COASTAL
FRONTIERS

Oceanside Receiver Site, April 2001 through November 2003

2003 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

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CFC-618-03

SANDAG
2003 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

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SANDAG

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May 2004

EXECUTIVE SUMMARY

This report presents the findings of the SANDAG 2003 Regional Beach Monitoring Program. As in past years, the general objective of the program was to document changes in the condition of the shorezone, thereby providing a basis for evaluating the impacts of natural events and human intervention. The specific focus was to monitor the fate of nourishment material introduced at twelve receiver beaches under SANDAG's Regional Beach Sand Project (RBSP). The RBSP provided a total of 2.1 million cubic yards (cy) of sand to the receiver beaches between April 6 and September 23, 2001.

The 2003 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on 61 shore-perpendicular transects, semi-annual oblique aerial photography at the twelve RBSP receiver sites, and monthly beach width measurements at three of the RBSP receiver sites. The lagoon entrance component addressed five sites in the Oceanside Littoral Cell: the jetty-stabilized entrances at Agua Hedionda and Batiquitos, and the unstabilized entrances at San Elijo, San Dieguito, and Los Peñasquitos. Topographic data and oblique aerial photographs were obtained at each entrance on a semi-annual basis, along with monthly observations and ground photographs at the three unstabilized entrances.

To provide continuity with SANDAG's previous monitoring work, November 2002 through October 2003 was defined as the 2003 Monitoring Year, the prior two one-year periods as the 2002 and 2001 Monitoring Years, and the three-year period from November 2000 through October 2003 as the RBSP Monitoring Period. The principal study findings are as follows:

1. Precipitation, streamflow, wave energy and storm frequency all increased during the 2003 Monitoring Year relative to 2001 and 2002. Nevertheless, the average values of these parameters during the three-year RBSP Monitoring Period remained well below the pre-RBSP averages. The primary implications of these environmental conditions are threefold: (1) the absence of large wave events following the implementation of the RBSP helped to prolong the life of the beach fills; (2) the scant precipitation and low streamflows failed to deliver significant quantities of beach-quality sediment to the coast; and (3) the low streamflows failed to flush coastal sediment from the lagoon entrances in the Oceanside Cell.

2. The only non-RBSP nourishment provided during the entire RBSP Monitoring Period was 2,000 at Moonlight Beach. As a result, two thirds of the RBSP fill material (1,401,000 cy) may be regarded as compensating for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 702,000 cy, represents incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 657,000 cy (equivalent to 219,000 cy/yr over the three-year RBSP Monitoring Period). The Mission Beach Cell received an additional 144,000 cy (48,000 cy/yr), while the Silver Strand Cell incurred a deficit of 99,000 cy (33,000 cy/yr) due to the lack of nourishment activities other than the RBSP. No nourishment was provided in any of the three littoral cells during the 2003 Monitoring Year.

3. The sand bypass rates at Agua Hedionda and Oceanside Harbor during the RBSP Monitoring Period (192,000 and 306,000 cy/yr, respectively) exceeded the average annual rates in prior years by about 50,000 cy/yr. (Note: the average annual rate for Agua Hedionda was derived by assuming that the quantities dredged in 2001 and 2003 apply to the four-year period 2001-2005.) The increased bypassing rates at these two sites constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor and both north and south of Agua Hedionda. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the pre- and post-RBSP rates is not meaningful.

4. During the 2003 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, but the shoreline tended to retreat. This apparent paradox may be explained by the fact that sediment moved from the subaerial portion of the profile to the submerged portion, but remained within the shorezone. The predominance of shoreline retreat is attributable to four factors: (1) offshore dispersal of the RBSP fill material, (2) a lack of significant sediment input from rivers and streams, (3) an increase in wave energy relative to the past two years, and (4) a lack of beach nourishment activities. The stability of the shorezone sediment volume is consistent with the fact that, in the absence of nourishment activities, major rainstorms, and severe storm events, significant quantities of material were neither added to nor removed from the coast.

5. Notwithstanding the loss of dry beach that occurred in 2003, the condition of the County's beaches improved substantially during the RBSP Monitoring Period. Beach widths increased by an average of 17 ft during this period, while shorezone volumes increased by an average of 15 cy/ft. The greatest gains occurred in the Oceanside Cell,

where more than 85% of the RBSP nourishment material was deposited. The primary reasons for this improvement in the state of the coast appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period. Although much of the RBSP fill material has been dispersed from the receiver sites, the residual benefits to the County's beaches include an increased area for recreational activities, and a more substantial buffer against storm-induced erosion.

6. The performance of the individual RBSP fills varied considerably. At some sites, such as Del Mar, Moonlight, and South Carlsbad, the gains in shorezone volume that occurred at the time of fill placement were short-lived. At others, such as Mission Beach and Oceanside, the gains persisted through the time of the Fall 2003 Survey. In many cases, dispersal of the fill material was accompanied by shorezone volume gains on the downdrift beaches. The positive impact of the RBSP was most evident in the Oceanside-North Carlsbad area, where the monitoring data suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally to benefit more than two miles of shoreline. A similar situation was observed in the Encinitas area involving the Batiquitos and Leucadia fills.

7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth during the RBSP Monitoring Period. Of the three unstabilized entrances, San Elijo closed on three occasions, San Dieguito on six, and Los Peñasquitos on seven. This pronounced variation in closure frequency resulted in the San Elijo entrance channel remaining open to tidal exchange for a greater percentage of time than the historical average (97% vs. 39% historically), the San Dieguito channel remaining open for a lesser percentage of time (45% vs. 76% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (87% vs. 92% historically).

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SANDAG
2003 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

1. INTRODUCTION

This report presents the findings of the SANDAG 2003 Regional Beach Monitoring Program. As in the case of seven prior annual monitoring programs conducted between 1996 and 2002 (Coastal Frontiers, 1997, 1998, 1999, 2000, 2001, 2002), the 2003 effort was performed on behalf of the San Diego Association of Governments (SANDAG) by Coastal Frontiers Corporation.

The study area extends 59 miles from the U.S.-Mexican Border to Oceanside Harbor, and contains the Silver Strand Littoral Cell, the Mission Beach Littoral Cell, and the southern half of the Oceanside Littoral Cell (Figure 1). As in past years, the general objective of the 2003 Monitoring Program was to document changes in the condition of the shorezone, thereby providing a basis for evaluating the impacts of natural events and human intervention. The specific focus was to monitor the fate of nourishment material introduced at twelve receiver beaches under SANDAG's Regional Beach Sand Project (RBSP). The RBSP, to be discussed in Section 2.2.1, provided a total of 2.1 million cubic yards of sand to the receiver beaches between April 6 and September 23, 2001.

The 2003 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on 61 shore-perpendicular transects, semi-annual oblique aerial photography of the twelve RBSP receiver sites, and monthly beach width measurements at three of the RBSP receiver sites. The lagoon entrance component addressed five sites in the Oceanside Littoral Cell: the jetty-stabilized entrances at Agua Hedionda and Batiquitos Lagoons, and the unstabilized entrances at San Elijo, San Dieguito, and Los Peñasquitos Lagoons (Figure 1). Topographic data and oblique aerial photographs were obtained at each entrance on a semi-annual basis, along with monthly observations and ground photographs at the three unstabilized entrances.

Although most of the 2003 Monitoring Program was sponsored by SANDAG, beach profile data for selected transects were provided by the Cities of Carlsbad, Encinitas, and

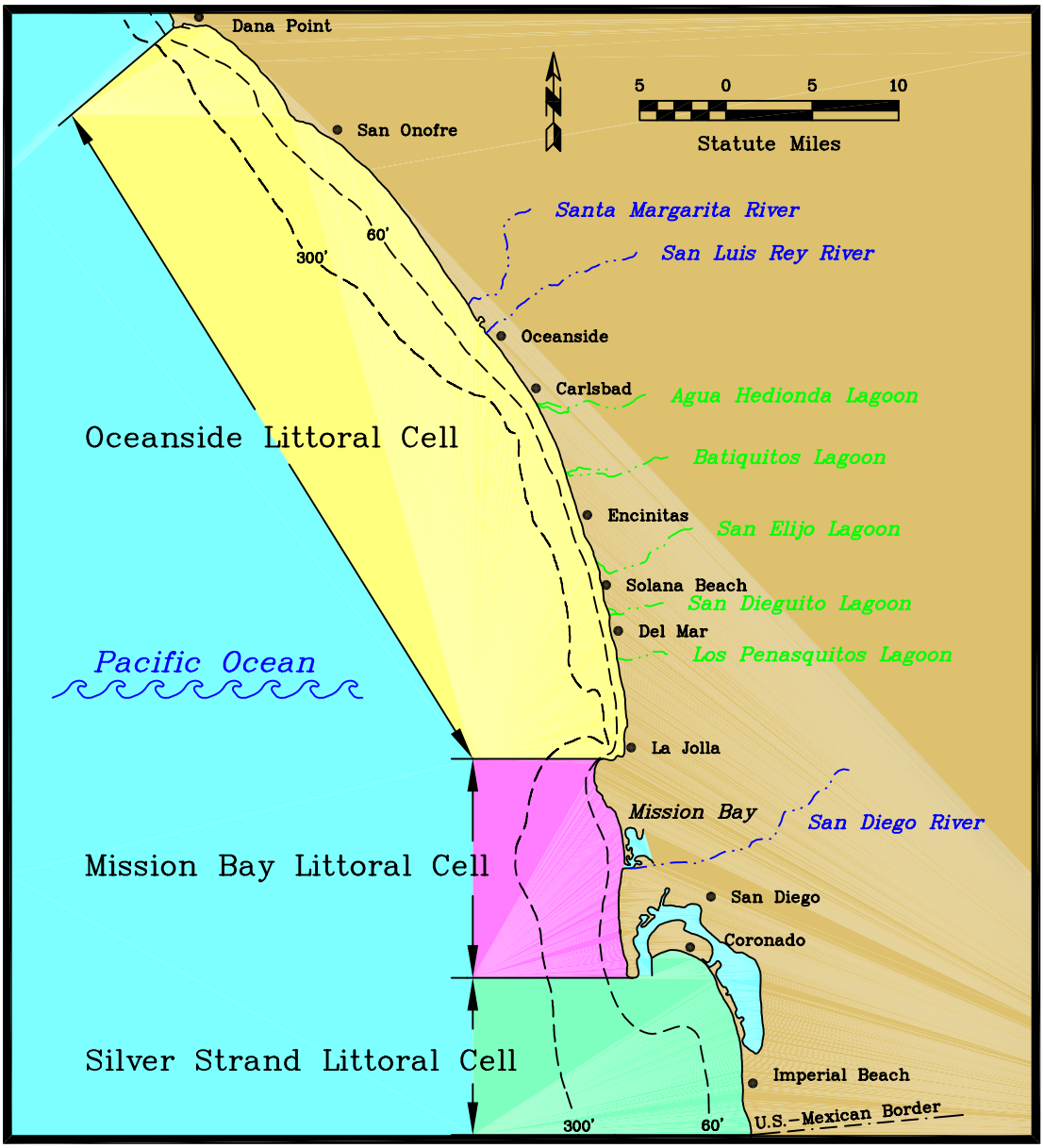


Figure 1. The Coast of San Diego County

Solana Beach. In addition, beach width measurements were provided by the Cities of Carlsbad, Encinitas, and Imperial Beach. Their contributions are gratefully acknowledged by SANDAG.

To provide continuity with SANDAG's previous monitoring work, the following definitions were adopted:

2001 Monitoring Year:	November 2000 through October 2001;
2002 Monitoring Year:	November 2001 through October 2002;
2003 Monitoring Year:	November 2002 through October 2003;
RBSP Monitoring Period:	November 2000 through October 2003 (3 years).

Although the primary focus of this report is the 2003 Monitoring Year, considerable emphasis also is placed on the evolution of the County's beaches during the three-year RBSP Monitoring Period.

The remainder of this report provides a detailed account of the 2003 Regional Beach Monitoring Program. Pertinent background information is provided in Section 2, which discusses the environmental conditions and human intervention that occurred during the RBSP Monitoring Period. Monitoring methods are described in Section 3, while Section 4 presents the results. The condition of San Diego County's beaches is analyzed in Section 5, with particular emphasis on the RBSP receiver sites. Section 6 discusses the condition of the five lagoon entrances in the Oceanside Cell. Conclusions are presented in Section 7. Selected tables, figures, and plates are interspersed with the text, while the remaining tables, plots and plates are provided in a separate volume containing Appendices A through I. All elevations are referenced to Mean Lower Low Water (MLLW), which lies 2.73 ft below Mean Sea Level (MSL).

In the spring of 2003, the National Oceanic and Atmospheric Administration (NOAA) issued revised tidal elevations based on water level data recorded during the 19-year period commencing in 1983 and ending in 2001. In the San Diego area, this new tidal epoch produced an increase of 0.26 feet in the elevation of MLLW relative to that derived from the previous epoch (1960-1978). To facilitate direct comparisons between survey data acquired during the prior and present tidal epochs, all of the elevations measured by SANDAG prior to Spring 2003 were adjusted to the new elevation of MLLW Datum by subtracting 0.26 ft. Shoreline positions, beach widths, and beach volumes then were recomputed based on the adjusted elevations. In consequence, many of the values for these parameters appearing in this report differ from those in prior reports, and should be regarded as superceding the previously-reported values.

2. BACKGROUND INFORMATION

This section presents background information on the natural and human factors that exert a significant influence on the state of the San Diego County coast. It is intended not only to provide a general context for the monitoring data, but also to aid in evaluating the performance of the twelve RBSP beach fills and their impact on coastal lagoons. Environmental conditions are discussed in Section 2.1, followed by sediment management activities (including the RBSP) in Section 2.2. In Section 2.3, the conditions that have prevailed during the three-year RBSP Monitoring Period are compared with those in the recent past. All data are presented in terms of "monitoring years" that commence on November 1 and end on October 31. The 2003 Monitoring Year, for example, extends from November 1, 2002 through October 31, 2003.

2.1. Environmental Conditions

Environmental conditions of importance to the shorezone include precipitation, streamflow, and waves. During periods of heavy precipitation, rivers and streams transport substantial quantities of beach-quality sediment to the coast. Conversely, riverine sediment input becomes negligible during dry periods (Inman and Masters, 1991). The nature and severity of the wave conditions control the rate of coastal sediment transport, particularly in the case of storm events.

2.1.1. Precipitation

Although the amount of precipitation varies with location in San Diego County, rainfall patterns tend to be similar throughout the region. In other words, periods of above- or below-average rainfall at one site can be used to infer similar conditions at other sites (Elwany, *et al*., 1998). The data acquired at San Diego's Lindberg Field were selected to represent precipitation in the entire study area, based on this station's extended period of record (1914-present).

Figure 2 shows the annual precipitation measured at Lindberg Field from 1915 through 2003 (Western Regional Climate Center, 2004). The average value prior to 2001 was 10.3 inches, with a maximum of 26.4 inches in 1941 and a minimum of 3.6 inches in 1961. During the SANDAG monitoring period that preceded the RBSP (1996-2000), above-average precipitation was recorded only in 1998 (corresponding to the El Niño winter of 1997-98). During the 2001 Monitoring Year, when the RBSP was implemented, the precipitation measured 7.3 inches, or about 30% below average. The precipitation during

the 2002 Monitoring Year was even lower, at 3.3 inches - the lowest value recorded during the entire period of record. In 2003, the total precipitation increased to 10.3 inches, thereby matching the long-term average.

