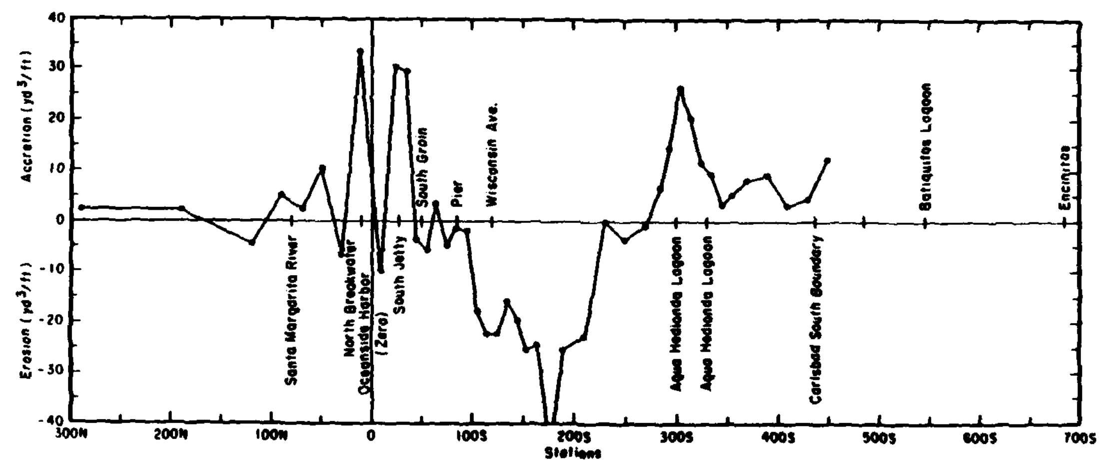


Figure 8 Erosion or Accretion per Unit Length of Beach as a Function of Distance Along Shore

south jetty, and in the vicinity of the Agua Hedionda Lagoon near Station 300+00 S. In general, the region south of Station 270+00 S accreted during the 1950 - 1972 time period.

LITTORAL CELLS - SEDIMENT BUDGET EQUATIONS

The 15 mile reach of shoreline from Las Flores Creek to a point just south of the southern boundary of the City of Carlsbad was divided into five sub-cells. A sediment balance equation was then developed for each sub-cell. The five sub-cells are depicted in figures 9 through 13. Sub-cell 1-2 covers the six mile reach from Las Flores Creek to the north side of Oceanside Harbor as shown in figure 9. At the north end of the cell sand is carried into and out of the cell by wave-caused longshore transport. The quantity in transport was determined from the data developed by Hales (1978). In other words, QN1 and QS1 in figure 9 were related to incident wave conditions. In fact, two sediment budgets were constructed termed Case 1 and Case 2. The gross transport rates calculated by Hales are believed to be high estimates because sea and swell were tabulated separately and the sum of their probabilities of occurrence total 136%. Since sea and swell can occur sumultaneously and they may interact to either increase or decrease transport, the true gross transport is not known. Therefore, a sediment budget was constructed for both the values of transport given by Hales (Case 1) and for transport rates 0.735 times those given by Hales (Case 2), i.e. 1/1.36=0.735.

The sediment balance equation for sub-cell 1-2 (Figure 9) is given by,

$$QS1 + Qsmr - QN1 - QS2 - B2 - Qoff1\text{-}2 = V1\text{-}2/t \quad (4)$$

where QS1 = average annual southward wave-caused longshore sediment transport rate at Las Flores Creek,

QN1 = average annual northward wave-caused longshore sediment transport rate at Las Flores Creek,

Qsmr = average annual sediment contribution to the coast by the Santa Margarita River during the 1950 - 1972 time period,

QS2 = average annual southward wave-caused longshore sediment transport rate at the north side of Oceanside Harbor,

B2 = average annual rate of sediment bypassing at the north end of Oceanside Harbor; southward is assumed positive (unknown),