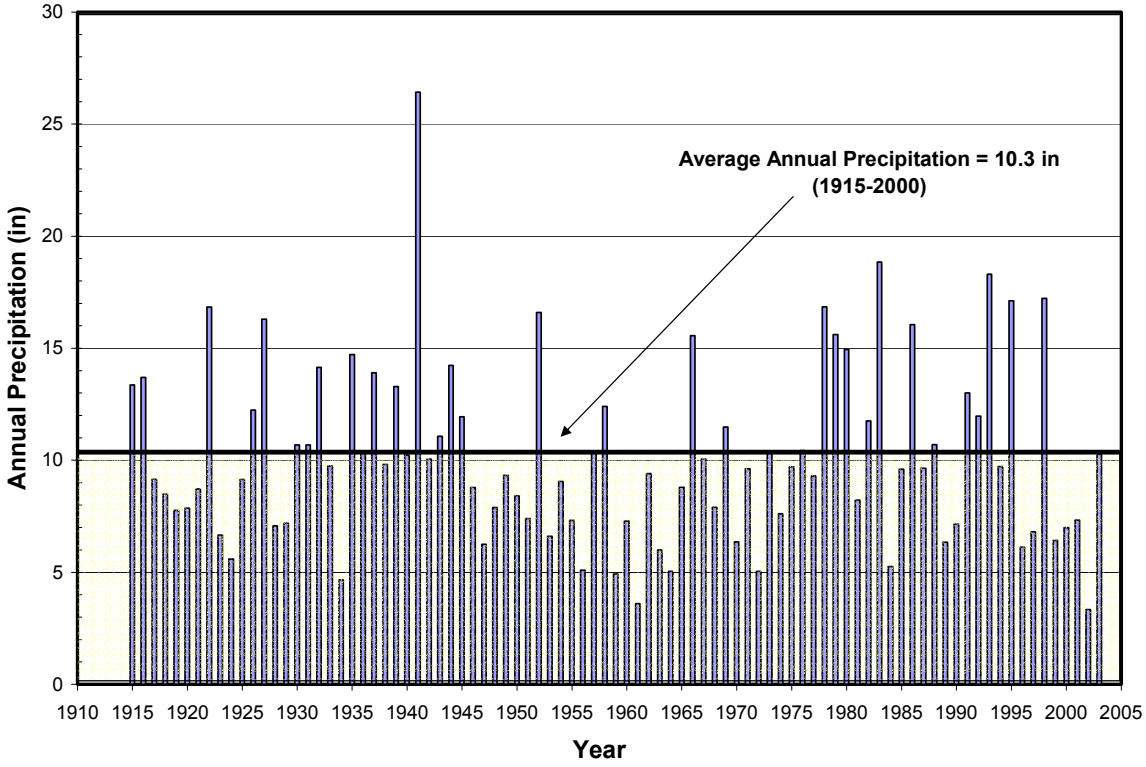


Figure 2. Annual Precipitation at Lindberg Field, 1915-2003

The cumulative residual rainfall at Lindberg Field is shown in Figure 3. Residual rainfall represents the difference between the rainfall observed in a particular year and the average annual rainfall. When the residual values are summed over extended periods of time, the resulting cumulative values provide an indication of long-term climatic trends (Inman and Jenkins, 1999). A positive slope to the graph denotes a "wet" period of above-average precipitation, while a negative slope denotes a "dry" period of below-average precipitation.

Notwithstanding several short-term exceptions, the period from 1945 through 1977 can be characterized as dry, while the period from 1978 through the mid-1990's can be characterized as wet. More recently, the five consecutive years of below-average to average rainfall that have followed the 1997-98 El Niño event suggest the onset of another dry period.

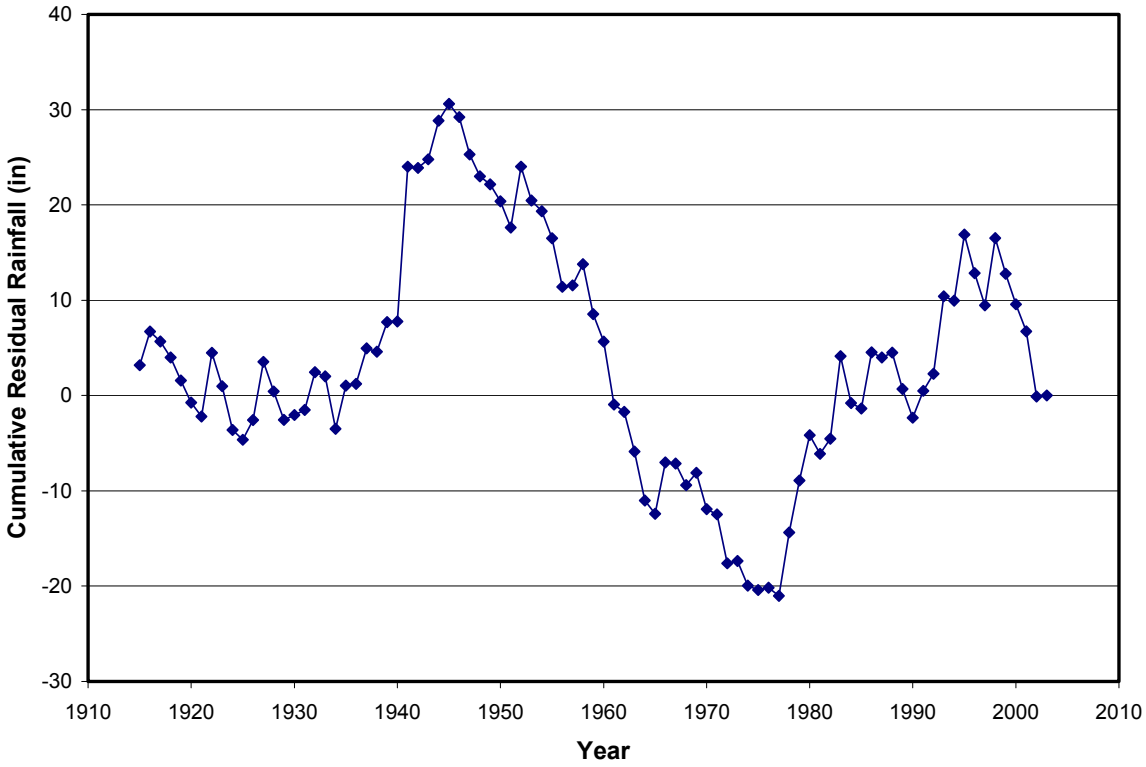


Figure 3. Cumulative Residual Rainfall at Lindberg Field, 1915-2003

2.1.2. Streamflow

Daily streamflow measurements for the San Luis Rey and San Diego Rivers were obtained from the U.S. Geological Survey (USGS, 2004). The mouth of the San Luis Rey River is located approximately 0.5 miles southeast of Oceanside Harbor, while that of the San Diego River adjoins the entrance to Mission Bay (Figure 1). These rivers were selected for analysis because they are among the largest in the study area, and because streamflow data are available for an extended period of record that includes the RBSP Monitoring Years.

Figure 4 presents the annual mean streamflow measured in each river between 1983 and 2003. In keeping with the rainfall data discussed in Section 2.1.1, the flow has been below average since the 1997-98 El Niño event. During the 2003 Monitoring Year, the streamflow in each river exceeded that recorded in the prior two years comprising the RBSP Monitoring Period but nevertheless remained substantially less than the long-term average. It should be noted that two substantial gaps exist in the data for the San Luis Rey: (1) October 1992-August 1993, and (2) November 1997-May 1998. Both of these periods

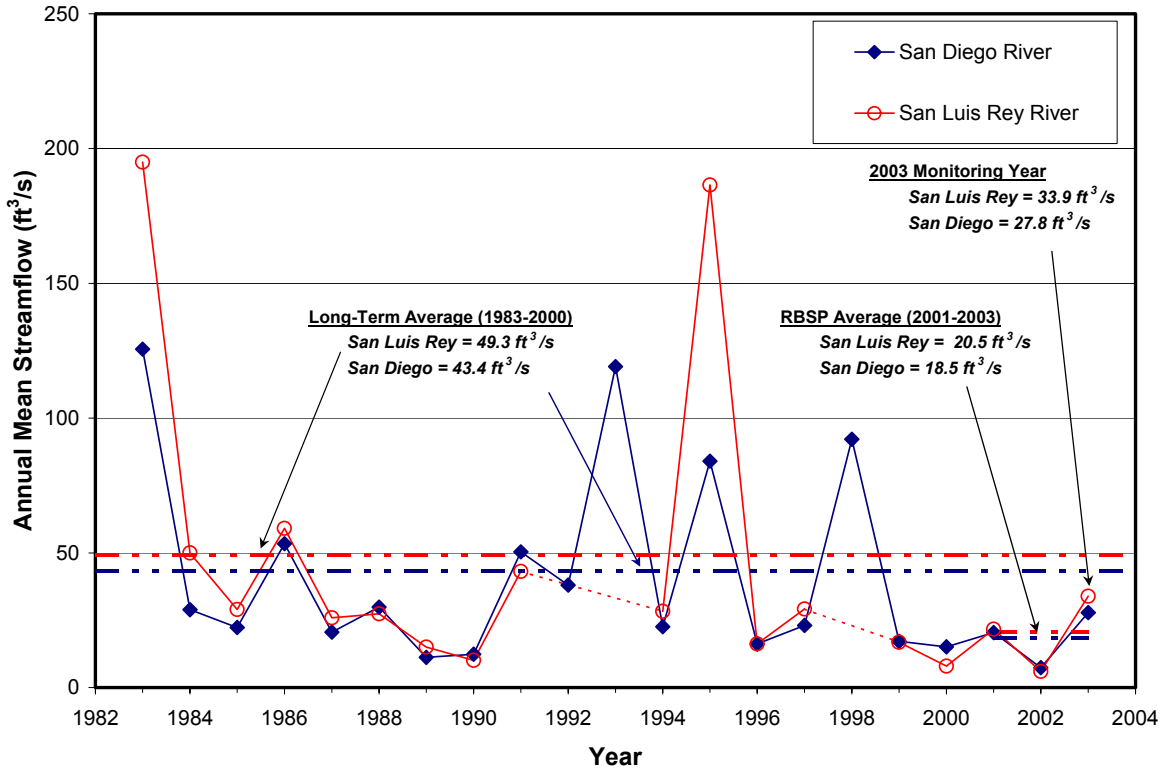


Figure 4. Annual Mean Streamflow in the San Luis Rey and San Diego Rivers, 1983-2003

were characterized by high flow rates in the San Diego River, suggesting that the true long-term average for the San Luis Rey is higher than that shown in Figure 4.

Figures 5 and 6 compare the monthly mean streamflow in each river during the 2001, 2002, and 2003 Monitoring Years with the long-term monthly mean values for the period 1983-2000. As in the case of the annual data presented in Figure 4, the monthly data indicate that the RBSP Monitoring Period has been characterized by below-average flow rates. The sole exceptions occurred in February and April 2003 (Months 4 and 6 in Figure 5), when the flows in the San Luis Rey exceeded the long-term values. It should be noted, however, that the long-term monthly values for the San Luis Rey would be higher than those shown in Figure 5 were it not for the two data gaps identified above.

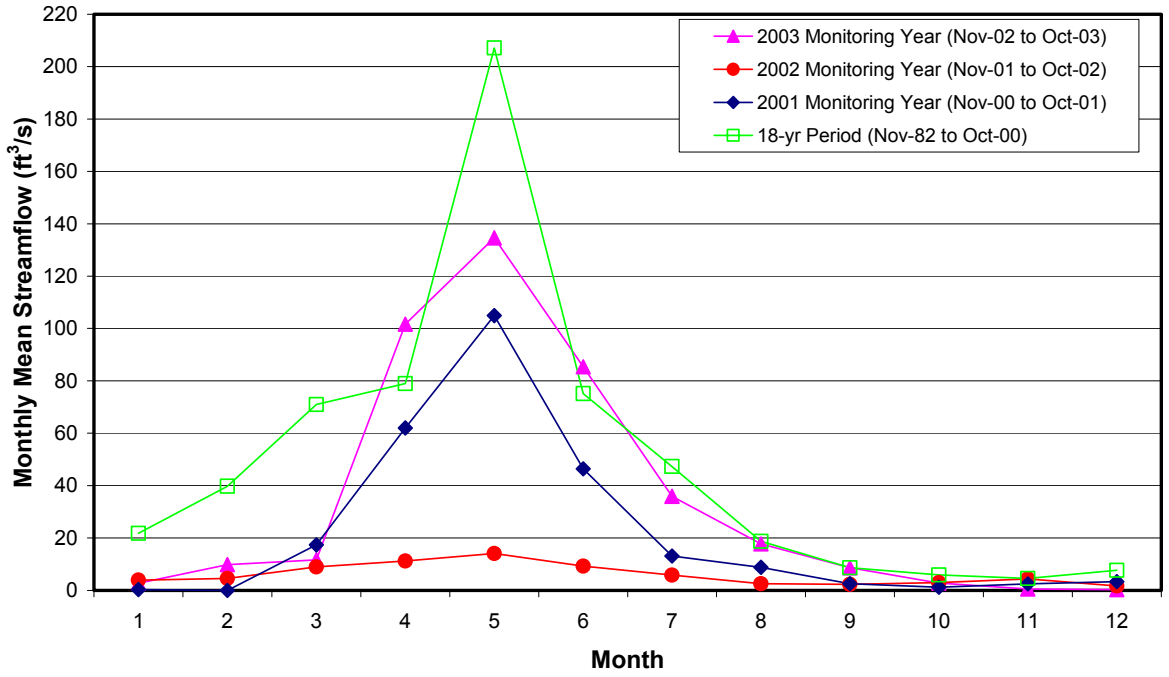


Figure 5. Monthly Mean Streamflow in the San Luis Rey River

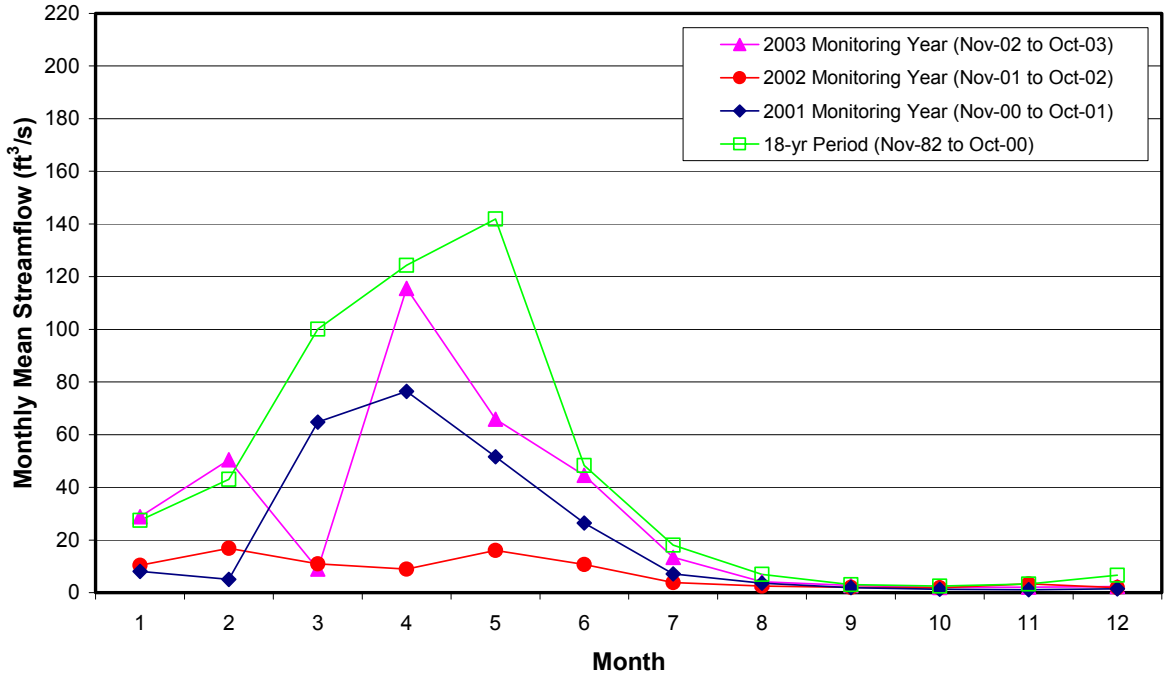


Figure 6. Monthly Mean Streamflow in the San Diego River

2.1.3. Wave Climate

Two measures of the wave climate were used to compare the potential for sediment transport during the RBSP Monitoring Period with that in previous years: (1) total wave energy, and (2) the number of storm events. Although both measures are imperfect, they nevertheless provide a first-order basis for the desired inter-annual comparison.

The analysis was undertaken with wave measurements acquired under the auspices of the Coastal Data Information Program (CDIP), which is operated by Scripps Institution of Oceanography (2004). The CDIP Oceanside Buoy was selected as the data source, primarily because the period of record (May 1997-present) exceeds that of the other offshore measurement stations in the area (Point La Jolla, Torrey Pines, and Dana Point).

The significant wave height (H_s), peak wave period (T_p), and wave direction recorded at the Oceanside Buoy during the 2003 Monitoring Year are presented as time series in Figure 7. Northerly swell characteristic of the winter months predominated in November, December, and January, while southerly swell characteristic of the summer months predominated from May through September. The remaining months, February through April in the spring and October in the fall, served as transitional periods with a mixture of northerly and southerly swell. The most severe storms occurred in December, February, and March.

The total wave energy in each Monitoring Year from 1998 through 2003 was compared using the Relative Incident Energy Index (E_r) developed by Seymour (1998). This index is based on the following proportionality between the wave power per unit crest length (P) in deep water, the significant wave height (H_s) and the peak wave period (T_p):

$$P \sim H_s^2 T_p \qquad (1)$$

The total energy per unit crest length (E) delivered in a year is found by integrating the wave power (P) over the time (t):

$$E = \int P \, dt \qquad (2)$$

Using Equations (1) and (2) with the wave height expressed in meters, the wave period in seconds, and the duration in hours, Seymour defined E_r as follows:

$$E_r = E/1000 \qquad (3)$$

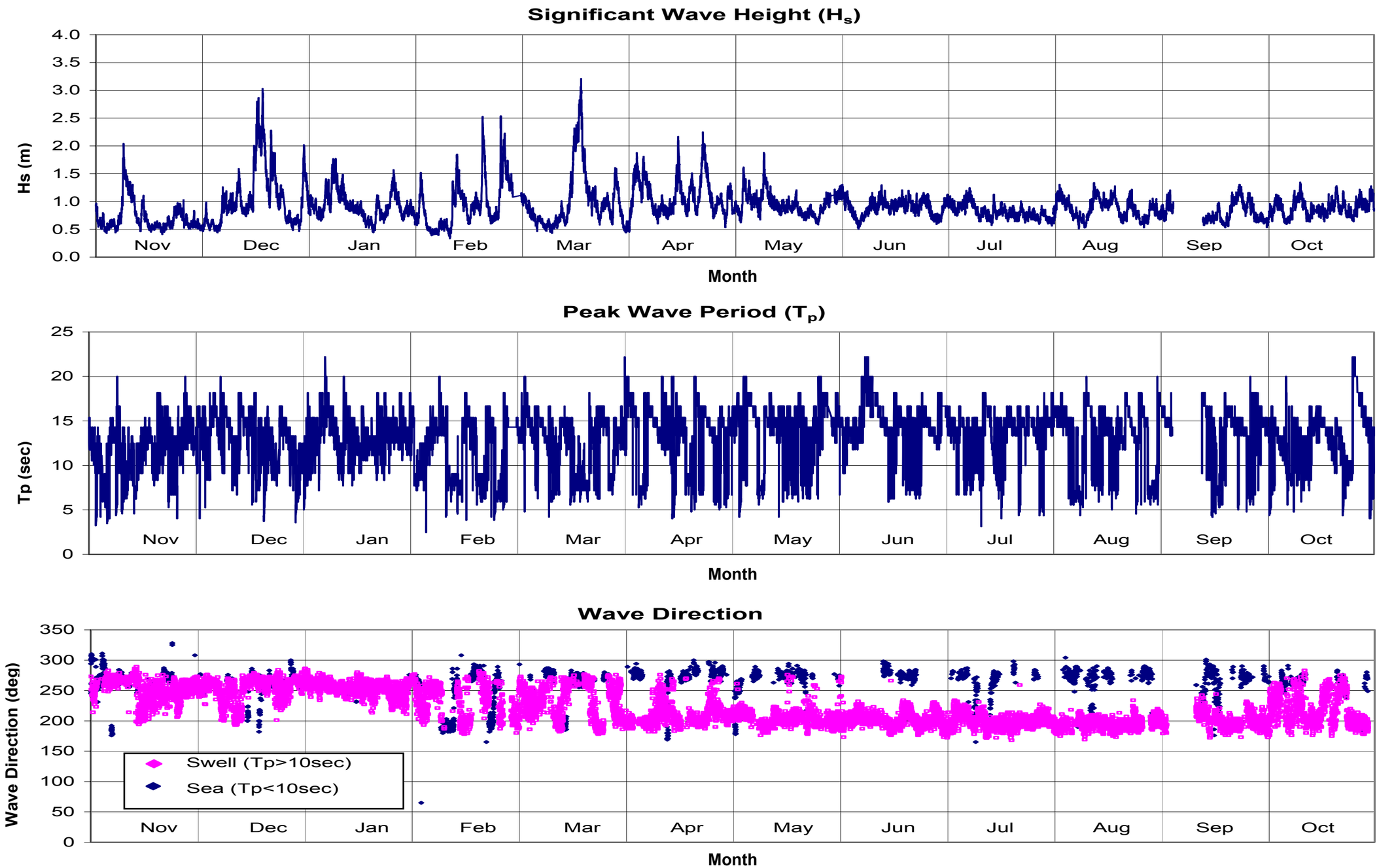


Figure 7. **Wave Characteristics at the Oceanside Buoy, 2003 Monitoring Year**

The computed values of Er are shown in Figure 8. Gaps in the Oceanside Buoy data were accounted for by assuming that the average wave power during the remainder of the year prevailed during the period lacking measurements. The highest Energy Index, with a value of 149, occurred during the 1998 El Niño year. The index then decreased during each of the next four years, attaining a minimum value of 87 in 2002 before rebounding to 103 in 2003.

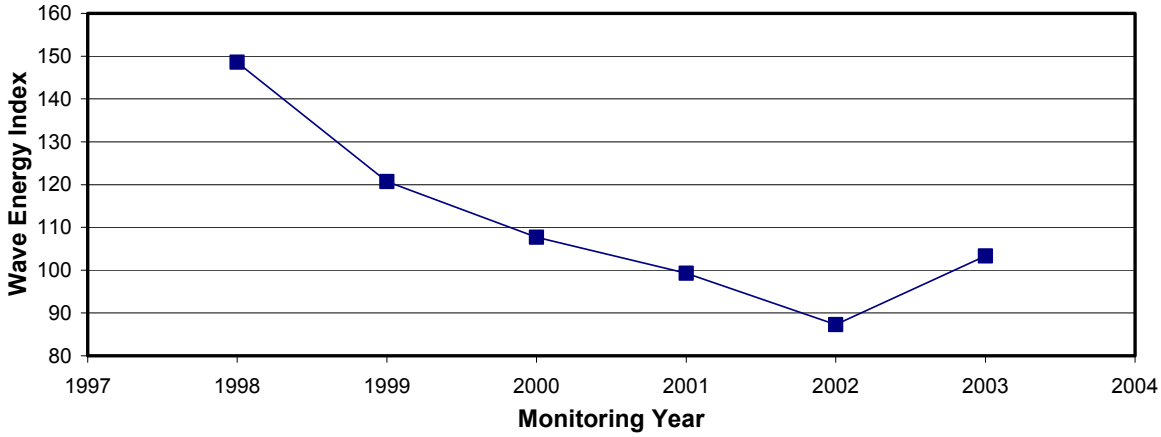


Figure 8. Relative Incident Energy Index at the CDIP Oceanside Buoy, 1998-2003

Figure 9 displays the number of storms per year with significant wave heights exceeding threshold values of 7 ft (2.1 m) and 10 ft (3.0 m). As in the case of the Relative Incident Energy Index, the storm frequency data indicate that the most severe conditions occurred in 1998, when H_s exceeded 7 ft on sixteen occasions and 10 ft on six occasions. During the 2001 Monitoring Year, H_s surpassed 7 ft on six occasions and 10 ft on two occasions. However, all of the 2001 storm events occurred before the initiation of the RBSP nourishment activities on April 6. The storms during the 2002 Monitoring Year were relatively mild, with H_s exceeding 7 ft on seven occasions but never attaining 10 ft. In 2003, H_s again exceeded 7 ft on seven occasions but also exceeded 10 ft on two. The maximum significant wave height in 2003, 10.5 ft (3.21 m), occurred on March 17 in the form of northwesterly seas with a peak period of only 7.7 sec.

2.2. Sediment Management Activities

Human activities that exert a significant influence on the San Diego County coast include beach nourishment projects such as the RBSP, and sand bypassing at littoral barriers such as Oceanside Harbor. The RBSP is discussed in Section 2.2.1, other nourishment projects in Section 2.2.2, and sand bypassing in Section 2.2.3.

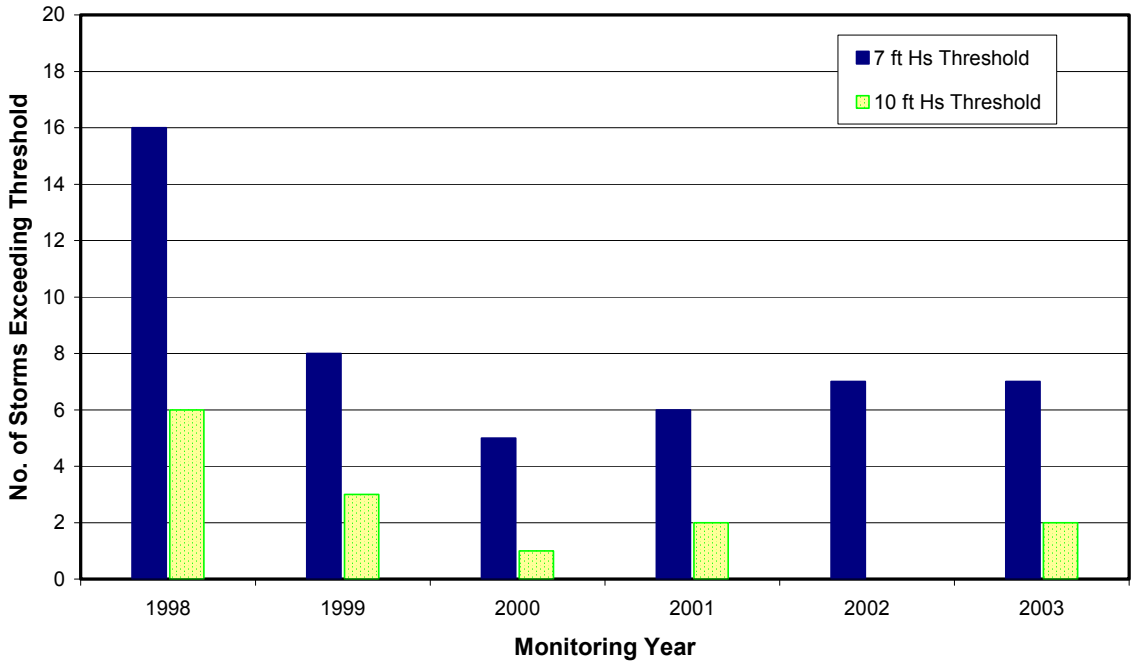


Figure 9. Storm Events per Year with Significant Wave Heights Exceeding 7 ft and 10 ft, 1998-2003

2.2.1. Regional Beach Sand Project

In 1993, SANDAG adopted a comprehensive plan for erosion mitigation known as the "Shoreline Preservation Strategy for the San Diego Region." The Strategy proposed an extensive beach building and maintenance program to provide for environmental quality, recreation, and storm protection in the coastal zone. Following a number of modest beach nourishment projects that were undertaken primarily on an opportunistic basis (i.e., when sand became available from other sources), the Regional Beach Sand Project (RBSP) was conceived as a more comprehensive approach to restoring the County's sand-starved beaches.

Between April 6 and September 23, 2001, the RBSP provided 2.1 million cubic yards (cy) of beach-quality sand to twelve receiver beaches located between Imperial Beach and Oceanside. The material was excavated from six offshore borrow areas using a trailing suction hopper dredge, and pumped onto the subaerial portion of each receiver beach (Noble, 2002). Once on the beach, the sand was shaped to the design configuration using conventional earth-moving equipment. The median grain size (d50) varied considerably among the borrow areas, ranging from 0.14 mm (fine sand) to 0.62 mm (coarse sand) (Noble Consultants, 2001).

Table 1 provides the volume, dimensions, and median grain size of each beach fill, along with the construction period. The majority of the sand, 1.8 million cy, was used to nourish ten receiver beaches in the Oceanside Littoral Cell. The nourishment quantities at these sites ranged from 421,000 cy at Oceanside to 101,000 cy at Cardiff. In the Mission Beach Cell, 151,000 cy were placed at Mission Beach while in the Silver Strand Cell, 120,000 cy were placed at Imperial Beach.

Table 1. RBSP Beach Fills

Littoral Cell	Receiver Beach	Fill Characteristics				Construction Period[2]
		Volume (cy)	Length (ft)	Width (ft)	d_{50} (mm)[1]	
Silver Strand	Imperial Bch	120,000	2300	120	0.24-0.52	5/22 - 6/04
	Total Nourishment in Silver Strand Cell = 120,000 cy					
Mission Beach	Mission Bch	151,000	2300	200	0.52	5/10 – 5/21
	Total Nourishment in Mission Beach Cell = 151,000 cy					
Oceanside	Torrey Pines	245,000	1600	160	0.14	4/06 – 4/27
	Del Mar	183,000	3200	120	0.14	4/27 – 5/10
	Fletcher Cove	146,000	1900	70	0.14	6/15 – 6/24
	Cardiff	101,000	900	150	0.34	8/02 – 8/10
	Moonlight Bch	105,000	1100	180	0.34-0.62	8/10 – 8/16
	Leucadia	132,000	2700	120	0.62	6/04 – 6/15
	Batiquitos	117,000	1500	180	0.62	8/16 – 8/23
	S. Carlsbad	158,000	2000	180	0.62	6/25 – 7/06
	N. Carlsbad	225,000	3100	100	0.14-0.62	7/06 – 8/02
	Oceanside	421,000	4400	185	0.62	8/24 – 9/23
	Total Nourishment in Oceanside Cell = 1,833,000 cy					
Total RBSP Nourishment = 2,104,000 cy						

Note: [1] d_{50} represents median grain size of fill material.
[2] All nourishment activities were conducted in 2001

Source: Noble Consultants, 2001

2.2.2. Other Nourishment Projects

A number of beach nourishment projects were undertaken in San Diego County prior to the RBSP, as well as two small projects after placement of the RBSP fill material. Nearly all of the pre-RBSP nourishment projects depended on "sand of opportunity" that was derived from activities whose primary motive was other than beach replenishment. The largest sources of opportunistic nourishment were the dredge spoils associated with lagoon restoration and harbor maintenance. The non-RBSP nourishment projects conducted between November 1993 and October 2003 are summarized below by littoral cell. Two periods are considered: (1) the seven-year span from November 1993 through October 2000, and (2) the RBSP Monitoring Period (November 2000 through October 2003). The November 1993-October 2000 time period was selected for analysis because it commences with the adoption of SANDAG's Shoreline Preservation Strategy and concludes just prior to the inception of the RBSP.