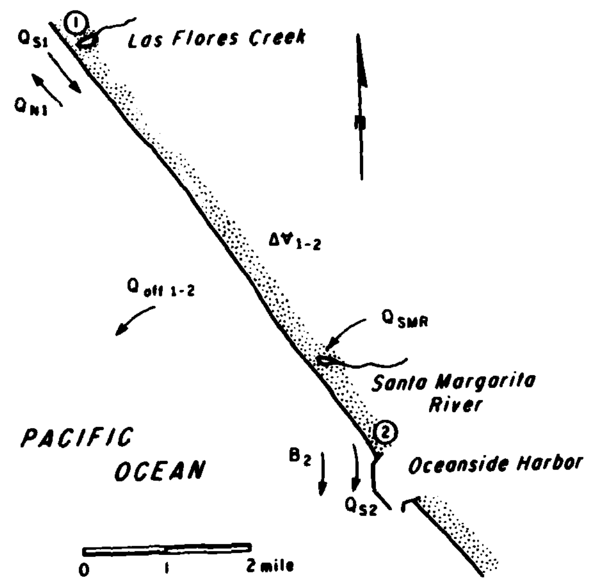


Figure 9   Oceanside Sub-Cell 1-2, Las Flores Creek to Oceanside Harbor

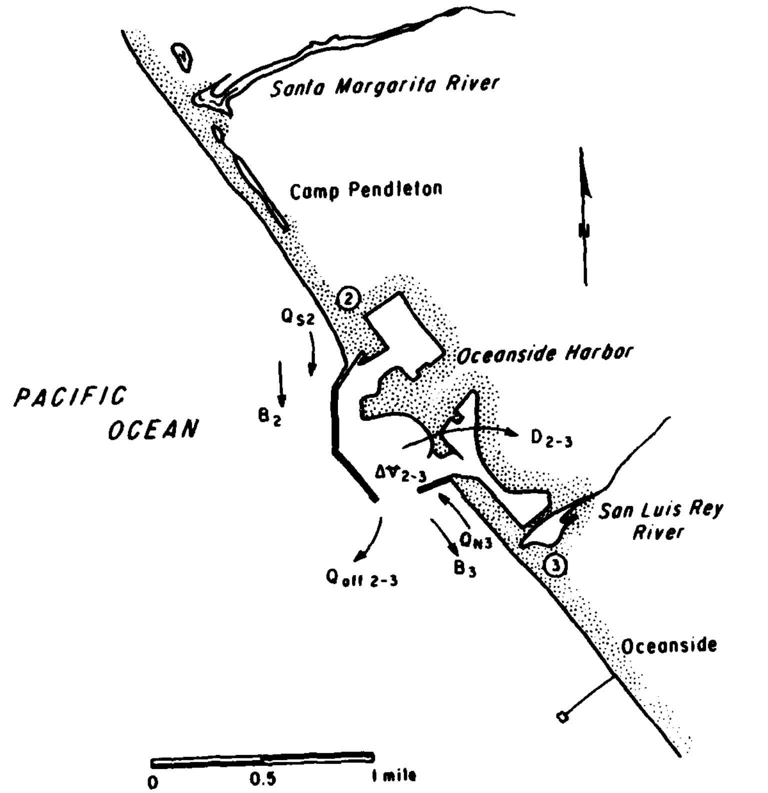


Figure 10   Oceanside Sub-Cell 2-3, Oceanside Harbor

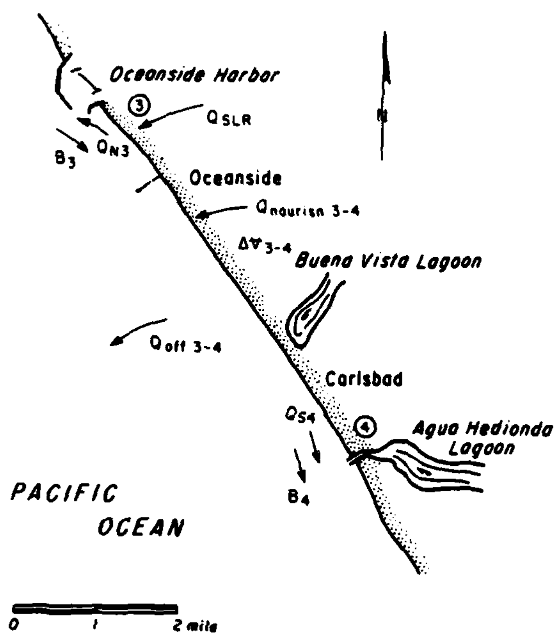


Figure 11 Oceanside Sub-Cell 3-4, Oceanside Harbor to Agua Hedionda Lagoon

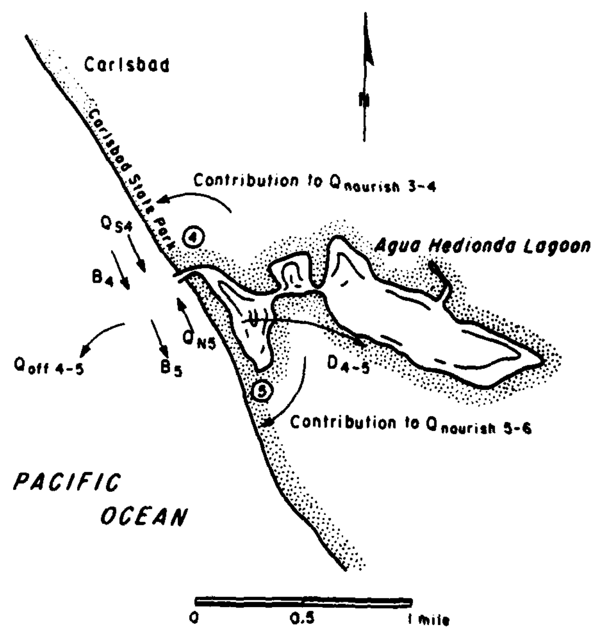


Figure 12 Oceanside Sub-Cell 4-5, Agua Hedionda Lagoon

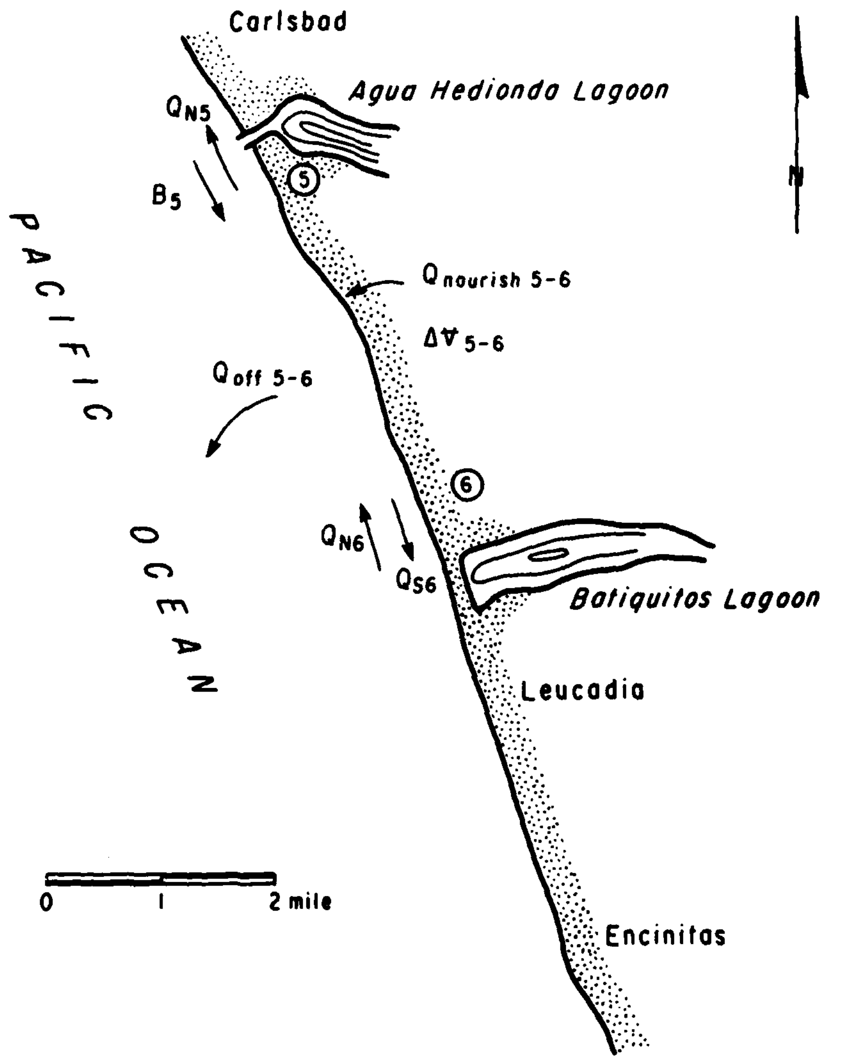


Figure 13 Oceanside Sub-Cell 5-6, Agua Hedionda Lagoon to Southern Boundary of the City of Carlsbad

Qoff1-2 = estimate of the average annual amount of sediment lost to the offshore due to relative change in sea level,
V1-2 = total volume change of sediment over beach profiles between Las Flores Creek and the Oceanside Harbor, and
t = the time period of the sediment budget; in this case 21.33 years.

In equation (4), B2 is the only unknown if the longshore transport rates are known. The other variables can be determined as discussed in preceding sections.

The sediment contributions and losses to sub-cell 2-3, Oceanside Harbor, are shown in figure 10. Contributions to the sub-cell include QS2 and the unknown B2 which couple sub-cell 2-3 with sub-cell 1-2. QN3, the northward transport at the south end of the harbor also contributes sediment to the harbor sub-cell. Losses from the sub-cell include maintenance dredging that removes sediment (D2-3)originating in the littoral zone from the harbor. (The material dredged from the harbor during its expansion is not included.) The unknown bypassing quantity, B3, is also a loss from sub-cell 2-3. An unknown offshore loss, Qoff2-3, is assumed to be caused by the harbor structures deflecting sediment offshore. The sediment balance equation for sub-cell 2-3 is, therefore, given by,

$$QS2 + B2 + QN3 - B3 - Qoff2\text{-}3 - D2\text{-}3 = V2\text{-}3/t \qquad (5)$$

where the variables are as defined above.

Sub-cell 3-4 is the beach between Oceanside Harbor and Agua Hedionda Lagoon (figure 11); this reach of beach includes the site of the proposed shore protection/beach erosion control project for Oceanside Beach. Contributions of sediment to this reach include the unknown Oceanside Harbor bypassing quantity, B3, and the contribution by the San Luis Rey River, Qslr. This reach of beach has also been periodically nourished, primarily from material dredged from Oceanside Harbor (both maintenance dredging and harbor expansion dredging) and from the Agua Hedionda Lagoon. Losses include the average annual southward longshore transport at Agua Hedionda Lagoon, QS4; the unknown bypassing quantity at Agua Hedionda Lagoon, B4; and the offshore loss due to a relative rise in sea level, Qoff3-4. The sediment balance equation for this sub-cell becomes,

$$B3 + Qslr + Qnourish3\text{-}4 - QS4 - QN3 - B4 - Qoff3\text{-}4 = V3\text{-}4/t \qquad (6)$$

in which, Qnourish3-4 = the combined quantity of beach nourishment to the sub-cell from Oceanside Harbor and Agua

Hedionda Lagoon. The other variables are as defined above.

Sub-cell 4-5 is the Agua Hedionda Lagoon itself. See figure 12. Contributions of sediment are by longshore transport from both the north and south, QS4 and QN5 respectively. The bypassing quantity, B4, contributes to the sub-cell while B5 removes sediment from the sub-cell. Other losses include an offshore loss, Qoff4-5, and material dredged from the lagoon, D4-5. This latter material was distributed between the beaches north and south of the lagoon and becomes a part of the nourishment for these adjacent sub-cell beaches and thus is not lost from the littoral system. The sediment balance equation for the Agua Hedionda Lagoon sub-cell is given by,

$$QS4 + B4 + QN5 - B5 - D4\text{-}5 - Qoff4\text{-}5 = V4\text{-}5/t \qquad (7)$$

where the variables are as defined above.

The last and southernmost sub-cell extends from Agua Hedionda Lagoon southward to approximately the southern boundary of the City of Carlsbad (figure 13). Sediment contributions are through bypassing around Agua Hedionda Lagoon, B5; nourishment by material dredged from the lagoon, Qnourish5-6; and longshore transport from the south end of the reach, QN6. Losses are to the offshore due to relative sea level rise, Qoff5-6, and longshore transport out of both the north boundary and south boundary of the cell, QN5 and QS6 respectively. The sediment balance equation for this sub-cell is given by,

$$B5 + Qnourish5\text{-}6 + QN6 - QN5 - QS6 - Qoff5\text{-}6 = V5\text{-}6/t \qquad (8)$$

where the variables are as defined previously.

SOLUTION OF SEDIMENT BUDGET EQUATIONS

Equations (4) through (8) define a set of simultaneous linear equations describing the distribution of sediment between the five sub-cells. In all, five quantities can be assumed as unknown and solved for in the equations. The remaining variables must be given, or reasonable assumptions must be made regarding their value. Four of the unknowns are the bypassing terms, B2, B3, B4 and B5.
A fifth unknown can be assumed to be the quantity of material deflected offshore by the Oceanside Harbor structures, Qoff2-3. Alternatively, the coefficient of proportionality relating longshore transport with wave energy flux can be assumed unknown if an assumption regarding the magnitude of Qoff2-3 is made.

For the present analysis, three sets of assumptions were made about the unknown variables. The sediment budget was then evaluated for each set of assumptions. These three sets of assumptions are referred to as Cases 1 through 3.