Silver Strand Littoral Cell

Five opportunistic beach nourishment projects were undertaken in the Silver Strand Littoral Cell during the seven-year period that preceded the RBSP. One was associated with lagoon enhancement at the Tijuana Estuary, while the other four originated with construction and maintenance activities in San Diego Harbor. As shown in Table 2, these projects resulted in an average annual nourishment rate of 73,000 cubic yards/year (cy/yr). In contrast, no sand replenishment projects have been undertaken in the Silver Strand Cell since the placement of the RBSP fill material at Imperial Beach in 2001.

Mission Beach Littoral Cell

Nourishment activity in the Mission Beach Cell preceding the RBSP was limited to the placement of approximately 12,000 cubic yards of sand off of Mission Beach as part of the aborted U.S. Navy Homeporting Project. This small amount equates to an average annual nourishment rate of about 2,000 cy/yr for the 1993-2000 period of interest. Other than the RBSP fill at Mission Beach, the littoral cell has received no additional nourishment material during the 2001, 2002, and 2003 Monitoring Years.

Table 2. Beach Nourishment in the Silver Strand Littoral Cell Preceding the RBSP, November 1993 through October 2000

Project	Date	Sediment Source	Placement Location	Nourishment Quantity (cy)
U.S. Navy Pier 2 Dredging	1995	San Diego Harbor	Imperial Beach (nearshore)	233,000
U.S. Coast Guard Ballast Point Dredging	1995	San Diego Harbor	Imperial Beach (nearshore)	41,000
SIO Nimitz Marine Facility Dredging	1996	San Diego Harbor	Imperial Beach (nearshore)	47,000
San Diego Harbor Maintenance Dredging	1996	San Diego Harbor	Silver Strand State Beach (nearshore)	175,000
Tijuana Estuary Tidal Restoration Project	1997	Tijuana Estuary	South of River Mouth	18,000
Average Annual Nourishment Rate in the Silver Strand Cell = 73,000 cy/yr				

Source: SANDAG, 1996 and 1999a; Sachs, 2002

Oceanside Littoral Cell

Eight nourishment projects, seven of which were opportunistic, were undertaken in the Oceanside Cell between 1993 and 2000. As enumerated in Table 3, the total volume of 2.75 million cubic yards was equivalent to an average annual nourishment rate of 393,000 cy/yr. Nearly two thirds of the material was derived from the Batiquitos Lagoon restoration project, which provided 1.8 million cubic yards for beach replenishment in Carlsbad. The only non-opportunistic beach fill activity occurred at Moonlight Beach, where approximately 1,000 cy of purchased sand was placed as a protective berm each year from 1996 through 2000.

Table 4 lists the two small non-RBSP nourishment projects undertaken in the Oceanside Cell during the RBSP Monitoring Period. Both were conducted at Moonlight Beach, where the aforementioned practice of adding 1,000 cy per year to construct a protective berm was continued in 2001 and 2002. In 2003, the berm was constructed from material already present on the beach rather than from imported material.

Table 3. Beach Nourishment in the Oceanside Littoral Cell Preceding the RBSP, November 1993 through October 2000

Project	Date	Sediment Source	Placement Location	Nourishment Quantity (cy)
Batiquitos Lagoon Enhancement	1994-97	Batiquitos Lagoon	Carlsbad	1,800,000
Descanso/Carlsbad Blvd. Lot Division	1994	Inland	Carlsbad	20,000
Santa Margarita River Desiltation	1995	River Mouth	Oceanside	40,000
Moonlight Beach Nourishment	1996-2000	Inland (non-opportunistic)	Encinitas	5,000
U.S. Navy Homeporting	1997	North Island	Oceanside	102,000
			Del Mar (nearshore)	170,000
Sand-for-Trash Pilot Program	1997	Inland	Oceanside	1,000
Agua Hedionda Facilities Modification	1998	Agua Hedionda Lagoon	Carlsbad	560,000
North County Commuter Rail Project	1999	Inland	Solana Beach	54,000
Average Annual Nourishment Rate in the Oceanside Cell (Nov 93 – Oct 00) = 393,000 cy/yr				

Source: SANDAG, 1996, 1999a; Sachs, 2002

Table 4. Non-RBSP Beach Nourishment in the Oceanside Littoral Cell, November 2000 through October 2003

Project	Date	Sediment Source	Placement Location	Nourishment Quantity (cy)
Moonlight Beach Nourishment	2001	Inland (non-opportunistic)	Encinitas	1,000
Moonlight Beach Nourishment	2002	Inland (non-opportunistic)	Encinitas	1,000
Average Annual Nourishment Rate in the Oceanside Cell (Nov 00 – Oct 03) = 1,000 cy/yr				

Source: Frenken, 2002; Keeley, 2003; Keeley, 2004

2.2.3. Sand Bypassing

Sand bypassing is used to return sediment to the littoral system that has been trapped by coastal features such as harbors, lagoon entrances, and jetties. Although bypassing does not increase the quantity of sediment in the littoral system, it plays a crucial role in maintaining the distribution of sediment within that system. Because sediment trapping is an ongoing process, bypassing operations typically are conducted at periodic intervals.

Bypassing is not undertaken in the Silver Strand and Mission Beach Cells, but occurs at Batiquitos Lagoon, Agua Hedionda Lagoon, and Oceanside Harbor in the Oceanside Cell. The bypassing operations at Batiquitos were initiated in 1997 following lagoon restoration, while the bypassing operations at Agua Hedionda and Oceanside Harbor have been performed on a regular basis for decades. The sediment quantities bypassed at each site between November 1993 and October 2000 (pre-RBSP) are shown in Table 5. It should be noted that the Oceanside Harbor bypass quantities differ from those presented in the 2001 Annual Report (Coastal Frontiers, 2002) because they reflect more accurate information provided by the U.S. Army Corps of Engineers (Ryan, 2003).

Relatively high bypass rates, averaging 252,000 and 143,000 cy/yr, were maintained at Oceanside and Agua Hedionda, respectively. In contrast, the average rate at Batiquitos was only 2,000 cy/yr. This large disparity may be explained by the aforementioned lagoon restoration project in Batiquitos Lagoon. The entrance channel was first opened to continuous tidal exchange in late 1995 (Webb, 2004), and the restoration project was not completed until 1997. In consequence, the years preceding the RBSP represented a transition period for the lagoon, and the low bypass rate at Batiquitos should be regarded as anomalous.

The sediment quantities bypassed at each site during the RBSP Monitoring Period (November 2000-October 2003) are presented in Table 6. At Oceanside Harbor, bypass operations were conducted in each of the three Monitoring Years. The average rate of 306,000 cy/yr exceeded the pre-RBSP rate by 54,000 cy/yr.

At Agua Hedionda, where bypassing typically occurs every second year, such operations were undertaken in 2001 and 2003. The average rate during the three-year RBSP Monitoring Period, 255,000 cy/yr, was substantially higher than the pre-RBSP rate of 143,000 cy/yr. This comparison is misleading, however, because bypassing probably will not occur again until 2005. If the quantities dredged in 2001 and 2003 are assumed to apply to a four-year period, the average rate declines to 192,000 cy/yr (which is 49,000 cy/yr

Table 5. Sand Bypassing in the Oceanside Littoral Cell Preceding the RBSP, November 1993 through October 2000

Bypass Project	Date	Placement Location	Bypass Quantity (cy)
Batiquitos Lagoon	1999	South of Entrance	11,000
	2000	South of Entrance	4,000
	Average Annual Bypass Rate at Batiquitos Lagoon = 2,000 cy/yr		
Agua Hedionda Lagoon	1994	Carlsbad	159,000
	1996	Carlsbad	443,000
	1997	Carlsbad	197,000
	1999	Carlsbad	203,000
	Average Annual Bypass Rate at Agua Hedionda Lagoon = 143,000 cy/yr		
Oceanside Harbor	1994	Oceanside	483,000
	1995	Oceanside	161,000
	1996	Oceanside	162,000
	1997	Oceanside	130,000
	1998	Oceanside	315,000
	1999	Oceanside	187,000
	2000	Oceanside	327,000
	Average Annual Bypass Rate at Oceanside Harbor = 252,000 cy/yr		

Source: Dillingham, 2002; Tucker, 2002; Ryan, 2003

higher than the pre-RBSP value). It is noteworthy that the unusually high quantity of material bypassed in 2001, 429,000 cy, was dredged prior to or concurrent with the start of the RBSP nourishment program. In consequence, the increased bypass rate at Agua Hedionda during the RBSP Monitoring Period cannot be attributed to trapping of the nourishment material.

At Batiquitos, bypassing was undertaken only in 2001. Although the resulting average rate of 15,000 cy/yr during the RBSP Monitoring period exceeded the pre-RBSP average of 2,000 cy/yr, the latter figure is anomalously low for the reasons presented above. In addition, 75,000 cy of sediment were dredged from the lagoon in 2003 but used to enhance least tern nesting sites within the lagoon rather than for bypassing (Dillingham, 2004). Hence, the bypass rate could have been substantially higher during the RBSP Monitoring Period if this material had been returned to the littoral system.

Table 6. Sand Bypassing in the Oceanside Littoral Cell November 2000 through October 2003

Bypass Project	Date	Placement Location	Bypass Quantity (cy)
Batiquitos Lagoon	2001	South of Entrance	45,000
	Average Annual Bypass Rate at Batiquitos Lagoon = 15,000 cy/yr		
Agua Hedionda Lagoon	2001	Carlsbad	429,000
	2003	Carlsbad	337,000
	Average Annual Bypass Rate at Agua Hedionda Lagoon = 255,000 cy/yr		
Oceanside Harbor	2001	Oceanside	80,000
	2002	Oceanside	400,000
	2003	Oceanside	438,000
	Average Annual Bypass Rate at Oceanside Harbor = 306,000 cy/yr		

Source: Dillingham, 2002; Tucker, 2002; Ryan, 2003, Hughes 2003

2.3. The RBSP Monitoring Period in Perspective

Table 7 compares the environmental conditions that prevailed during the RBSP Monitoring Period with those in the recent past. Although precipitation, streamflow, wave energy and storm frequency all increased in 2003 relative to 2001 and 2002, the average values of these parameters over the three-year Monitoring Period remained well below the pre-RBSP averages. The implications are threefold:

- The mild wave conditions helped to prolong the life of the beach fills.
- The scant precipitation and low streamflows failed to deliver significant quantities of beach-quality sediment to the coast.
- The low streamflows failed to flush coastal sediment from the lagoon entrances in the Oceanside Cell.

In Table 8, the beach nourishment volume provided to each littoral cell during the RBSP Monitoring Period is compared with the average annual volume provided during the seven prior monitoring years. To aid in assessing the significance of the RBSP, comparisons are made both with and without the RBSP fill quantities.

Table 7. Environmental Conditions: RBSP Monitoring Period vs. Historical Average

Parameter[1]	Historical Average	RBSP Average[5]	% of Hist. Average[6]
Precipitation[2] (in.)	10.3	7.0	68%
Streamflow[3] (cfs)			
San Luis Rey River	49.3	20.5	42%
San Diego River	43.4	18.5	43%
Wave Climate[4]			
Energy Index	126	97	77%
Storms w/ H_s>7 ft	9.7	6.7	69%
Storms w/ H_s>10 ft	3.3	1.3	39%

Notes:
(1) Parameters represent annual values.
(2) Historical Average Precipitation based on the period 1915-2000.
(3) Historical Average Streamflow based on the period 1983-2000.
(4) Historical Average Energy Index and Storms based on the period 1998-2000.
(5) RBSP Average based on the RBSP Monitoring Period (2001-2003).
(6) % of Hist. Average represents RBSP Average divided by Historical Average.

Table 8. Beach Nourishment Rates: RBSP Monitoring Period vs. Historical Average

Littoral Cell	Historical Average[1] (cy/yr)	RBSP Average[2] (cy/yr)		Difference[3] (cy/yr)	
		Without RBSP	With RBSP	Without RBSP	With RBSP
Silver Strand	73,000	0	40,000	(73,000)	(33,000)
Mission Beach	2,000	0	50,000	(2,000)	+48,000
Oceanside	393,000	1,000	612,000	(392,000)	+219,000
Total	468,000	1,000	702,000	(467,000)	+234,000

Notes:
(1) Historical Average based on the period 1993-2000.
(2) RBSP Average based on the RBSP Monitoring Period (2001-2003).
(3) Difference represents RBSP Average minus Historical Average.

As indicated above, the only non-RBSP nourishment provided during the RBSP Monitoring Period was 2,000 cy (less than 1,000 cy/yr) at Moonlight Beach. As a result, two thirds of the RBSP fill material (1,401,000 cy) may be regarded as compensating for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 702,000 cy, represents incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 657,000 cy (equivalent to 219,000 cy/yr over the three-year RBSP Monitoring Period). The Mission Beach Cell received an additional 144,000 cy (48,000 cy/yr), while the Silver Strand Cell incurred a deficit of 99,000 cy (33,000 cy/yr)

due to the lack of nourishment activities other than the RBSP. Of particular note is the fact that absolutely no nourishment was provided in any of the three littoral cells during the 2003 Monitoring Year.

The sand bypass rates at Batiquitos, Agua Hedionda, and Oceanside Harbor during the RBSP Monitoring Period are displayed with the average values from the seven prior monitoring years in Table 9. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the two rates is not meaningful. At both Oceanside and Agua Hedionda, the RBSP rate exceeded the prior value by about 50,000 cy/yr. This increase in the bypassing rate constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor and both north and south of Agua Hedionda.

Table 9. Sand Bypassing: RBSP Monitoring Period vs. Historical Average

Location	Historical Average[1] (cy/yr)	RBSP Average[2] (cy/yr)	Difference[3] (cy/yr)
Batiquitos	2,000	15,000	n/m[4]
Agua Hedionda	143,000	192,000[5]	49,000
Oceanside Harbor	252,000	306,000	54,000

Notes:
(1) Historical Average based on the period 1993-2000.
(2) RBSP Average based on the RBSP Monitoring Period (2001-2003).
(3) Difference represents RBSP Average minus Historical Average
(4) Difference not meaningful because Historical Average bypass rate was derived from the period during and immediately after lagoon restoration.
(5) RBSP Average adjusted from 255,000 to 192,000 cy/yr based on the assumption that bypassing at Agua Hedionda Lagoon is conducted every two years.

3. MONITORING METHODS

As indicated in Section 1, the general objective of the 2003 Regional Beach Monitoring Program was to detect changes in the condition of the shorezone between the U.S.-Mexican Border and Oceanside Harbor. The specific focus was to track the performance of the twelve RBSP beach fills, including their impacts on the neighboring beaches and lagoon entrances.

Although the two program components, beach monitoring and lagoon entrance monitoring, resembled those in the years preceding the RBSP, both were expanded in 2001 to develop more detailed information about the outcome of the nourishment activities. The underlying rationale was to provide coverage of each of the twelve receiver beaches, enhanced coverage of four of these sites (North Carlsbad, Leucadia, Mission Beach, and Imperial Beach), and enhanced coverage of the three unstabilized lagoon entrances in the Oceanside Cell (San Elijo, San Dieguito, and Los Peñasquitos). The program was further enhanced in 2002 by adding four beach profile transects and removing one transect of questionable value. The 2003 monitoring effort was identical to that undertaken in 2002.

Data acquisition and reduction under each program component are described in the subsections that follow.

3.1. Beach Monitoring

The beach monitoring component consisted of semi-annual beach profile surveys, semi-annual oblique aerial photography, and monthly beach width measurements. The beach profiling and aerial photography were performed by Coastal Frontiers personnel, while the beach width measurements were made by representatives of the cities in whose jurisdictions the beaches were located.

3.1.1. Semi-Annual Beach Profile Surveys

Beach profile data were obtained in the Spring and Fall of 2003, corresponding to the transitions between the winter and summer wave seasons along 61 previously established transects. The locations of the transects are listed in Table 10, and illustrated in Figures 10a and 10b.