Case 1 assumed that the longshore transport rates given by Hales (1978) are correct and that the five unknowns in the equations are B2, B3, B4, B5 and Qoff2-3. Under this set of conditions, equations (4) through (8) become respectively,

$$444.6 + 4.23 - 349.4 - 594.0 - B2 - 32.6 = 36.39 \quad (9)$$

$$594.0 + B2 + 487.3 - B3 - Qoff2\text{-}3 - 165.3 = 23.21 \quad (10)$$

$$B3 + 12.0 + 471.04 - 764.5 - 487.3 - B4 - 27.5 = -125.74 \quad (11)$$

$$764.5 + B4 + 615.5 - B5 - 88.48 - 3.0 = 27.22 \quad (12)$$

$$B5 + 156.54 + 710.5 - 615.5 - 854.5 - 15.5 = 51.64 \quad (13)$$

where the quantities are given in thousands of cubic yards per year and each term corresponds with the terms in equations (4) through (8), i.e. QS1=444.6; Qsmr=4.23; QN1=349.4; QS2=594.0; Qoff1-2=32.6 and V1-2/t=36.39. Upon simplification, equations (9) through (13) reduce to,

$$B2 = -563.56 \quad (14)$$

$$B2 - B3 - Qoff2\text{-}3 = -892.79 \quad (15)$$

$$B3 - B4 = 670.5 \quad (16)$$

$$B4 - B5 = -1261.3 \quad (17)$$

$$B5 = 670.1 \quad (18)$$

which upon solution give,

$$B2 = -563.56$$

$$B3 = 79.3$$

$$B4 = -591.2$$

$$B5 = 670.1$$

and, $$Qoff = 249.93$$

The results are presented graphically in figures 14 through 18.

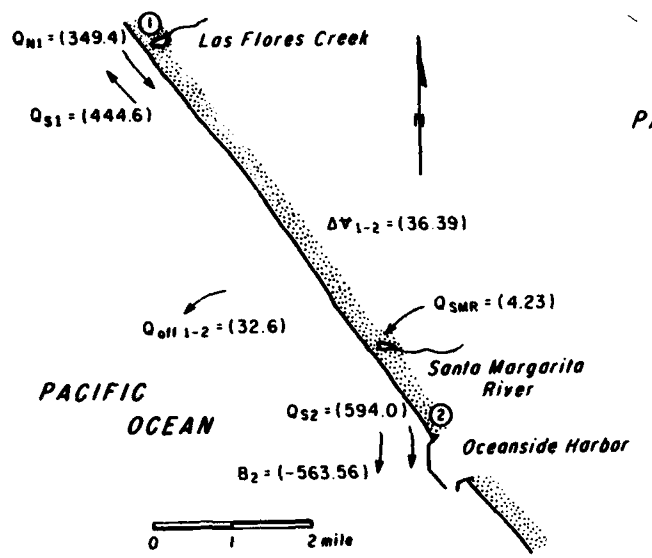


Figure 14 Case 1 Sediment Budget, Sub-Cell 1-2

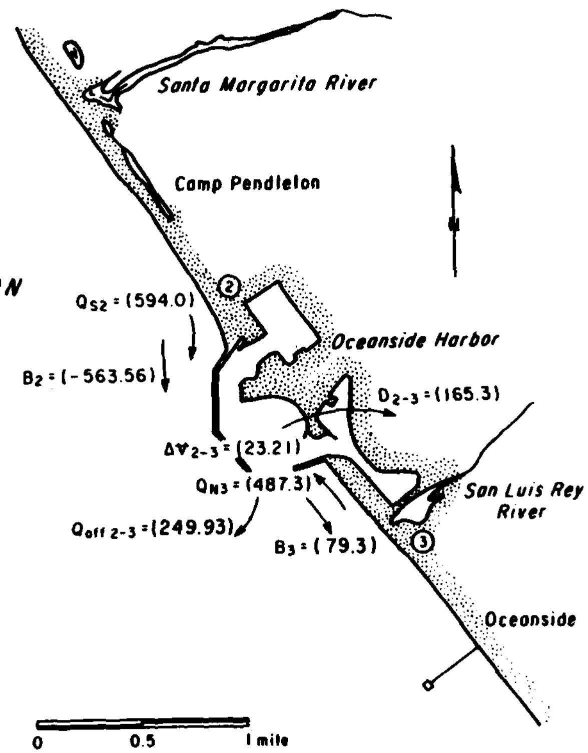


Figure 15 Case 1 Sediment Budget, Sub-Cell 2-3

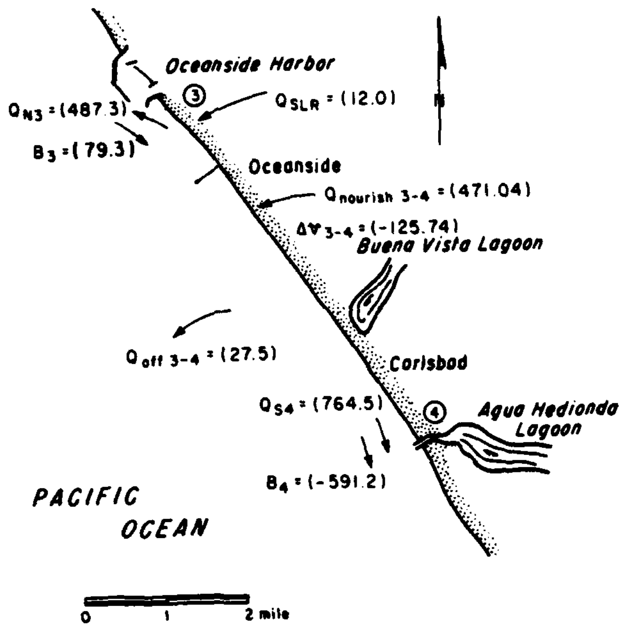


Figure 16 Case 1 Sediment Budget, Sub-Cell 3-4

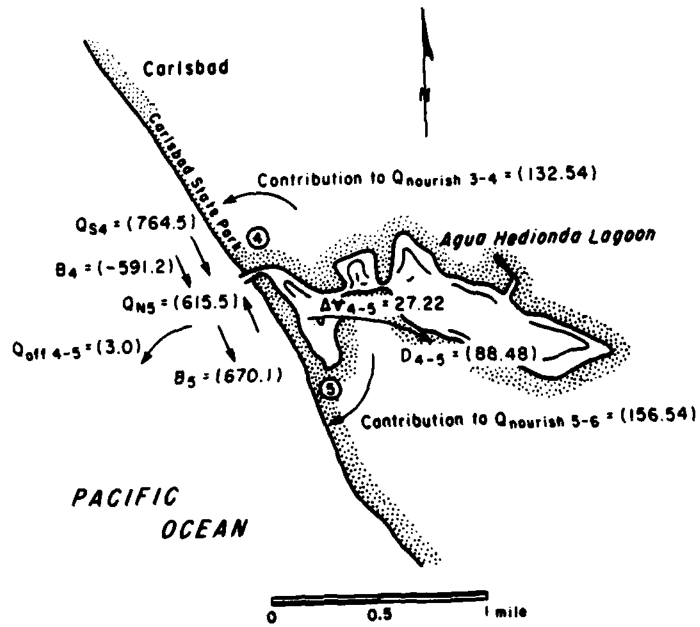


Figure 17 Case 1 Sediment Budget, Sub-Cell 4-5

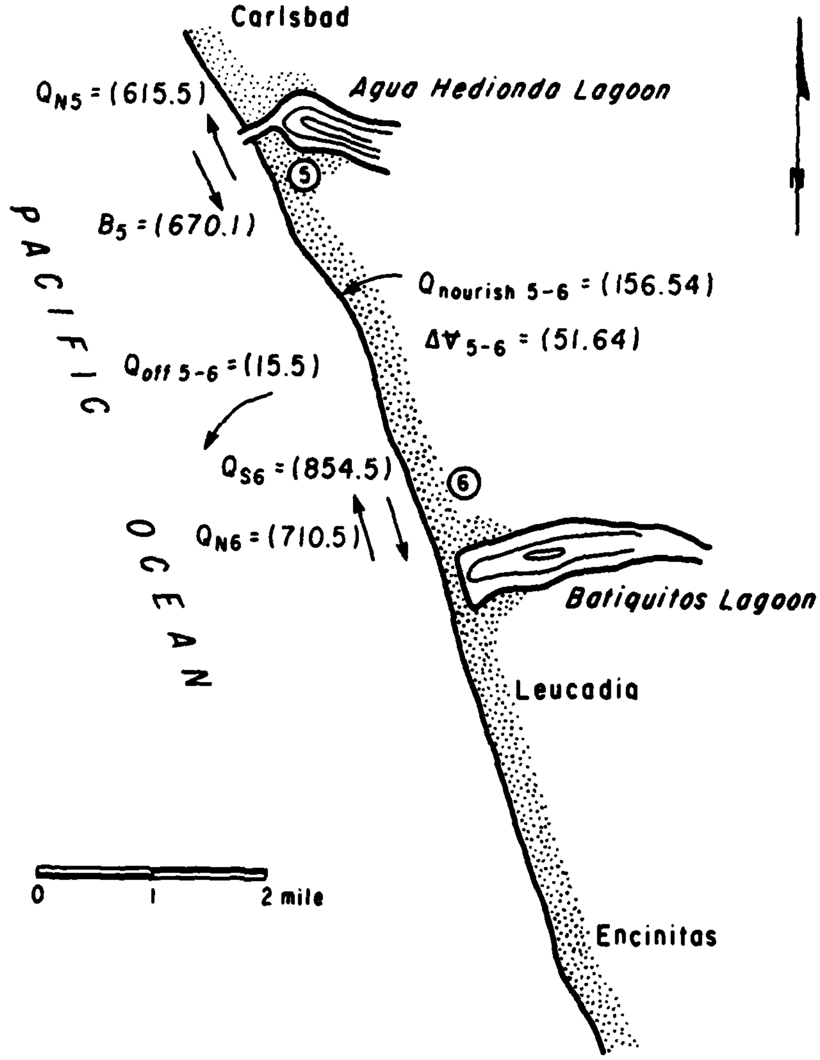


Figure 18 Case 1 Sediment Budget, Sub-Cell 5-6

Case 2 assumed that Hales' longshore transport rates were too large because of his separate tabulation of sea and swell. The longshore transport rates were reduced by a factor of 1/1.36 or 0.735 since his probabilities of occurrence total to 136%. Under this assumption, equations (4) through (8) become,

$$326.78 + 4.23 - 256.81 - 436.59 - B2 - 32.6 = 36.39 \quad (19)$$

$$436.59 + B2 + 358.17 - B3 - Qoff2\text{-}3 - 165.3 = 23.21 \quad (20)$$

$$B3 + 12 + 471.04 - 561.91 - 358.17 - B4 - 27.5 = -125.74 \quad (21)$$

$$561.91 + B4 + 452.39 - B5 - 88.48 - 3.0 = 27.22 \quad (22)$$

$$B5 + 156.54 + 522.22 - 452.39 - 628.06 - 15.5 = 51.64 \quad (23)$$

where the equations can be compared term by term with equations (4) through (8). Solution of these equations gives,

$$B2 = -431.38$$

$$B3 = -88.0$$

$$B4 = -426.77$$

$$B5 = 468.83$$

$$Qoff2\text{-}3 = 262.87$$

The results of the analysis for Case 2 is shown graphically in figures 19 through 23.

Case 3 assumed that Qoff2-3 = 0 and that the longshore transport rates were in proportion to those presented by Hales (1978) but that they were each multiplied by an unknown factor k. The factor k was then found by solving the sediment balance equations. Under these assumptions, k = 10.48, indicating that longshore transport rates must be more than 10 times greater than those given by Hales to balance the sediment budget. Since Hales's estimates of longshore transport are thought to be high, further increases in transport rates seem unrealistic. Therefore, no further discussion of Case 3 is included herein and the assumption that Qoff2-3 = 0 must be rejected.

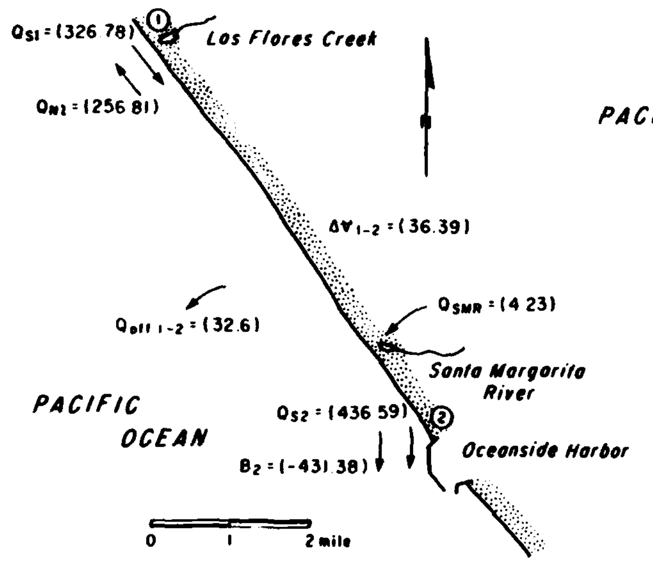


Figure 19 Case 2 Sediment Budget, Sub-Cell 1-2

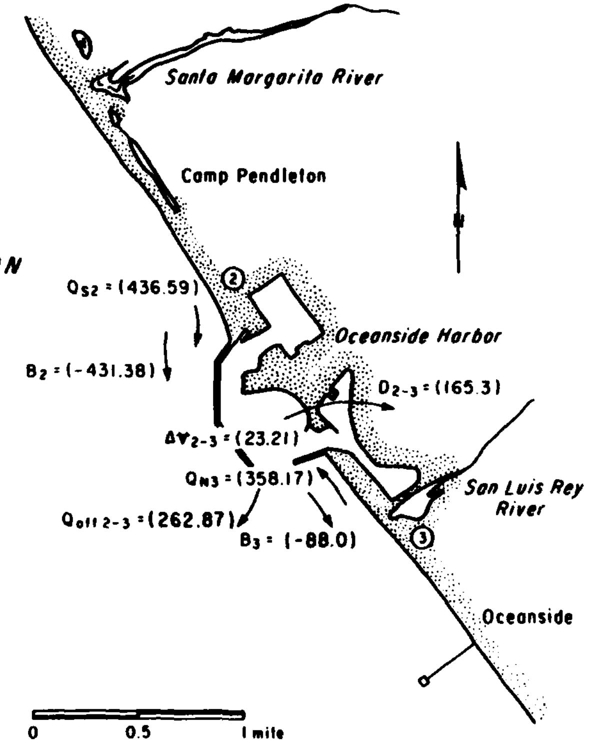
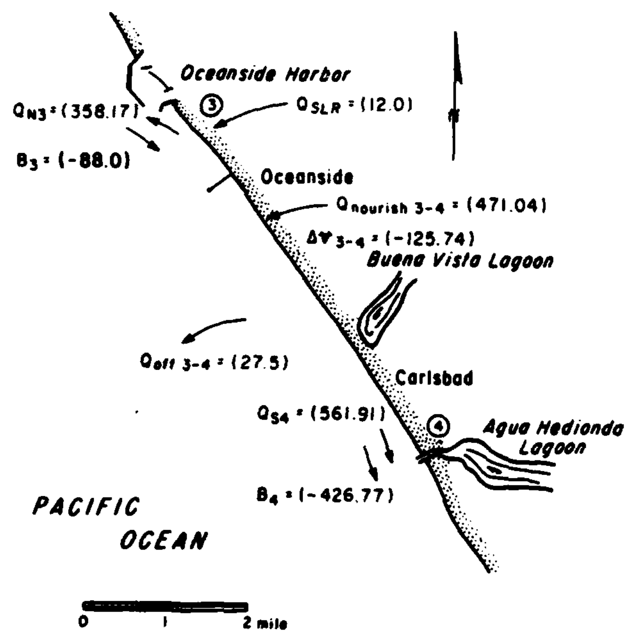