Table 10. Beach Profile Transect Locations

	TRANSECT[6]	LOCATION	SPONSOR	TRANSECT[5]	LOCATION	SPONSOR
Silver Strand Littoral Cell	SS-0003	Tijuana Estuary	SANDAG	SS-0035[3]	Imperial Beach	SANDAG
	SS-0005[4]	Tijuana Estuary	SANDAG	SS-0050[2,3]	Imperial Beach	SANDAG
	SS-0015[3]	Imperial Beach	SANDAG	SS-0077	Silver Strand	SANDAG
	SS-0020[1,2,3]	Imperial Beach	SANDAG	SS-0090	Silver Strand	SANDAG
	SS-0025[1,2,3]	Imperial Beach	SANDAG	SS-0160	Coronado	SANDAG
Mission Beach Littoral Cell	OB-0230	Ocean Beach	SANDAG	MB-0384[3]	Mission Beach	SANDAG
	MB-0310[3]	Mission Beach	SANDAG	PB-0408	Pacific Beach	SANDAG
	MB-0320[2,3]	Mission Beach	SANDAG			
	MB-0335[1,2,3]	Mission Beach	SANDAG			
	MB-0340[1,3]	Mission Beach	SANDAG			
Oceanside Littoral Cell	LJ-0443	La Jolla	SANDAG	SD-0690[1,2,3]	Leucadia	SANDAG
	LJ-0450	La Jolla	SANDAG	SD-0695[2,3]	Leucadia	SANDAG
	LJ-0445	La Jolla	SANDAG	SD-0700[3]	Grandview	SANDAG
	LJ-0460	Scripps Pier	SANDAG	SD-0710[1,2]	Batiquitos	Encinitas
	TP-0470	Blacks Beach	SANDAG	CB-0720	Batiquitos	SANDAG
	TP-0520[1]	Torrey Pines	SANDAG	CB-0740	South Carlsbad	Carlsbad
	TP-0530[1]	Torrey Pines	SANDAG	CB-0760	Ponto Beach	SANDAG
	DM-0565[2]	South Del Mar	SANDAG	CB-0775[1,2]	South Carlsbad	SANDAG
	DM-0560[4]	Del Mar	SANDAG	CB-0780	Carlsbad	Carlsbad
	DM-0580[1]	Del Mar	SANDAG	CB-0800	Carlsbad	Carlsbad
	DM-0590	Del Mar	SANDAG	CB-0820	Aqua Hedionda	Carlsbad
	SD-0595[4]	Seascape Surf	Solana	CB-0830	Carlsbad	SANDAG
	SD-0600[1]	Fletcher Cove	SANDAG	CB-0840[3]	Carlsbad	Carlsbad
	SD-0610[4]	Tide Park	Solana	CB-0850[3]	Carlsbad	Carlsbad
	SD-0620	Seaside Park	Encinitas	CB-0865[1,2,3]	Carlsbad	SANDAG
	SD-0625	San Elijo	Encinitas	CB-0880[1,3]	Buena Vista	SANDAG
	SD-0630[1]	Cardiff	SANDAG	OS-0900[3]	Oceanside	Carlsbad
	SD-0650	San Elijo Park	Encinitas	OS-0915[1,2]	Oceanside	SANDAG
	SD-0660	Swami's	Encinitas	OS-0930[1]	Buccaneer Bch	SANDAG
	SD-0670[1,3]	Moonlight Beach	SANDAG	OS-1000	Oceanside	SANDAG
	SD-0675[2,3]	Stone Steps	SANDAG	OS-1030	Oceanside	SANDAG
	SD-0680[3]	Beacons	SANDAG	OS-1070	Oceanside	SANDAG

Notes:
(1) Transect crosses RBSP nourishment site (red type).
(2) Transect established to support RBSP in 2001.
(3) Transect used for monthly beach width measurements.
(4) Transect added to monitoring program in 2002.
(5) Transect locations shown in Figures 10a and 10b.

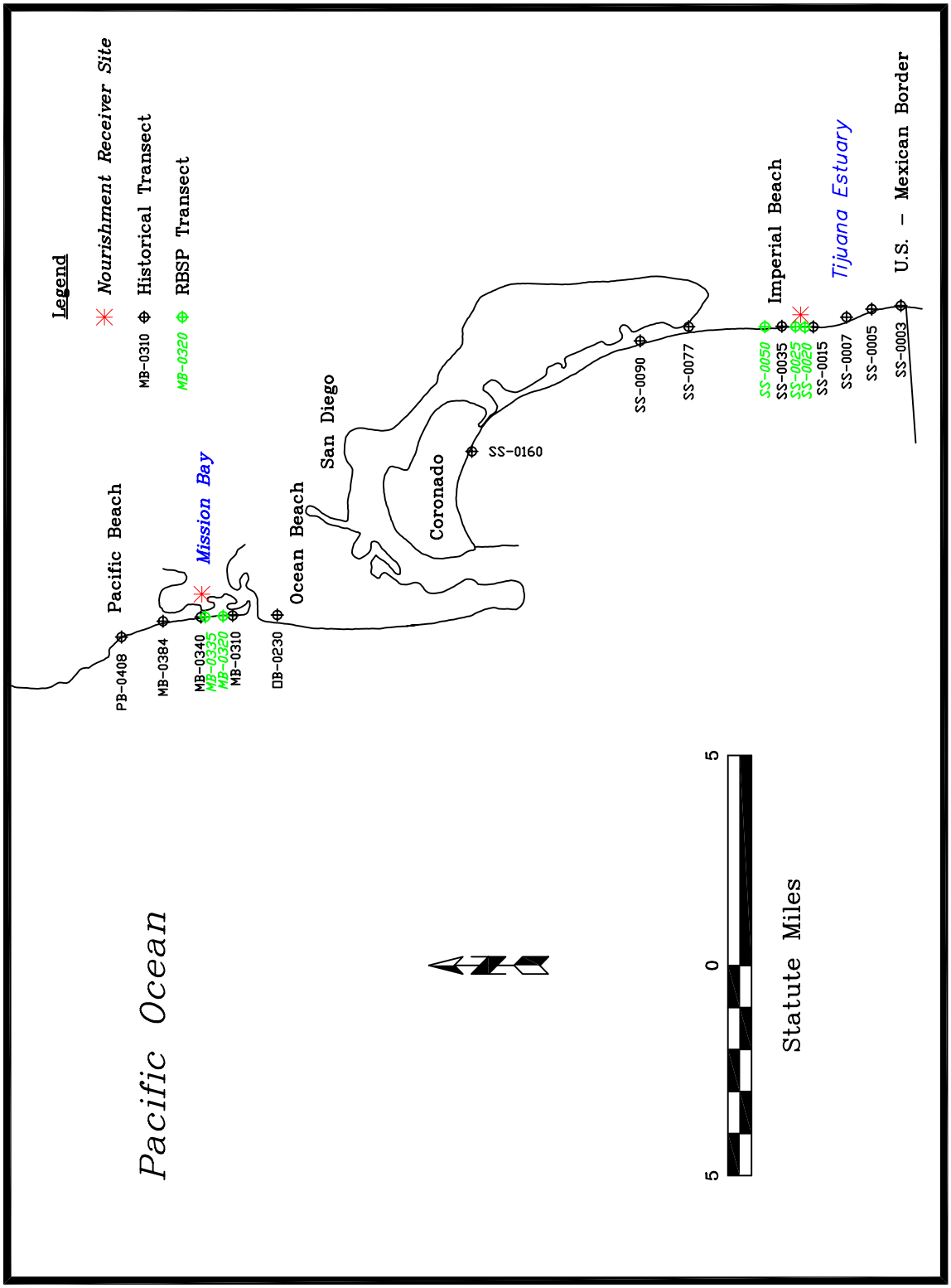


Figure 10a. Beach Profile Transects in the Silver Strand and Mission Beach Littoral Cells

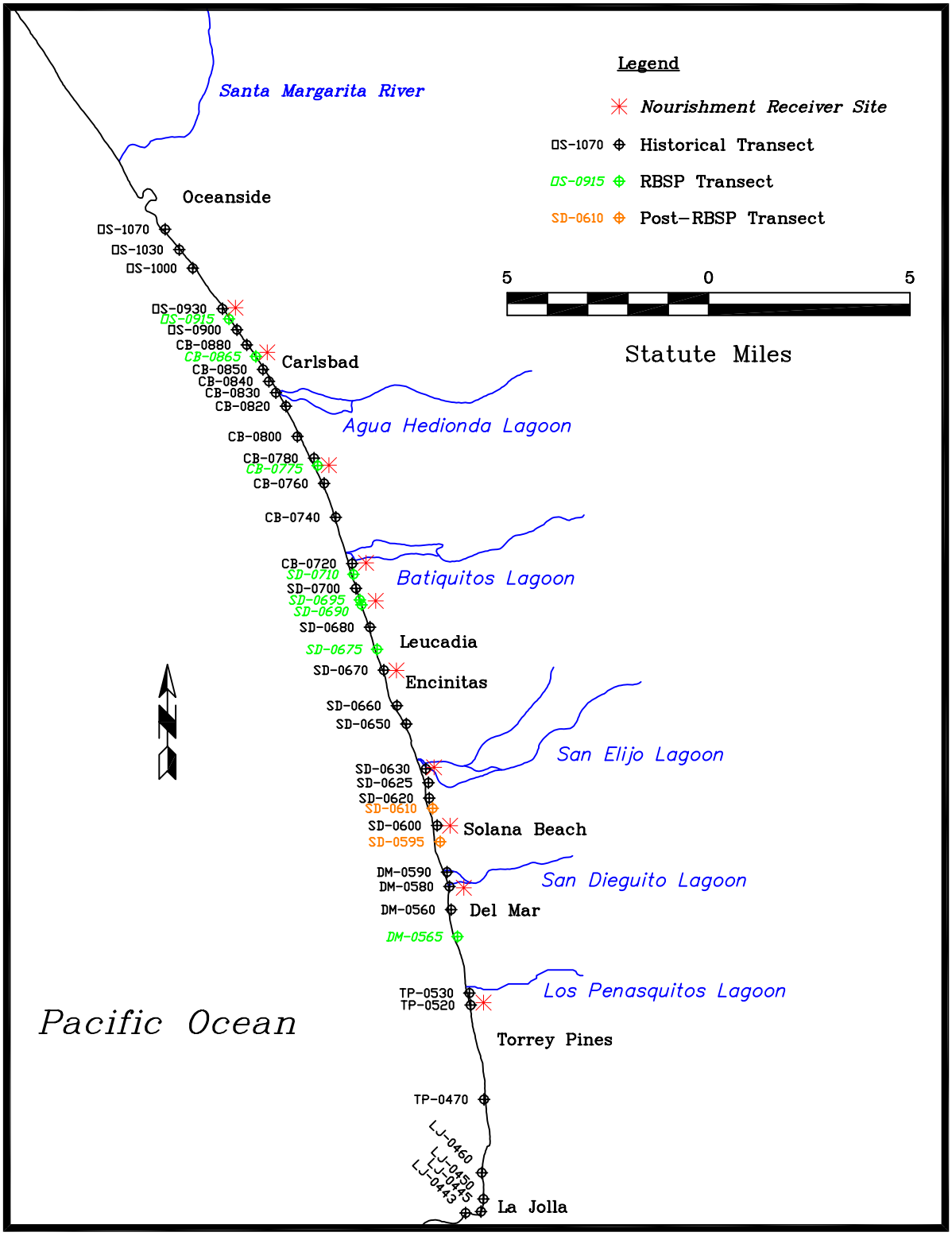


Figure 10b. Beach Profile Transects and Lagoons Entrances in the Oceanside Littoral Cell

Although the Spring 2003 Survey was planned for late April, recurrent periods of high surf necessitated postponement of the start date. Ultimately, the beach profiling activities were conducted over an eight-day period that began on May 13 and ended on May 21. The transects in the Oceanside Cell were surveyed between May 13 and 15. Field activities then were suspended due to another episode of heavy surf. The conditions improved several days later, allowing the Silver Strand and Mission Beach Cell transects to be surveyed on May 20 and 21, respectively. Despite the initial postponement and subsequent interruption of the data acquisition effort in response to large waves, all of the Spring profile data were acquired under favorable conditions that typically included light winds and seas less than 4 ft.

The Fall 2003 beach profiling activities were conducted over a nine-day period that began on October 7 and ended on October 15. The data were acquired under favorable conditions that typically included light winds and seas less than 3 ft.

The data acquisition and processing methods used for the 2003 profile surveys are described below. The methods remained similar to those employed in previous SANDAG and city monitoring programs (Leidersdorf, *et al.*, 1999). In consequence, the results are directly comparable.

Data Acquisition

The wading and bathymetric portions of the survey were performed concurrently by two crews. Data were acquired along each transect from the survey marker to an offshore limit that ranged from the 35-ft isobath in the Silver Strand Cell to the 50-ft isobath in the northern portion of the Oceanside Cell. Each survey marker was located at the back beach, while each offshore limit was located seaward of the "depth of closure" indicated by prior survey data. (The depth of closure is the depth at which sediment transport is not substantially affected by littoral processes.)

The beach and surf zone were surveyed using an electronic total station and a survey rod. The total station was used to determine the position and elevation of the beach at each location occupied by the rod. Each transect was surveyed from the back beach seaward through the surf zone until the rod no longer protruded above the water surface when held erect. This location, typically in a water depth of 10 to 12 ft below MLLW, provided substantial overlap with the landward portion of the bathymetric survey.

Bathymetric data were acquired with a digital acoustic echo sounder operated from a shallow-draft inflatable survey vessel. To improve the resolution of the sonar system,

particularly in areas of localized vertical relief, two additional devices introduced in 2002 were used again in 2003: (1) a dynamic motion sensor to provide real-time corrections for vessel heave, and (2) a ruggedized field computer to log sounding and position data. The position data were acquired with a GPS unit receiving real-time corrections (DGPS) broadcast from the U.S. Coast Guard Station on Point Loma.

At each transect, the boat traveled from the offshore limit to the surf zone guided by DGPS navigation. Soundings were acquired on a near-continuous basis (approximately three per second). Vessel positions were recorded at 1-second intervals and merged with the soundings using Hypack bathymetric survey software. The calibration of the echo sounder was checked at the beginning and end of each survey session, and at periodic intervals during each session, using a standard "bar check" procedure. In addition, a recording conductivity-temperature-depth (CTD) instrument was used to measure the speed of sound in sea water.

Data Processing

The data from the wading portion of each survey were processed using software developed by Spectra Precision Software Corporation. The raw total station data were read by the software, and the coordinates and elevation of each data point were calculated and inserted into a CAD drawing.

The raw data from the bathymetric portion of each survey consisted of Hypack files containing the heave-compensated soundings and corresponding positions. These data were edited for outliers using the Hypack Single-Beam Processing Module. The soundings then were examined to confirm that the motion compensator had properly filtered wave contamination from the soundings. In several cases where the vessel heave had exceeded the operating range of the motion compensator, the measured depths were smoothed to minimize the influence of wave contamination.

Corrections for the draft of the transducer and the measured speed of sound in sea water then were applied to the measured depths. The speed-of-sound profiles were confirmed using the results of the "bar check" calibration procedure. Finally, the corrected soundings were adjusted to MLLW datum using water level measurements made by the U.S. Department of Commerce, NOAA, at La Jolla.

The adjusted soundings were thinned to a nominal interval of 10 ft to produce a manageable file size suitable for developing beach profile plots. The resulting x, y, z data (easting, northing, and elevation) were inserted into the CAD drawing containing the wading

data. As indicated above, the field work was conducted in such a manner as to provide substantial overlap between the wading and bathymetric portions of the survey. The processed data were examined in this region to insure that the two data sets were compatible. Once this confirmatory inspection had been completed, only the more detailed data in the region of overlap were retained (typically the bathymetric data). The soundings then were projected onto the transect alignment, and the resulting range and elevation data were used to create a continuous beach profile plot.