Figure 20 Case 2 Sediment Budget, Sub-Cell 2-3



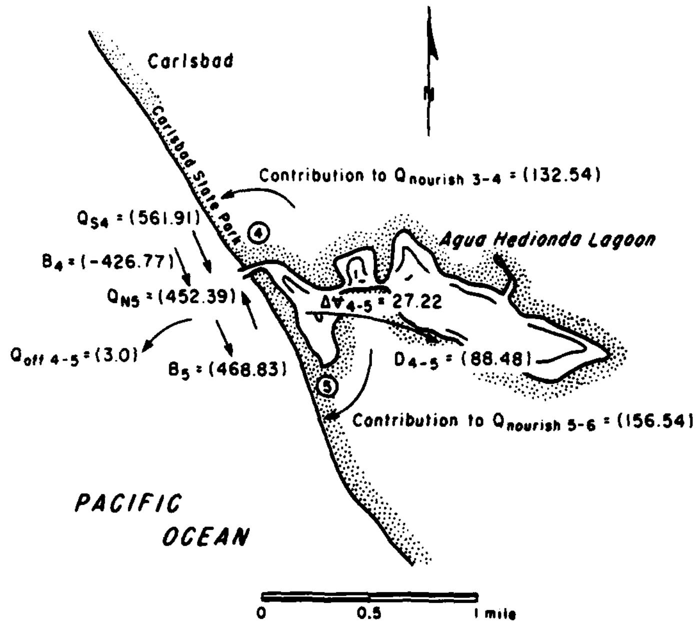


Figure 21 Case 2 Sediment Budget, Sub-Cell 3-4

Figure 22 Case 2 Sediment Budget, Sub-Cell 4-5

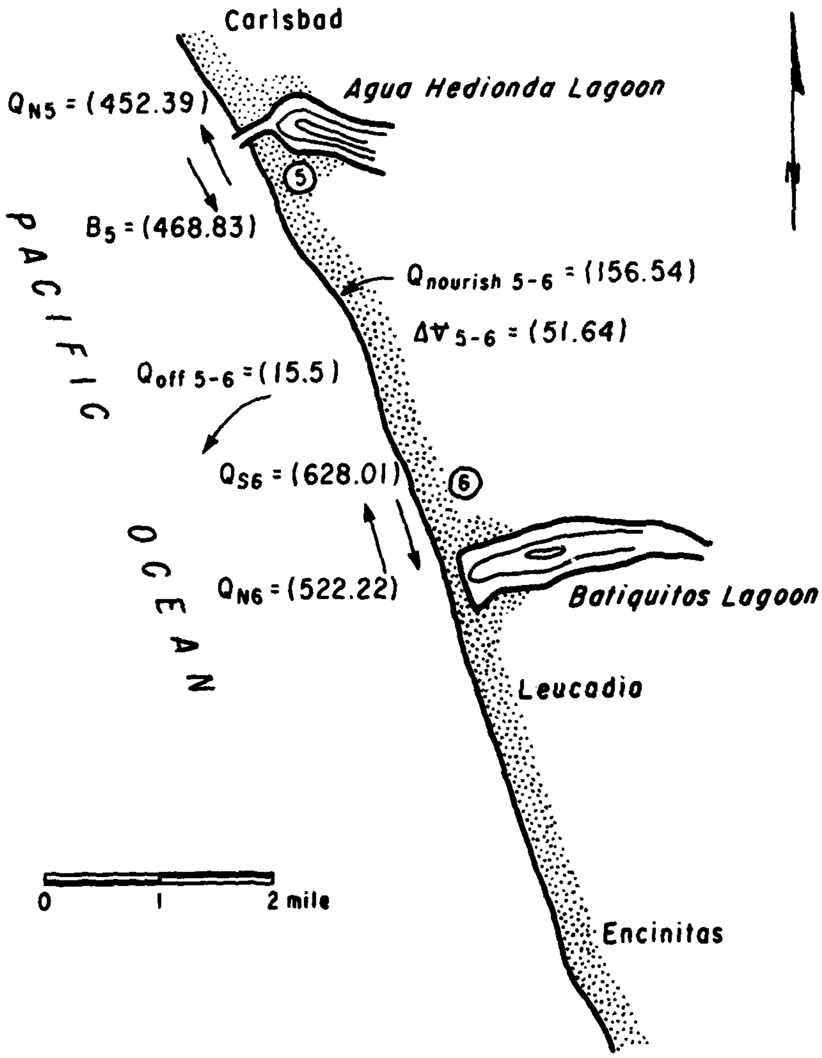


Figure 23 Case 2 Sediment Budget, Sub-Cell 5-6

SEDIMENT BUDGET EVALUATION FOR GROIN FIELD ALTERNATIVE

The preceding sediment budget cases provide a rough estimate of the disposition of sediments in the Oceanside area. Cases 1 and 2 can be used as baseline conditions with which to evaluate the effect of the proposed structural measures to alleviate erosion problems on Oceanside and adjacent beaches.

One proposed solution to the erosion problem on Oceanside Beach is the construction of a groin field starting about 7,200 feet south of Oceanside Harbor and extending about 12,000 feet southward. About 1,000 feet of the southerly end of the groin field is a transition section with the length of each successive groin being shorter than the one immediately north of it. The groin field would be included in reach 3-4 of the preceding sediment budget analysis.

CASE 1a

The effect of the proposed groin field project on downdrift beaches was evaluated by modifying the Case 1 and Case 2 pre-project sediment budgets while making assumptions regarding the effect of the project on the pre-project budget. Under Case 1a the results of the pre-project sediment budget of Case 1 were used and applied to the region between Oceanside Harbor and Agua Hedionda Lagoon. Specifically, sub-cell 3-4 was further subdivided into three smaller cells, the area between Oceanside Harbor and the northern end of the project, the project itself, and the area from the southern end of the project to the lagoon. A sediment balance equation was written for each sub-cell under the assumption that the inflow and outflow of sediment at the updrift boundary (Oceanside Harbor) and at the downdrift boundary (Agua Hedionda Lagoon) are unchanged from pre-project conditions. This does not recognize any influence the project itself might have on the sediment budget. Referring to figure 24, the northern end of the project is designated point "a", while the southern end is designated point "b". The beach between Oceanside Harbor and the northern end of the groin field is thus sub-cell 3-a, the project is sub-cell a-b, and the beach from the groin field to the Agua Hedionda Lagoon is sub-cell b-4.

The groin field cannot control the amount of sediment lost offshore due to sea level rise; therefore, the beach losses in the sub-cells 3-a and a-b were assumed to equal these offshore losses. The project was assumed to divert sediment offshore but the amount diverted, Qoffa-b, is not

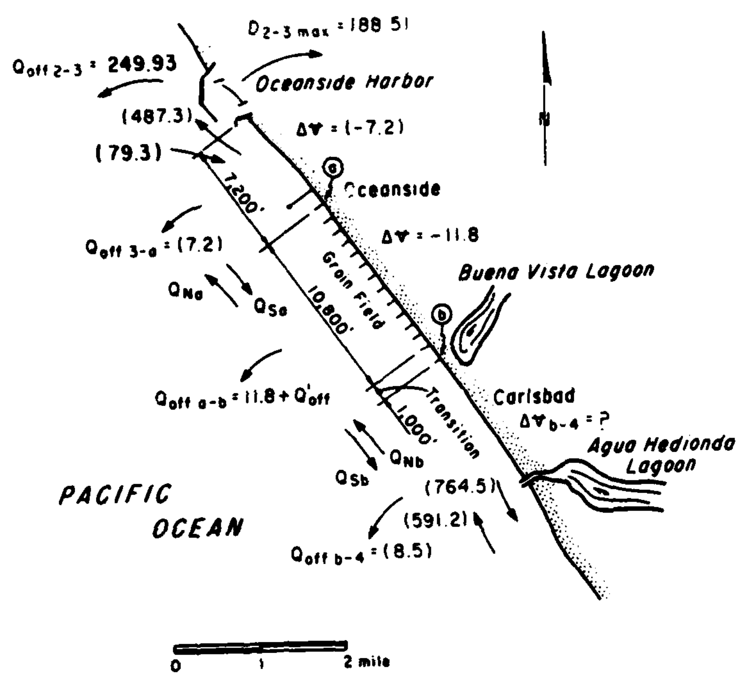


Figure 24 Groins Alternative, Post-Project Sediment Budget, Case 1a

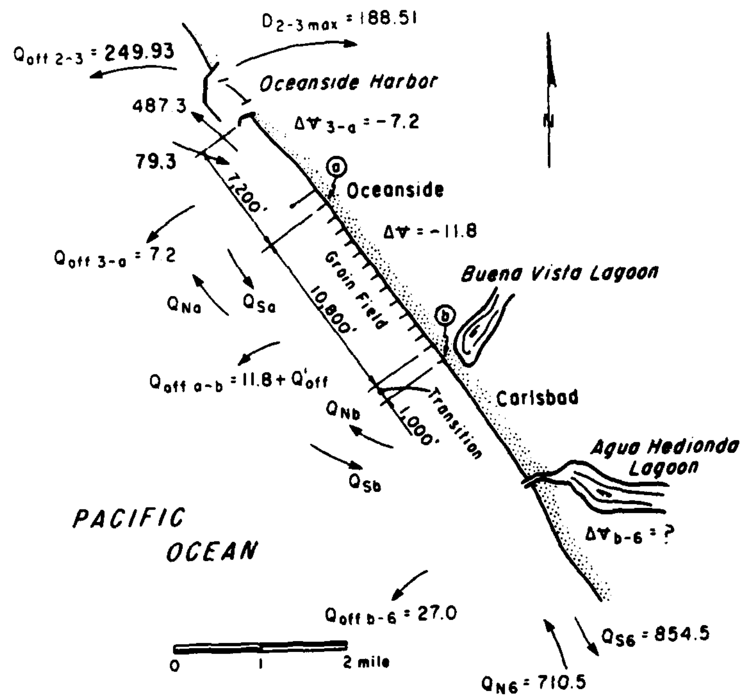


Figure 25 Groins Alternative, Post-Project Sediment Budget, Case 1b

known. The deficit of sand on the downdrift beach, Vb-4, is unknown and represents the primary impact of the project on the adjacent beaches.

The sediment balance equation for sub-cell 3-a is,

$$79.3 - 487.3 - QSa + QNa - 7.2 = V3\text{-}a \qquad (24)$$

in which QSa is the southward transport from the sub-cell 3-a into the project area, QNa is the transport into sub-cell 3-a from the project and V3-a is the loss from the sub-cell beach. This latter value is assumed to equal the amount of sediment lost to the offshore, -7.2. See figure 24.

The sediment balance equation for the project area, sub-cell a-b, is given by,

$$QSa - QNa - Q'off - 11.8 - QSb + QNb = -11.8 \qquad (25)$$

where the offshore losses are again assumed to balance the beach losses in the project area.