Based on past experience, the vertical accuracy of the processed soundings is approximately ±0.5 ft. According to the GPS equipment specifications, the root mean square (RMS) accuracy of horizontal positions obtained in the manner described above is 3.1 ft. The electronic total station used to conduct the survey is capable of measuring elevation differences to within ±0.1 ft and ranges to within ±0.5 ft. However, because the swimmer was subjected to waves and currents in the surf zone, the horizontal accuracy perpendicular to each transect (parallel to the shoreline) varied from minimal at short ranges to approximately ±15 ft at the offshore end.

3.1.2. Semi-Annual Aerial Photography

To augment the beach profile data, oblique aerial photographs of the twelve RBSP receiver sites were acquired at approximately the same time as the Spring and Fall surveys. The photographs were taken from a fixed-wing aircraft circling each site at altitudes of 500 to 1,000 ft.

The Spring photos were obtained on May 12, immediately preceding the beach profile survey activities. Impaired visibility (due to forest fires) and adverse weather conditions necessitated delaying the Fall photo mission until November 6, approximately three weeks after completion of the Fall beach profile survey.

3.1.3. Monthly Beach Width Measurements

Monthly beach width measurements were initiated by the cities of Carlsbad, Encinitas, San Diego, and Imperial Beach in 2001 to provide secondary information on the condition of the RBSP fill material at the North Carlsbad, Leucadia, Mission Beach, and Imperial Beach receiver sites. The measurements were made by city personnel at five beach profile transects associated with each of the North Carlsbad, Mission Beach, and Imperial Beach fills, and at six transects associated with the Leucadia fill (a total of 21 transects, each of which is identified in Table 10). Data acquisition commenced on May 31, 2001 at

Imperial Beach, June 1, 2001 at Mission Beach and North Carlsbad, and July 13, 2001 at Leucadia.

Prior to the start of the measurement program, the individuals involved were provided with equipment, training, written instructions, and forms for data acquisition. The instructions specify that data are to be obtained monthly, at a time when the predicted tide height is 1 to 3 ft above MLLW. The beach width is to be measured from a permanent marker on the back beach to the estimated intersection of the still water level and the beach face. In addition, the foreshore slope is to be measured just above the still water level and recorded along with the date and time of the observation.

As in the case of 2001 and 2002, the beach width data for Imperial Beach, North Carlsbad, and Leucadia were transmitted to Coastal Frontiers for processing at the end of the 2003 Monitoring Year. In 2003, however, the City of San Diego failed to acquire the corresponding data for Mission Beach. Each measurement was adjusted to approximate the MSL beach width using the corresponding foreshore slope and the still water level recorded at the NOS tide gauge on Scripps Pier. Measurements obtained when the still water level was less than +1 ft (MLLW) were removed from the data set because the mild beach slopes that typically prevail below this elevation produce inaccurate estimates of the MSL beach width.

3.2. Lagoon Entrance Monitoring

The 2003 lagoon monitoring effort was virtually identical to those of 2001 and 2002, and included semi-annual surveys and oblique aerial photography at the entrances to Agua Hedionda, Batiquitos, San Elijo, San Dieguito, and Los Peñasquitos Lagoons. In addition, the unstabilized entrance channels at San Elijo, San Dieguito, and Los Peñasquitos were inspected and photographed on a monthly basis. The surveys and aerial photography were performed by Coastal Frontiers; the monthly channel inspections were undertaken by SANDAG. Each of the three components is described in a separate subsection below.

3.2.1. Semi-Annual Topographic Surveys

The lagoon entrance surveys were conducted in the Spring and Fall in conjunction with the beach profile data collection activities. The Spring work was performed on May 12, 20, and 21, while the Fall work was performed on October 6 and 7.

In the case of Agua Hedionda and Batiquitos Lagoons, where the entrances are stabilized by jetties, an electronic total station and conventional wading techniques were

used to obtain two profiles across each channel. One profile was located at the jetty tips, while the other was located at the seaward edge of the coast road bridge.

At San Elijo, San Dieguito, and Los Peñasquitos Lagoons, which lack stabilizing jetties, the condition of each entrance channel was documented by obtaining topographic data from wading depth in the ocean to the coast road bridge. The study area is extended at Los Peñasquitos Lagoon and includes the region immediately shoreward of the coast road. Particular emphasis was placed on areas perceived either to limit tidal access ("sills") or to contain shoals. As in the case of the jetty-protected entrance channels, the data were obtained using an electronic total station and conventional wading techniques.

All of the lagoon entrance data were processed in the manner described above for the wading portion of the beach profile surveys.

3.2.2. Semi-Annual Oblique Aerial Photography

Oblique aerial photographs of the five lagoon entrances were obtained in the Spring and Fall, during the same missions used to photograph the RBSP receiver sites (May 12 and November 6). As described in Section 3.1.2, the work was performed from a fixed-wing aircraft that circled each site at altitudes of 500 to 1000 ft.

To facilitate the discovery of shoals in the entrance channels, each photo mission was undertaken during a period of low tidal elevations. The water levels ranged from -0.1 to +1.5 ft (MLLW) during the Spring overflight, and +0.4 to +0.8 ft during the Fall overflight.

3.2.3. Monthly Inspections and Photography

Monthly inspections by SANDAG personnel of the entrances to San Elijo, San Dieguito, and Los Peñasquitos Lagoons were added to the SANDAG Monitoring Program in 2001 to provide a greater understanding of the condition of each channel after placement of the RBSP fill material. These inspections continued during the 2002 and 2003 Monitoring Years. In addition to photographs from repeatable locations, the site visits included notes on whether the channels were open to tidal exchange.

4. MONITORING DATA

This section presents the results of the 2003 Regional Beach Monitoring Program, consisting of direct measurements and computed values. The data derived from the beach component of the program are described in Section 4.1, while those derived from the lagoon entrance component are described in Section 4.2.

4.1. Beach Data

As discussed in Section 3.1, beach data acquisition consisted of semi-annual profile surveys, semi-annual oblique aerial photography, and monthly beach width measurements. The results of these activities are provided in Sections 4.1.1 through 4.1.3.

4.1.1. Beach Profile Data (Appendices A-F)

Table 11 presents the number of transects included in each of the semi-annual surveys conducted by SANDAG and the Cities of Carlsbad, Encinitas, and Solana Beach since the inception of the Regional Beach Monitoring Program in 1996. The 2003 beach profile data were used in conjunction with data from the prior surveys to create profile plots and compute changes in shoreline position, beach width, and sediment volume. Selected historical data acquired prior to the SANDAG Monitoring Program also were utilized. A summary of the historical beach profile data for the San Diego region known to exist in the public domain is provided in **Appendix A**, while a summary of the recent profile data acquired by SANDAG, Carlsbad, Encinitas, and Solana Beach is provided in **Appendix B**. To facilitate the identification of changes in beach condition attributable to the RBSP, those transects that cross the RBSP fill sites are identified by red type in Appendix B.

Beach profile plots for the nearshore portion of each transect are provided in **Appendix C**, while plots for the entire length of each transect are provided in **Appendix D**. In addition to the Spring and Fall 2003 data, the plots display the profiles from Fall 2002, Spring and Fall 2001, and Fall 1984 (when available), and the envelope of all profiles obtained during the SANDAG monitoring period that preceded the RBSP (Spring 1996-Spring 2001, to the extent that data are available). Post-Nourishment (as-built) profiles also are included for the transects that cross or adjoin the RBSP fill sites. These data, which are limited to the subaerial portion of the beach, were provided by Noble Consultants based on aerial photography (2002).

Table 11. Number of Transects Included in Each SANDAG Survey

Survey	Number of Transects
Spring 1996, Fall 1996	24
Spring 1997	37
Fall 1997, Spring 1998, Fall 1998	39
Spring 1999, Fall 1999, Spring 2000	40
Fall 2000	45
Spring 2001, Fall 2001	58
Spring 2002	60
Fall 2002, Spring 2003, Fall 2003	61

When reviewing **Appendices C** and **D**, it is important to recognize that the pronounced vertical relief evident in the Fall 2002, Spring 2003, and Fall 2003 profiles resulted from the improved survey resolution (Section 3.1.1) rather than from actual changes in the sea bottom. A representative example is provided in Figure 11, which displays the nearshore portion of the recent profiles obtained on Transect CB-0880 in Carlsbad. The most likely explanation for the "jaggedness" evident in the Fall 2002 and subsequent profiles is the presence of exposed rock reefs (which were not identifiable until the on-board dynamic motion sensor and data acquisition computer were added to the equipment suite in 2002). Although the data obtained in such areas can vary somewhat from survey to survey due to differences in the vessel track and wave conditions, the improved resolution afforded by the new technology is beneficial in identifying potential hard-bottom habitat.

Comparing the Spring and Fall profiles provides an indication of seasonal changes, while comparing the three Fall profiles illustrates the nature of inter-annual and long-term changes. A significant difference between the pre-RBSP envelope and one or more of the post-nourishment profiles indicates a material change in the beach condition that may have resulted from the RBSP nourishment activities.

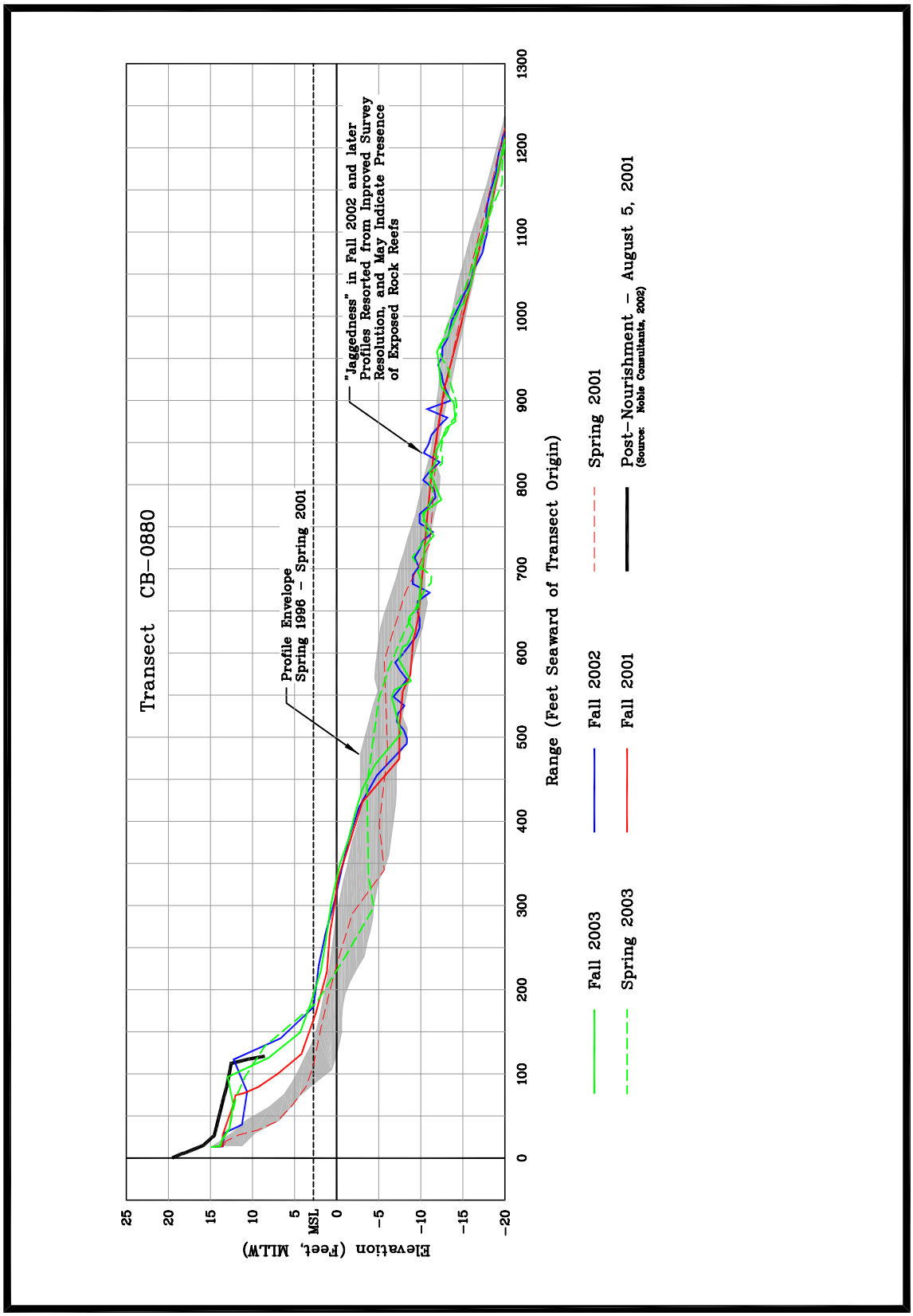


Figure 11. Transect CB-0880 in Carlsbad

Tables and plots of shoreline position and beach width derived from the profile data are provided in **Appendix E**. Data from the following 19 surveys were utilized to the extent that they were available:

Pre-1984:	Date Varies	1999:	Spring and Fall
1984:	Fall	2000:	Spring and Fall
1989:	Fall	2001:	Spring and Fall
1996:	Spring and Fall	2002:	Spring and Fall
1997:	Spring and Fall	2003:	Spring and Fall
1998:	Spring and Fall		

Because the survey data acquired prior to 1984 are relatively sparse in both time and space, it was not possible to select a single survey from this period that encompassed more than a small percentage of the transects. Therefore, pre-1984 data for each transect were selected on an individual basis, with preference given to data collected during the Fall. The Fall 1984 and Fall 1989 data were selected for analysis because many of the historical transects were profiled at these times.

The following shoreline and beach width tabulations were prepared:

MSL Shoreline Positions

The shoreline position was computed as the horizontal distance, in feet, between the transect origin (typically a permanent marker located near the back beach) and the point at which the beach profile intersected the plane of MSL Datum. Notwithstanding the use of MLLW as the elevation reference for the profile data, MSL was adopted as the shoreline reference in the belief that it provides a more accurate indicator of changes in beach configuration.

Seasonal Changes in MSL Shoreline Position:

Seasonal changes in MSL shoreline position were determined for the eight most recent summers (1996 through 2003), and seven most recent winters (1996-97, 1997-98, 1998-99, 1999-2000, 2000-2001, 2001-2002, and 2003-2003). The changes are expressed in feet, with positive values denoting shoreline advance and negative values denoting shoreline retreat.

Long-Term Changes, Long-Term Change Rates, and Annual Changes:

Long-term shoreline changes were calculated for three intervals that preceded the RBSP: pre-1984 to Fall 1984; Fall 1984 to Fall 1989 (5 years); and Fall 1989 to Fall 2000 (11 years). Long-term change rates were calculated by dividing the change in MSL shoreline position by the corresponding time interval. To reflect the seasonal nature of changes in beach configuration, the time interval was computed in one-quarter year increments (Winter, Spring, Summer, and Fall). For example, the time interval between surveys conducted in September 1984 (Fall 1984) and November 1989 (Fall 1989) was taken as 5 years rather than 5.17 years. The change rates are expressed in feet/year, with positive values denoting shoreline advance and negative values denoting retreat. To facilitate comparisons between long- and short-term changes, the long-term changes and change rates are tabulated with the annual changes in shoreline position recorded between Fall 1996 and Fall 2003.

MSL Beach Widths:

Beach width provides an indication of recreational area as well as the protection afforded to upland facilities. The width was computed as the distance between the landward edge of the beach sand and the MSL shoreline position.

Sediment volume changes are tabulated in **Appendix F**. The volume changes were computed along each transect for the entire width of the shorezone, and for that portion of the profile located above MSL.