The equation for the beach between the southern end of the project and the Agua Hedionda Lagoon, sub-cell b-4, is,

$$QSb - QNb + 591.2 - 764.5 - 8.5 = Vb\text{-}4 \qquad (26)$$

where Vb-4 is the sediment deficit on the downdrift beach, the primary impact of the project on the downdrift beaches.

Equations (24) through (26) include six unknowns, QNa, QNb, QSa, QSb, Q'off and Vb-4; however, by grouping QNa with QSa and QNb with QSb, an expression can be obtained for Vb-4 in terms of Q'off. Solution of the above equations gives,

$$Vb\text{-}4 = -589.8 - Q'off \qquad (27)$$

which indicates that beaches south of the project area will experience a deficit of at least 589,800 cu yds of sediment per year if all sediment supplied from the upcoast beach is cut off. This is a rather extreme situation since the Oceanside Harbor was assumed to continue to divert 250,000 cu yd of sediment offshore. With construction of a groin field, seaward diversion of sediment by the harbor should decrease; at least the beaches south of Oceanside Harbor should no longer be a source of sediment to the harbor. If we assume that the Oceanside Harbor offshore losses find their way to the beaches south of the harbor, a set of equations similar to those above can be developed. This sediment will therefore reduce the sediment deficit on the downdrift beaches. The expression for the downdrift beach sediment deficit is then,

$$Vb\text{-}4 = -339.87 - Q'off \qquad (28)$$

The deficit is now reduced to only about 340,000 cu yd/yr in addition to whatever amount of sediment the project itself diverts offshore.

If the sediment dredged from Oceanside Harbor is bypassed and used to make up the sand losses on the beaches between Oceanside Harbor and the southern end of the project with the remainder placed on the downdrift beach, the downdrift deficit will be further reduced. For the case where the dredged material is bypassed but Oceanside Harbor offshore losses continue, the downdrift deficit is given by,

$$Vb\text{-}4 = -420.29 - Q'off \qquad (29)$$

If the dredged material is bypassed and the Oceanside Harbor offshore losses find their way to the downdrift beaches, the deficit is given by,

$$Vb\text{-}4 = -170.36 - Q'off \qquad (30)$$

All of the preceding expressions for the downdrift deficit make no assumptions regarding the value of Q'off. They suggest a minimum deficit which could be larger depending on the groin field's tendency to divert sediment offshore. There is presently no way to estimate the magnitude of Q'off.

CASE 1b

The assumptions under Case 1b are the same as those of Case 1a except that the downdrift deficit is now distributed along the beaches between the southern end of the project and the end of the sediment budget area near the southern boundary of the City of Carlsbad. In general, the sediment deficits are of about the same magnitude; however, they are distributed over a longer stretch of beach. Under these assumptions the equations for sub-cells 3-a, a-b and b-6 are given by,

$$79.3 - 487.3 - QSa + QNa - 7.2 = -7.2 \qquad (31)$$

$$QSa - QNa - Q'off - 11.8 - QSb + QNb = -11.8 \qquad (32)$$

$$QSb - QNb + 710.5 - 854.5 - 27.0 = Vb\text{-}6 \qquad (33)$$

See figure 25.

For the situation with continued offshore diversion of sediment by Oceanside Harbor and no sand bypassing (sediment dredged from Oceanside Harbor is disposed of elsewhere), the deficit is given by,

$$Vb-6 = -579.0 - Q'off \quad (34)$$

For no sand bypassing but with Oceanside Harbor offshore losses making their way to downdrift beaches, the deficit is given by,

$$Vb-6 = -270.07 - Q'off \quad (35)$$

For the situation where sediment dredged from Oceanside Harbor is placed on downdrift beaches but the offshore losses continue, the deficit is given by,

$$Vb-6 = -409.49 - Q'off \quad (36)$$

and for the case where both harbor dredging places sediment on the downdrift beaches and the offshore losses make their way to the downdrift beaches, the deficit is given by,

$$Vb-6 = -100.56 - Q'off \quad (37)$$

This last case is the least damaging to the downdrift beaches with only a 100,000 cu yd/yr deficit; however, it requires that all sediment dredged from Oceanside Harbor be bypassed to the beaches south of the project and that the project completely halt the offshore diversion of sediment by Oceanside Harbor. This latter condition is highly unlikely although some decrease in this offshore diversion might be expected.

CASE 2a

Under Case 2a the pre-project sediment budget of Case 2 was used. Case 2 assumed that the longshore transport rates obtained by Hales should be reduced by a factor of 0.735. Downdrift sediment deficits were assumed to be distributed over the beach south of the project area to the Agua Hedionda Lagoon. Under Case 2a the sediment budget equations for sub-cells 3-a, a-b and b-4 are,

$$-358.17 - 88.0 - 7.2 - QSa + QNa = -7.2 \quad (38)$$

$$QSa - QNa - 11.8 - Q'off - QSb + QNb = -11.8 \quad (39)$$

$$QSb - QNb - 8.5 - 561.91 + 426.77 = Vb-4 \quad (40)$$

respectively. See figure 26.

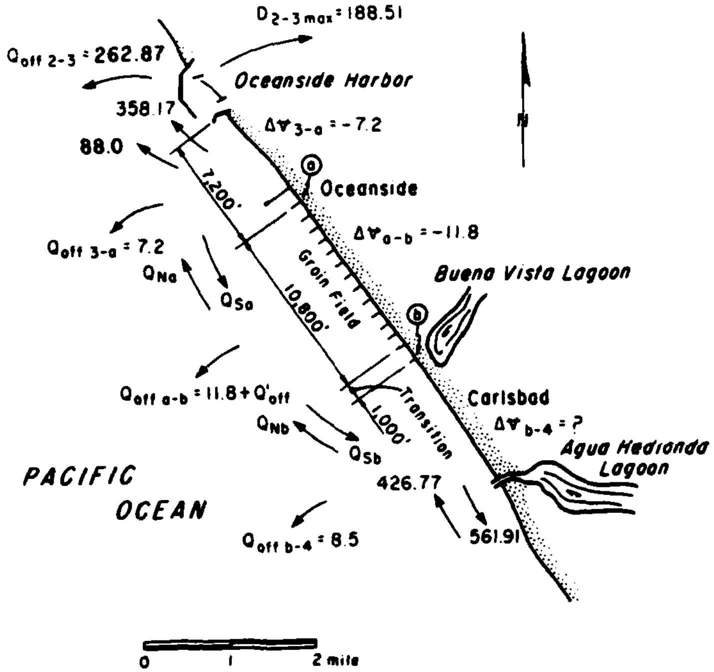


Figure 26 Groins Alternative, Post-Project Sediment Budget, Case 2a

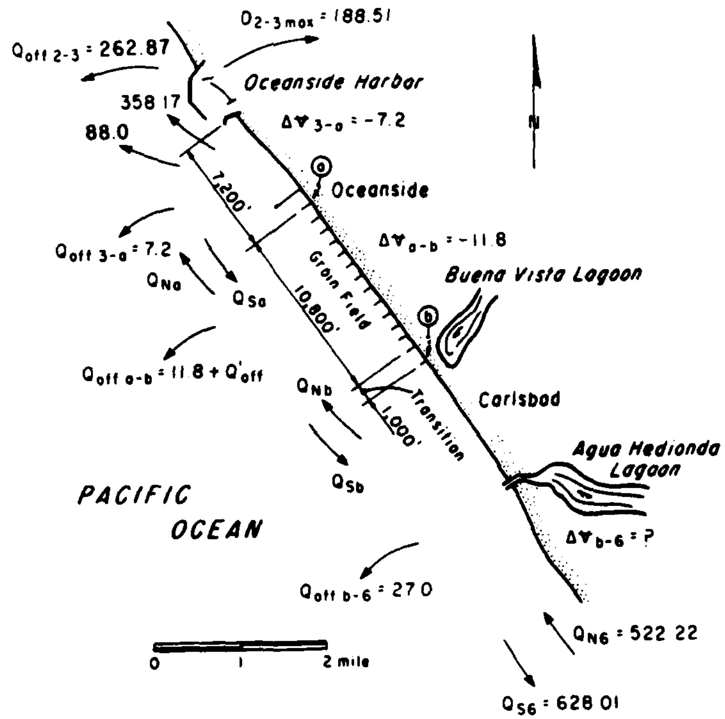


Figure 27 Groins Alternative, Post-Project Sediment Budget, Case 2b

Solution of equations (38) through (40) give the following expression for the downdrift beach deficit in terms of the unknown offshore losses caused by the project, Q'off.

$$Vb\text{-}4 = -589.81 - Q'off \qquad (41)$$

Equation (41) assumes no bypassing and that Oceanside Harbor offshore losses continue. For the case of no bypassing and offshore losses making their way to the downdrift beaches, the downdrift beach deficit is given by,

$$Vb\text{-}4 = -326.94 - Q'off \qquad (42)$$

With bypassing of the material dredged from Oceanside Harbor to make up the deficit on the project beaches and with the remainder being placed on the downdrift beaches, but with offshore harbor losses continuing, the downdrift beach deficit is,

$$Vb\text{-}4 = -420.30 - Q'off \qquad (43)$$

For the case with both bypassing and offshore harbor losses on downdrift beaches, the downdrift beach sediment deficit is given by,

$$Vb\text{-}4 = -265.71 - Q'off \qquad (44)$$

CASE 2b

Under Case 2b the pre-project sediment budget of Case 2 was used but the downdrift losses were assumed to be distributed over the beaches between the southern end of the project and the southern end of the sediment budget area. The equations for the three sub-cells, 3-a, a-b and b-6 are,

$$-358.17 - 88.0 - 7.2 - QSa + QNa = -7.2 \qquad (45)$$

$$QSa - QNa - 11.8 - Q'off - QSb + QNb = -11.8 \qquad (46)$$

$$QSb - QNb - 27.0 + 522.22 - 628.01 = Vb\text{-}6 \qquad (47)$$

respectively. See figure 27.