In the SANDAG annual monitoring reports prepared prior to 2002, the onshore boundary of the control volume for both the shorezone and the beach above MSL was placed at the origin of each transect. In 2002, however, the boundary was modified for seven sites that contain seacliffs: DM-0565, SD-0650, SD-0710, CB-0740, CB-0775, CB-0780, and CB-0850. At these locations, the onshore boundary was moved from the top of the seacliff to its base to eliminate the inaccuracies introduced by profiling a steep, uneven cliff face. All of the volume changes reported in Appendix F have been adjusted to reflect this change, including those pertaining to the prior Monitoring Years as well as to 2002 and 2003.

The offshore boundary of the control volume for the beach above MSL was placed at the intersection of the profile and a horizontal line corresponding to the elevation of MSL. The offshore boundary for the shorezone was placed at the "statistical range of closure".

This parameter represents the distance seaward of the transect origin beyond which profile variations are smaller than the accuracy of the survey technique. As implied by its definition, the statistical range of closure was adopted as the offshore boundary to separate the signal of true profile change from the noise of survey inaccuracy. The sea bottom elevation at the range of closure corresponds to the "depth of closure" described in Section 3.1.1.

The statistical range of closure for each transect was derived prior to preparing the 2001 Annual Monitoring Report (Coastal Frontiers, 2002). As described in that report, the procedure was as follows:

- The successive survey profiles were interpolated to obtain sea bottom elevations at a common set of ranges spaced 15 ft apart.
- The sample standard deviation (σ) of the sea bottom elevations was computed at each 15-ft range increment.
- Statistical closure was assumed to occur at the smallest range at which σ decreased below the survey accuracy of 0.5 ft, provided that the average value of σ remained less than or equal to 0.5 ft seaward of that point. If this condition was not satisfied by the first downcrossing below 0.5 ft, the next downcrossing seaward of that location was checked.
- In determining statistical closure, attention was restricted to depths greater than 12 ft (MLLW) to insure that the berm-bar portion of the profile would be included in the control volume.

To the extent that data were available, the determination of statistical closure was based on the ten semi-annual surveys that commenced in Fall 1997 and ended in Spring 2002. Surveys prior to Fall 1997 were not used, because they tended either to omit a significant number of the current transects, or to terminate landward of the depth of profile closure. The final two surveys, Fall 2001 and Spring 2002, were included in an attempt to define a control volume that would encompass the seaward dispersion of the RBSP fill material. In the case of transects that lacked profile data for the relatively severe El Niño winter of 1997-98, the range of closure was estimated from one or more adjoining transects with similar exposure and beach characteristics. The results are presented in Table 12.

The values shown in Table 12 were used without modification in 2002 and 2003 to facilitate a direct comparison of annual volume changes in the shorezone. Unless extraordinary events cause substantial profile changes outside the computed ranges of

Table 12. Range and Depth of Closure at Each Profile Location

	Transect[2]	Location	Range of Closure[3]	Depth of Closure
Silver Strand Littoral Cell	SS-0003	Tijuana Estuary	1501	-32
	SS-0005[5]	Tijuana Estuary	1175	-25
	SS-0007	Tijuana Estuary	1132	-17
	SS-0015	Imperial Beach	1448	-19
	SS-0020[1,4]	Imperial Beach	1463	-22
	SS-0025[1,4]	Imperial Beach	2064	-27
	SS-0035	Imperial Beach	2260	-29
	SS-0050[4]	Imperial Beach	2445	-30
	SS-0077	Silver Strand	1893	-30
	SS-0090	Silver Strand	1499	-29
	SS-0160	Coronado	2109	-25
Mission Beach Littoral Cell	OB-0230	Ocean Beach	2249	-23
	MB-0310	Mission Beach	1460	-24
	MB-0320[4]	Mission Beach	1785	-29
	MB-0335[1,4]	Mission Beach	1740	-29
	MB-0340[1]	Mission Beach	1687	-29
	MB-0384	Mission Beach	1764	-27
	PB-0408	Pacific Beach	1074	-14
Oceanside Littoral Cell	LJ-0443	La Jolla Shores	1038	-13
	LJ-0445	La Jolla	802	-13
	LJ-0450	La Jolla	1195	-17
	LJ-0460	Scripps	1047	-19
	TP-0470	Blacks Beach	1573	-29
	TP-0520[1]	Torrey Pines	1398	-26
	TP-0530[1]	Torrey Pines	1464	-25
	DM-0565[4]	Del Mar	1770	-25
	DM-0560[5]	Del Mar	1800	-29
	DM-0580[1]	Del Mar	1899	-29
	DM-0590	San Dieguito	1146	-16
	SD-0595[4]	Seascape Surf	1072	-13
	SD-0600[1]	Solana Beach	910	-13
	SD-0610[4]	Tide Park	838	-13
	SD-0620[4]	Seaside Park	1935	-30

(continued)

Table 12. Range and Depth of Closure at Each Profile Location (continued)

	Transect[2]	Location	Range of Closure[3]	Depth of Closure
Oceanside Littoral Cell (continued)	SD-0625[1,4]	San Elijo Lagoon	1800	-30
	SD-0630[1]	Cardiff	1808	-30
	SD-0650[4]	San Elijo St. Bch	1590	-30
	SD-0660[4]	Swami's	1650	-30
	SD-0670[1]	Moonlight Bch.	1639	-29
	SD-0675[4]	Stone Steps	1230	-21
	SD-0680[4]	Leucadia	1357	-21
	SD-0690[1,4]	Leucadia	1470	-27
	SD-0695[4]	Leucadia	1500	-27
	SD-0700[4]	Grandview	1515	-27
	SD-0710[1,4]	Leucadia	1485	-27
	CB-0720	Batiquitos	1556	-27
	CB-0740	S. Carlsbad	1264	-18
	CB-0760	Ponto Beach	1322	-24
	CB-0775[1,4]	South Carlsbad	1500	-25
	CB-0780	Carlsbad	1527	-25
	CB-0800	Carlsbad	1026	-13
	CB-0820	Agua Hedionda	1270	-22
	CB-0830	Carlsbad	1134	-21
	CB-0840	Carlsbad	984	-17
	CB-0850	Carlsbad	947	-14
	CB-0865[1,4]	Carlsbad	1105	-16
	CB-0880[1]	Buena Vista	1030	-16
	OS-0900	S. Oceanside	1317	-26
	OS-0915[1,4]	Oceanside	1230	-26
	OS-0930[1]	Buccaneer	1313	-24
	OS-1000	Oceanside	1082	-19
	OS-1030	Oceanside	1247	-21
	OS-1070	Oceanside	1455	-17

Notes:
(1) Transect crosses RBSP nourishment site (shown in red type).
(2) Transect locations are indicated in Figures 10a and 10b.
(3) Range of closure measured from transect origin, and based on Fall 1997 through Spring 2002 Survey data unless otherwise noted.
(4) Range of closure estimated from nearby transects due to insufficient data.

closure, these values will serve as the basis for all shorezone volume computations throughout the period in which the fate of the RBSP fills remains under investigation. In the case of transects added since the inception of the RBSP Monitoring Period (such as SS-0005 and DM-0560), the range of closure was estimated in the manner described above.

For each survey at each transect, the shorezone volume per linear foot of shoreline (cy/ft) was calculated as the area under the profile to an arbitrary basement elevation of –60 ft. Volume changes then were computed for the following 20 periods:

Winter:

Fall 1997 to Spring 1998
Fall 1998 to Spring 1999
Fall 1999 to Spring 2000
Fall 2000 to Spring 2001
Fall 2001 to Spring 2002
Fall 2003 to Spring 2003

Summer:

Spring 1998 to Fall 1998
Spring 1999 to Fall 1999
Spring 2000 to Fall 2000
Spring 2001 to Fall 2001
Spring 2002 to Fall 2002
Spring 3003 to Fall 2003

Annual:

Fall 1997 to Fall 1998
Fall 1998 to Fall 1999
Fall 1999 to Fall 2000
Fall 2000 to Fall 2001
Fall 2001 to Fall 2002
Fall 2002 to Fall 2003

Long-Term:

Fall 1997 to Fall 2000 (Pre-RBSP)
Fall 2000 to Fall 2003 (RBSP)

The beach volume above MSL, like the beach width, provides an indication of the recreational area and the protection afforded to upland facilities. Changes in beach volume above MSL were developed for the same 20 periods as changes in shorezone volume above the depth of closure.

4.1.2. Aerial Photographs (Section 5)

Representative aerial photographs obtained at the twelve RBSP receiver sites in 2001, 2002, and 2003 are provided in Section 5. A more extensive set of aerial photographs covering the twelve sites was provided to SANDAG in digital form following each overflight.

4.1.3. Beach Width Measurements (Appendix G)

The monthly beach width data obtained by the Cities of Carlsbad, Encinitas, San Diego, and Imperial Beach are presented as time-series plots in **Appendix G**. As indicated in Section 3.1.3, the measurements were adjusted to approximate the MSL beach width using the corresponding water levels and beach slopes. The MSL beach widths obtained from the 2001, 2002, and 2003 profile data, which are inherently more accurate than the monthly measurements, also are shown on the plots in Appendix G.

4.2. Lagoon Entrance Data

Lagoon entrance data acquisition consisted of semi-annual surveys and oblique aerial photography at all five entrances, and monthly observations and photographs at the unstabilized entrances to San Elijo, San Dieguito, and Los Peñasquitos.

4.2.1. Topographic Data (Appendix H)

The 2003 lagoon entrance monitoring data are presented in graphical form in **Appendix H**. For Agua Hedionda and Batiquitos, all channel cross-sections obtained since Fall 2000 are displayed with those from Spring and Fall 2003 to illustrate the changes in configuration.

For each of the three unstabilized entrances (San Elijo, San Dieguito, and Los Peñasquitos), the following six contour maps were prepared to illustrate changes in the condition of the channel:

- A contour map depicting the topographic data obtained in Fall 2002;
- A contour map depicting the topographic data obtained in Spring 2003;
- A contour map depicting the topographic data obtained in Fall 2003;
- A contour map illustrating the elevation changes that occurred between Fall 2002 and Spring 2003, as well as the net change in volume within the survey area;
- A contour map illustrating the elevation changes that occurred between Spring 2003 and Fall 2003, as well as the net change in volume within the survey area;
- A contour map illustrating the elevation changes that occurred between Fall 2002 and Fall 2003, as well as the net change in volume within the survey area.

4.2.2. Aerial Photographs (Section 6)

Representative aerial photographs obtained at the five lagoon entrances in 2001, 2002, and 2003 are provided in Section 6. A more extensive set of aerial photographs covering the five sites was provided to SANDAG in digital form following each overflight.

4.2.3. Inspection Results (Appendix I)

Selected ground photographs obtained by SANDAG on a monthly basis at the entrances to San Elijo, San Dieguito, and Los Peñasquitos Lagoons are provided in **Appendix I**.

5. BEACH CONDITION

Based on the data presented in Sections 2 and 4, this chapter assesses the condition of San Diego County's beaches during the 2003 Monitoring Year (November 2002 through October 2003), and the entire RBSP Monitoring Period (November 2000 through October 2003). Section 5.1 provides a regional overview, while Section 5.2 describes the performance of each of the twelve RBSP beach fills. To insure that the findings are directly comparable, all of the statistical characterizations of shoreline and volume changes are derived from the 44 transects with measurements dating back to Fall 2000 (i.e., predating the RBSP Monitoring Period).

5.1. Regional Overview

During the 2003 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, but the shoreline tended to retreat. This apparent paradox may be explained by the fact that sediment moved from the subaerial portion of the profile to the submerged portion, but remained within the shorezone. The predominance of shoreline retreat is attributable to four factors: (1) offshore dispersal of the RBSP fill material, (2) a lack of significant sediment input from rivers and streams, (3) an increase in wave energy relative to the past two years, and (4) a lack of beach nourishment activities. The stability of the shorezone sediment volume is consistent with the fact that, in the absence of nourishment activities, major rainstorms, and severe storm events, significant quantities of material were neither added to nor removed from the coast.

Notwithstanding the loss of dry beach that occurred in 2003, the condition of the County's beaches improved substantially during the RBSP Monitoring Period. Beach width and sediment volume both tended to increase over this three-year span, with the greatest gains occurring in the Oceanside Littoral Cell. The primary reasons for this improvement in the state of the coast appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period. Although much of the RBSP fill material has been dispersed from the receiver sites, the residual benefits to the County's beaches include an increased area for recreational activities, and a more substantial buffer against storm-induced erosion.

5.1.1. Shoreline and Subaerial Volume Changes

The changes in MSL shoreline position that occurred during the 2003 Monitoring Year and the entire RBSP Monitoring Period are summarized in Figure 12 and Table 13.

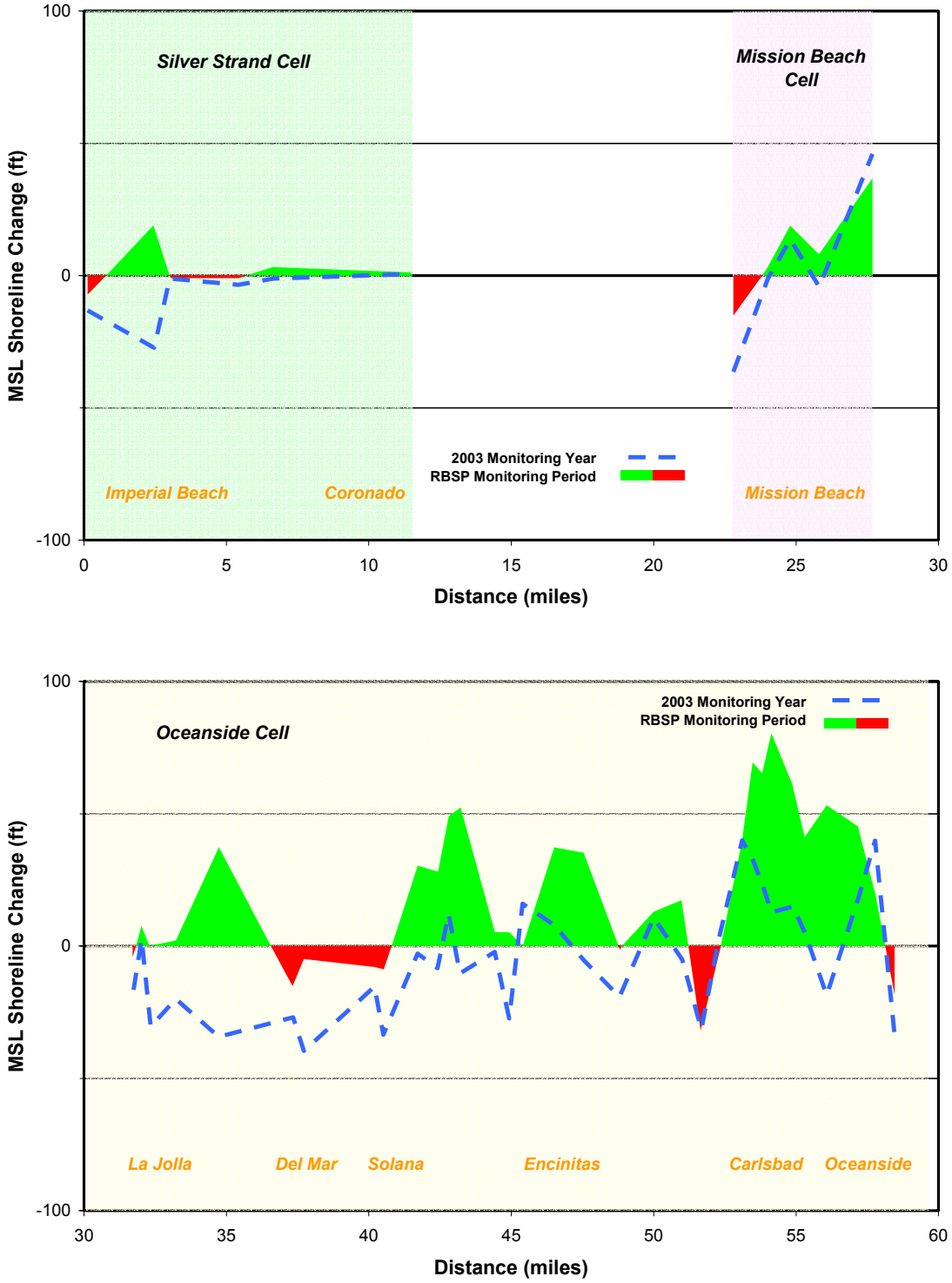


Figure 12. MSL Shoreline Changes during the 2003 Monitoring Year and RBSP Monitoring Period

Table 13. MSL Shoreline Changes during the 2003 Monitoring Year and RBSP Monitoring Period[1]

Littoral Cell	MSL Shoreline Change (no. of transects)			Average Change (ft)
	Advance	No Change[2]	Retreat	
Silver Strand Cell				
2003 Mon. Year	0	4	2	-7
RBSP Mon. Period[3]	1	5	0	2
Mission Beach Cell				
2003 Mon. Year	1	3	1	0
RBSP Mon. Period[3]	2	2	1	10
Oceanside Cell				
2003 Mon. Year	10	10	13	-4
RBSP Mon. Period[3]	18	12	3	21
All Cells Combined				
2003 Mon. Year	11	17	16	-4
RBSP Mon. Period[3]	21	19	4	17

Note: [1] Shoreline change statistics are derived from the 44 transects with measurements dating back to Fall 2000.
[2] "No Change" indicates a shoreline change of 10 ft or less.
[3] RBSP Monitoring Period extends from November 2000 through October 2003.