For the case of no bypassing and continued offshore losses at Oceanside Harbor, the equations yield,

$$Vb\text{-}6 = -578.96 - Q'off \qquad (48)$$

while for the case of no bypassing but offshore Oceanside

Harbor losses making their way to the downdrift beaches the equations yield,

$$Vb\text{-}6 = -316.09 - Q'off \qquad (49)$$

For the situation when material dredged from Oceanside Harbor is bypassed to the beaches and the Oceanside Harbor offshore losses continue, the downdrift beach sediment deficit is given by,

$$Vb\text{-}6 = -409.45 - Q'off \qquad (50)$$

For both bypassing and no Oceanside Harbor offshore losses, the downdrift deficit is given by,

$$Vb\text{-}6 = -146.58 - Q'off \qquad (51)$$

The preceding expressions for downdrift beach losses are summarized on Table 3. The table gives the values of "a" in the expression,

$$V = -a - Q'off \qquad (52)$$

In general, the analysis supposes that the proposed groin system will protect the Oceanside Beaches within the project area but that downdrift beaches will continue to experience erosion. The magnitude of the downcoast problem cannot be determined with confidence since the effect of the project in diverting sediment offshore is not known nor is the effect of the project on the sediment budget known. Also, the extent of the beaches over which the deficit occurs is not known. To maintain beach stability within the proposed groin system, a portion of the sediment dredged from the harbor should be placed on the Oceanside Beaches for nourishment within the groin system and the remaining sediment placed directly on the beach immediately south of the project. This placement would reduce the erosion problem along the downdrift beaches. Transition groins might also be considered south of the project area.

TABLE 3
Summary of Project Effects - Groins
Value of "a" in Expression V = -a - Q'off
for Selected Cases

Case	No Bypassing		Bypassing	
	Harbor Losses	No Harbor Losses	Harbor Losses	No Harbor Losses
1a	589.80	339.87	420.29	170.36
1b	579.00	270.07	409.49	100.56
2a	589.81	326.94	420.30	265.71
2b	578.96	316.09	409.45	146.58

SEDIMENT BUDGET EVALUATION FOR OFFSHORE BREAKWATERS ALTERNATIVE

A second alternative solution to the erosion problem at Oceanside Beach calls for construction of a series of nearshore breakwaters extending 11,800 feet southward along the beach starting from a point 7,200 feet south of the harbor. The crest elevation of the breakwaters would be at about MLLW and at minus 5 ft. in the gaps. The breakwaters would be armored to preclude scour by seaward moving currents. A terminal groin would be constructed at each end of the series of breakwaters so that the structures would essentially enclose the beach. Two short groins would be constructed at the downcoast end of the breakwaters to provide a smooth transition between the breakwaters and the shoreline.

The evaluation of effects of the breakwater alternative on the sediment budget parallels the calculations presented for the groins alternative in the preceding section. The only difference between the two analyses involves sediment losses from the beach. Under the breakwaters alternative the beach was assumed to be completely stabilized and sediment losses from the beach were assumed to be zero. Consequently, losses to the offshore due to sea level rise must come from elsewhere, specifically from the longshore influx of sediment. As a result, for each case, the sediment deficit on the downdrift beaches is higher by the amount of offshore loss over the project area, 11,800 cu yd/yr.

The contributions and losses of sediment to the project sub-cell under the four cases, 1a, 1b, 2a and 2b are summarized in figures 29 through 31.

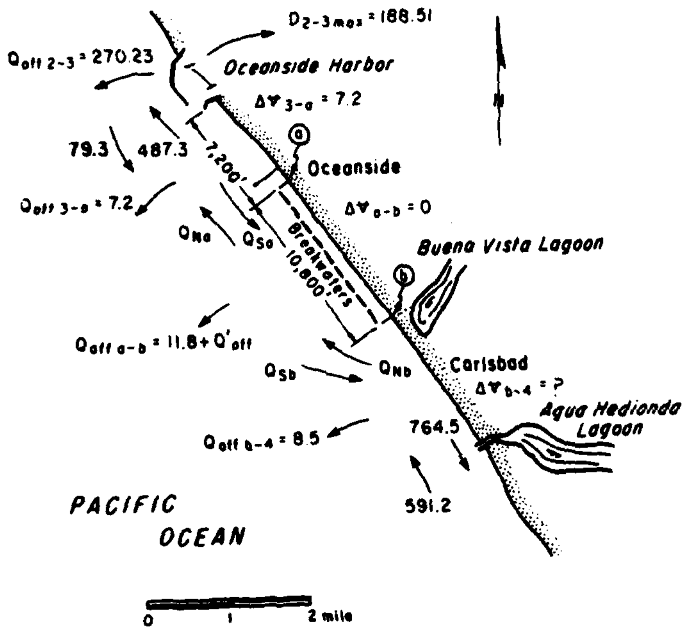


Figure 28 Nearshore Breakwaters Alternative, Post-Project Sediment Budget, Case 1a

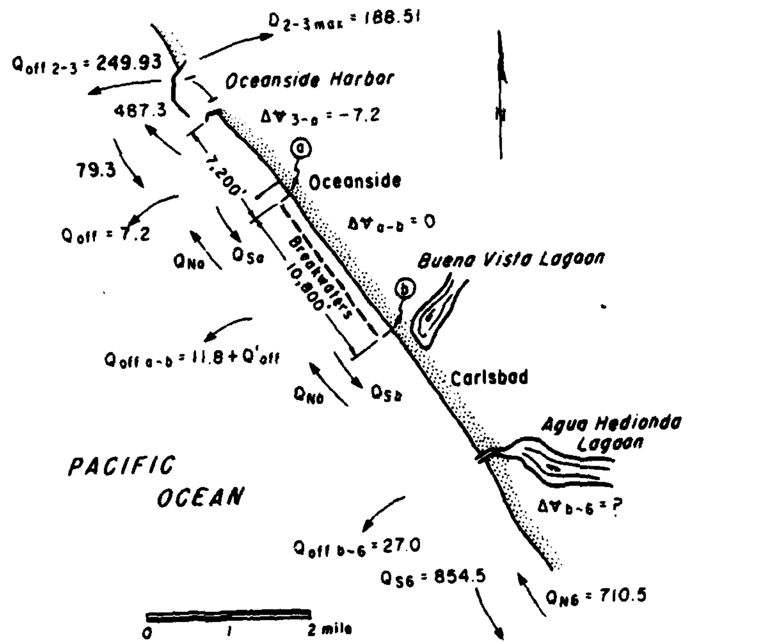


Figure 29 Nearshore Breakwaters Alternative, Post-Project Sediment Budget, Case 1b

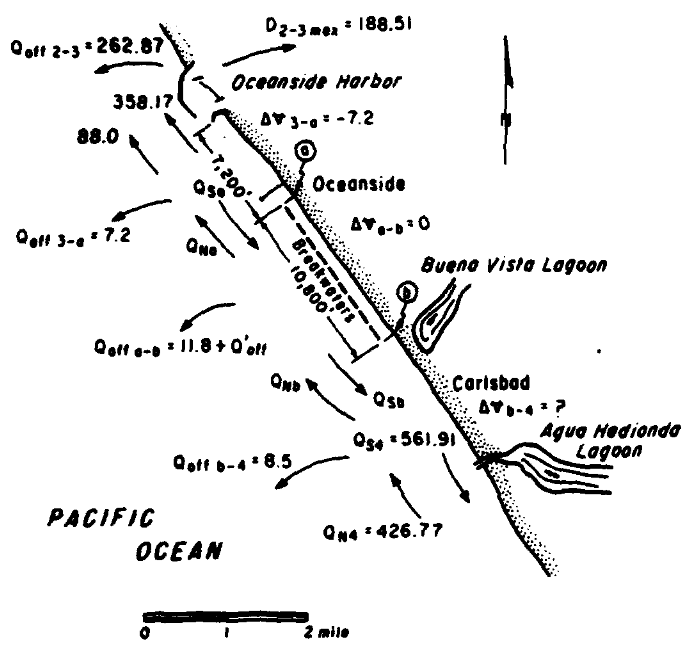


Figure 30 Nearshore Breakwaters Alternative, Post-Project Sediment Budget, Case 2a

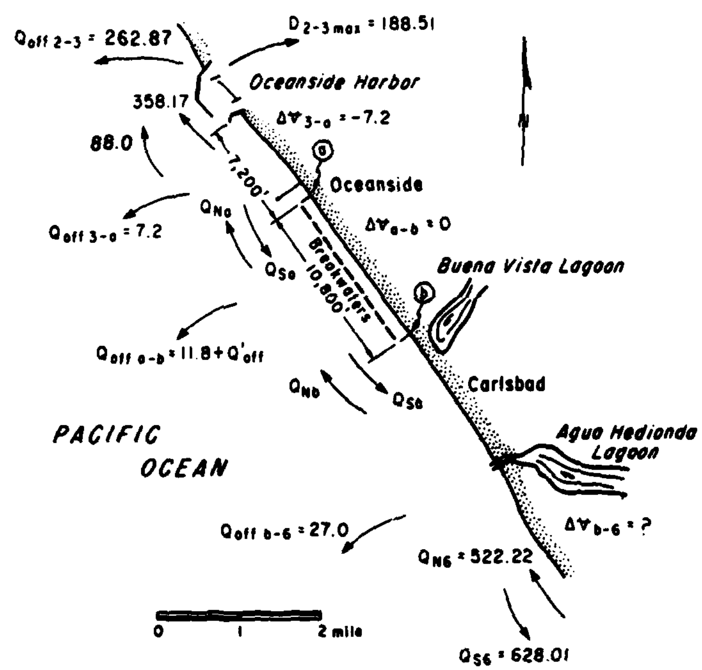


Figure 31 Nearshore Breakwaters Alternative, Post-Project Sediment Budget, Case 2b

CASE 1a

Under Case 1a the sediment balance equations are similar to equations (24) through (26) except that the right hand side of equation (25) is 0 rather than -11.8. See figure 28. Solving these equations under the assumption that there is no bypassing of sediment from Oceanside Harbor to the beaches south of the project and that offshore losses at the harbor continue after construction of the project, the expression for the sediment deficit on the downdrift beaches is given by,

$$Vb\text{-}4 = -601.6 - Q'off \qquad (53)$$

where Q'off is the unknown amount of sediment diverted offshore by the breakwater project. Because the breakwaters are to be built nearshore, the amount of sediment diverted offshore by the breakwaters can be expected to be lower than the amount diverted offshore by the groin field alternative.

For the situation of no bypassing of harbor sediments, but offshore losses at Oceanside Harbor cease, the downdrift sediment deficit is given by,

$$Vb\text{-}4 = -351.67 - Q'off \qquad (54)$$

If the material dredged from Oceanside Harbor is bypassed to the downdrift beaches and the offshore losses at Oceanside Harbor continue, the downdrift deficit is given by,

$$Vb\text{-}4 = -432.17 - Q'off \qquad (55)$$

If the material from Oceanside Harbor is bypassed and the offshore losses at Oceanside Harbor cease and the sediment finds its way to downdrift beaches, the downdrift deficit is given by,

$$Vb\text{-}4 = -182.16 - Q'off \qquad (56)$$

CASE 1b

Under Case 1b the sediment balance equations are similar to equations (31) through (33) for the groin field alternative; however, the right hand side of equation (32) equals 0 instead of -11.8. See figure 29. The downdrift sediment deficit is distributed over the beaches from the project southward to the southerly boundary of the sediment budget near the southern boundary of the City of Carlsbad.

For the case with no bypassing and continued offshore losses at Oceanside Harbor, the downdrift beach deficit is given by,

$$Vb-6 = -590.8 - Q'off \qquad (57)$$

For the case of no bypassing but with the offshore losses making their way to downdrift beaches, the deficit is given by,

$$Vb-6 = -281.87 - Q'off \qquad (58)$$

If sediment is bypassed from Oceanside Harbor but the offshore losses at the harbor continue, the deficit is given by,

$$Vb-6 = -421.29 - Q'off \qquad (59)$$

For bypassing and with offshore losses making their way to the downdrift beaches, the deficit is a minimum and is given by,

$$Vb-6 = -112.36 - Q'off \qquad (60)$$

CASE 2a

Under Case 2a the losses are distributed between the south end of the project and the Agua Hedionda Lagoon. The sediment budget equations are similar to equations (38) through (40) with the right hand side of equation (39) replaced by 0 instead of -11.8. See figure 30.

For the case of no bypassing and continuing harbor losses, the deficit is,

$$Vb-4 = -601.61 - Q'off \qquad (61)$$

For the case of no bypassing but with harbor losses making their way to the downdrift beaches, the deficit is,

$$Vb-4 = -338.74 - Q'off \qquad (62)$$

If sediment is bypassed from Oceanside Harbor but offshore losses continue, the deficit is,

$$Vb-4 = -432.10 - Q'off \qquad (63)$$

and if sediment is bypassed and offshore losses make their way to the downdrift beaches, the deficit is,

$$Vb-4 = -277.51 - Q'off \qquad (64)$$

CASE 2b

Under Case 2b the downdrift sediment deficit is distributed over the beaches between the southern project boundary and the southern end of the sediment budget area. The reduced longshore transport rates of Case 2 were used. See figure 31. The sediment budget equations are similar to equations (45) through (47) with 0 replacing the -11.8 on the right hand side of equation (46).

For the case of no bypassing and continuing offshore losses at Oceanside Harbor, the downdrift deficit is,

$$Vb\text{-}6 = -590.76 - Q'off \qquad (65)$$

For the case of no bypassing but with the Oceanside Harbor offshore losses finding their way to the downdrift beaches, the deficit is,

$$Vb\text{-}6 = -327.98 - Q'off \qquad (66)$$

If sediment is bypassed from Oceanside Harbor to the downdrift beaches and the offshore losses from Oceanside Harbor continue, the deficit is,

$$Vb\text{-}6 = -421.25 - Q'off \qquad (67)$$

For bypassing and with offshore losses on the downdrift beaches, the deficit is,

$$Vb\text{-}6 = -158.38 - Q'off \qquad (68)$$

The preceding expressions for the downdrift sediment deficit for Cases 1a through 2b are summarized in Table 4. In general, the effect of the breakwater alternative on downdrift beaches is similar to that of the groins alternative. The breakwaters serve to protect the beach in the project area but erosion will continue along the beaches south of the project.

TABLE 4
Summary of Project Effects - Breakwaters
Value of "a" in Expression V = -a - Q'off
for Selected Cases

Case	No Bypassing Harbor Losses	No Bypassing No Harbor Losses	Bypassing Harbor Losses	Bypassing No Harbor Losses
1a	601.60	351.67	432.17	182.16
1b	590.80	281.87	421.29	112.36
2a	601.61	338.74	432.10	277.51
2b	590.76	327.98	421.25	158.38

SUMMARY AND CONCLUSIONS

The preceding Oceanside, California, sediment budget should be considered as approximate. The pre-project budget is based on beach change data, longshore transport data derived from wave hindcasts, and sediment discharge data derived from streamflow records. Assumptions were made about the mechanism of offshore sediment loss due to sea level rise. The bypassing quantities at harbors and lagoons and the amount of sediment diverted offshore by the Oceanside Harbor were assumed to be unknowns in the sediment balance equations. Since the equations for each of the sub-cells are coupled with the equations for adjacent sub-cells, errors in the data will affect the overall sediment balance of the system. Probably the greatest potential source of error is with the beach profile data. Small errors in elevation of the offshore areas could lead to large errors in estimated quantities of erosion and/or accretion. A second source of error is the longshore transport estimates. Two sets of longshore transport estimates were used, those of Hales (1978) and Hales' values reduced by a factor of 0.735.

The pre-project budget was used to investigate the effect of proposed structural alternatives on adjacent beaches. The groin field and breakwater alternatives were assumed to divert some sediment offshore but the amount diverted offshore is unknown for each structure type. Even if the proposed stuctures do not divert sediment offshore, sediment deficits along the downdrift beaches south of the project will continue with or without a project.

Construction of the groin system plan or nearshore breakwater plan combined with the bypassing of the sediment dredged from Oceanside Harbor would provide protection to the Oceanside beach and could be beneficial to the Carlsbad beaches which presently suffer a deficit of sediment. Both plans, however, should require that all sediment dredged from Oceanside Harbor be used to nourish the project area (when necessary) and the beaches south of the project. If groin or breakwater construction decreases the offshore diversion of sediment by Oceanside Harbor, the deficit on downdrift beaches should be smaller. Since some sediment presently trapped by Oceanside Harbor probably originates on the beaches south of the harbor, the project could decrease the amount of sediment trapped and, therefore, decrease the amount of harbor maintenance dredging required.

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