Detailed supporting data appear in Appendix E.

As indicated above, shoreline advance predominated during the RBSP Monitoring Period despite a reversal of this trend during the most recent monitoring year. When the three littoral cells are considered together, the breakdown of shoreline changes during the three-year RBSP Monitoring Period is as follows:

- 21 transects (48%) exhibited shoreline advance in excess of 10 ft;
- 19 transects (43%) exhibited essentially no shoreline change (10 ft or less);
- 4 transects (9%) exhibited shoreline retreat in excess of 10 ft.

The average shoreline change during this period was an advance of 17 ft. This value reflects a 2-ft average advance for the six transects in the Silver Strand Cell, a 10-ft average advance for the five transects in the Mission Beach Cell, and a 21-ft average advance for the 33 transects in the Oceanside Cell.

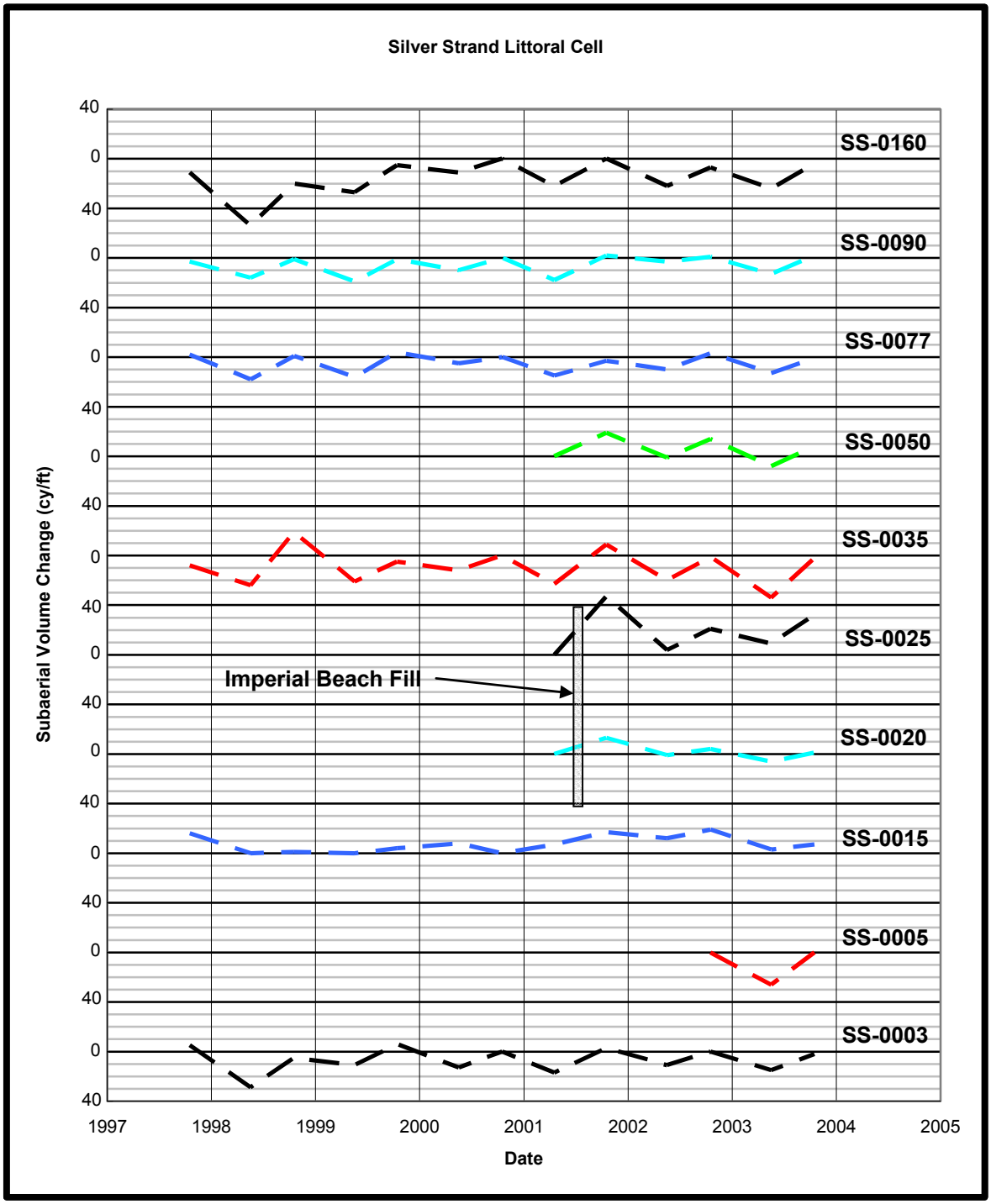
Figures 13a, b, and c present time series of the changes in subaerial sediment volume (above MSL) that occurred between Fall 1997 and Fall 2003. In the case of the 44 transects that pre-dated the RBSP Monitoring Period, the changes were reckoned from the volumes that prevailed at the beginning of that period (Fall 2000). Hence, if the volume change in Fall 2003 exceeds zero, the subaerial volume has increased during the RBSP Monitoring Period. In the case of the 17 transects that were added to the monitoring program after Fall 2000, the changes were reckoned from the volumes that prevailed at the time of the initial survey.

Noteworthy aspects of the time series plots are summarized below:

- A strong seasonal signal is evident on most of the transects, with the subaerial volume increasing during the summer months and decreasing during the winter months. This trend is consistent with the anticipated seasonal oscillation in the direction of cross-shore transport: onshore in summer and offshore in winter.
- A significant increase in subaerial volume occurred at the time of fill placement at all RBSP receiver sites except Del Mar. In some cases, such as Fletcher Cove, the gain was quickly reversed; in others, such as Oceanside and North Carlsbad, the subaerial volume at the time of the Fall 2003 survey remained well above that which preceded the nourishment program.

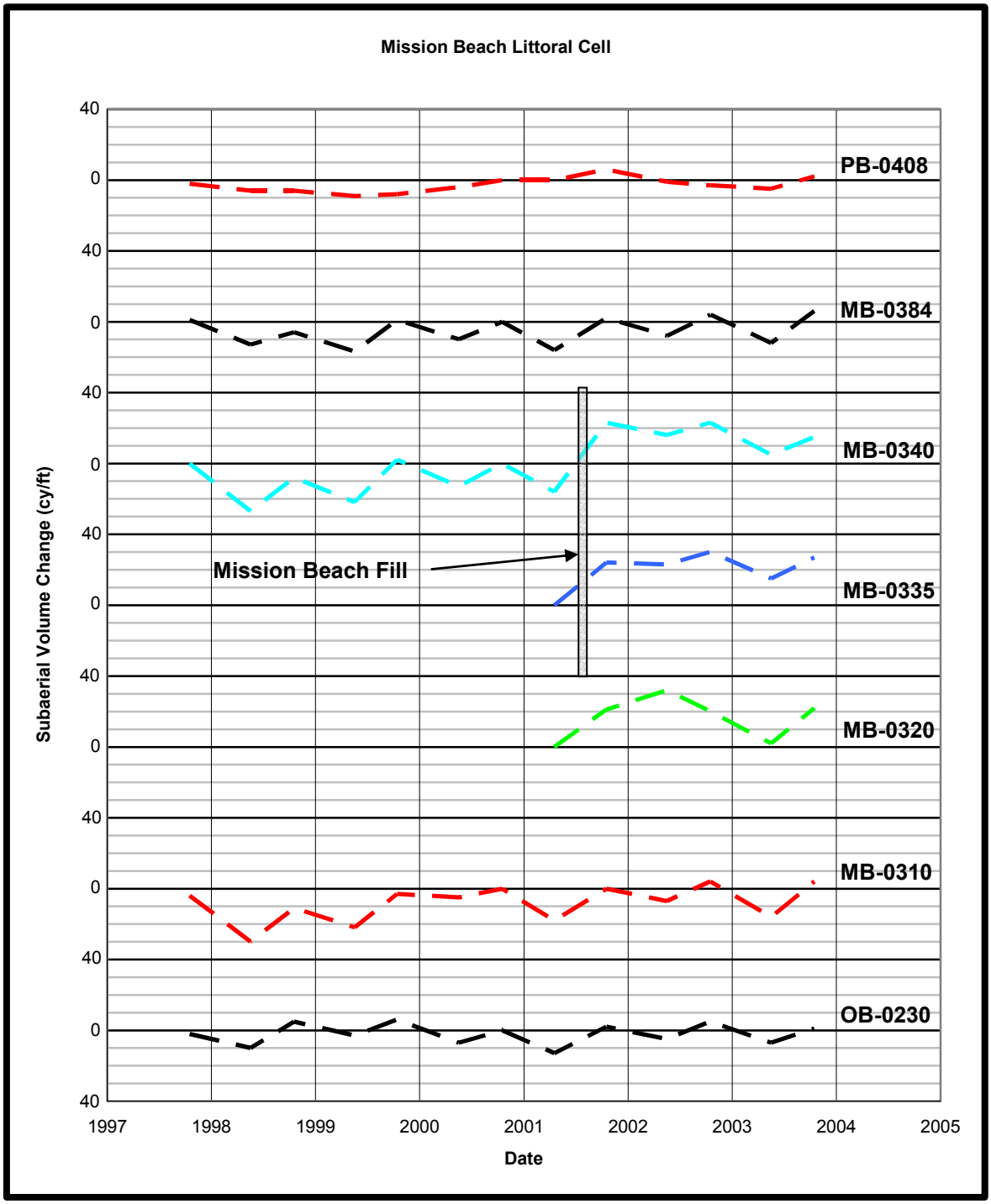
5.1.2. Beach Widths

In Figures 14a and b, the MSL beach widths measured in Spring 2003 and Fall 2003 are compared with the envelope of widths measured prior to the RBSP (Spring 1996-Spring 2001 or Spring 1997-Spring 2001, to the extent that data are available). At more than one-third of the transects with measurements dating back to 1997 (14 of 38 transects), the beach width in Fall 2003 exceeded that noted in any of the pre-RBSP years. The largest increase relative to the pre-RBSP envelope, 62 ft, occurred in Carlsbad on Transect CB-0850. At three locations, the beach width in Spring 2003 fell below the pre-RBSP envelope: a 17-ft shortfall at Transect SS-0035 in Imperial Beach, a 2-ft shortfall at Transect CB-0820 in Carlsbad, and a 5-ft shortfall at Transect OS-1070 in Oceanside.



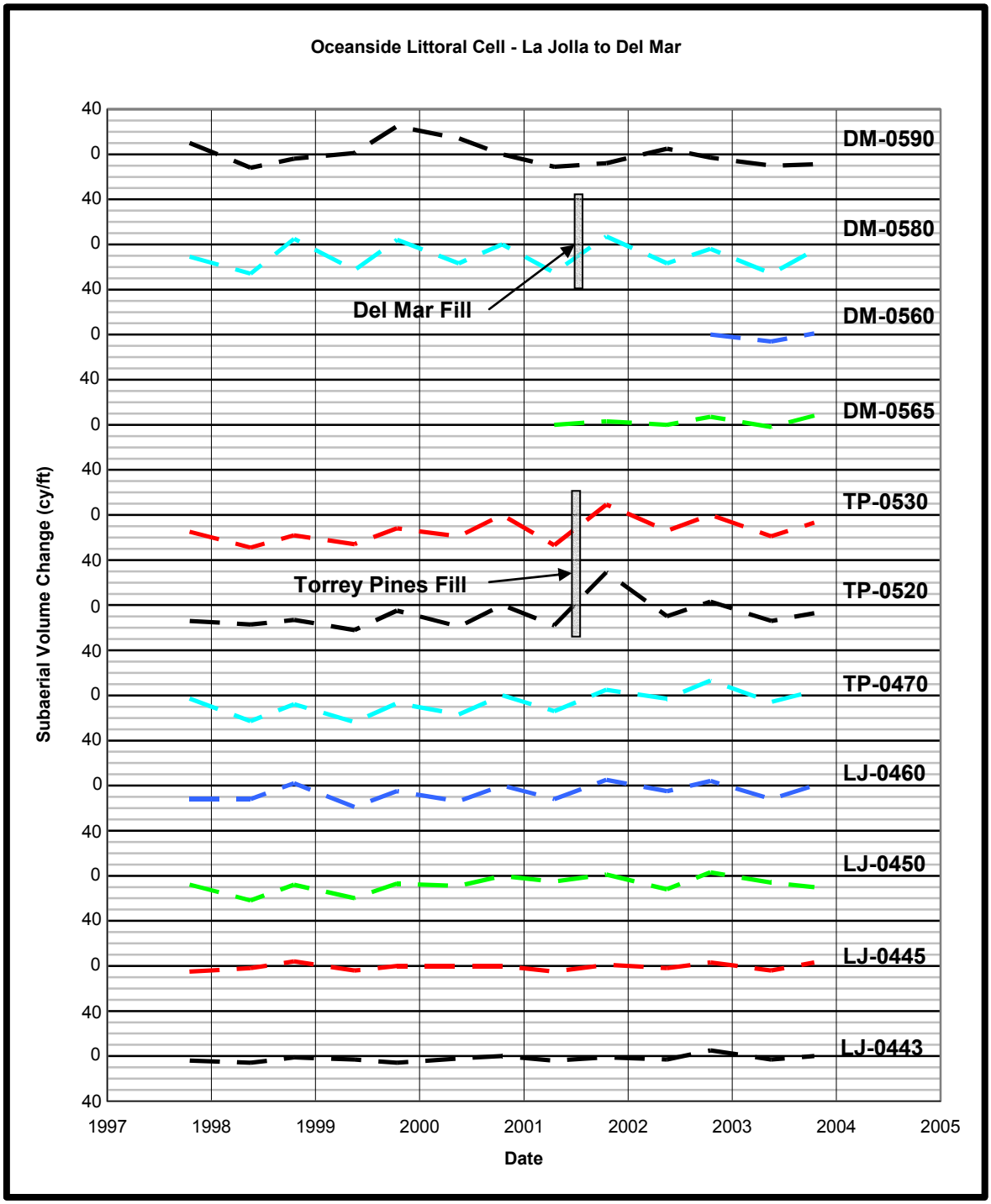
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13a. Time Series of Subaerial Volume Change in the Silver Strand Littoral Cell



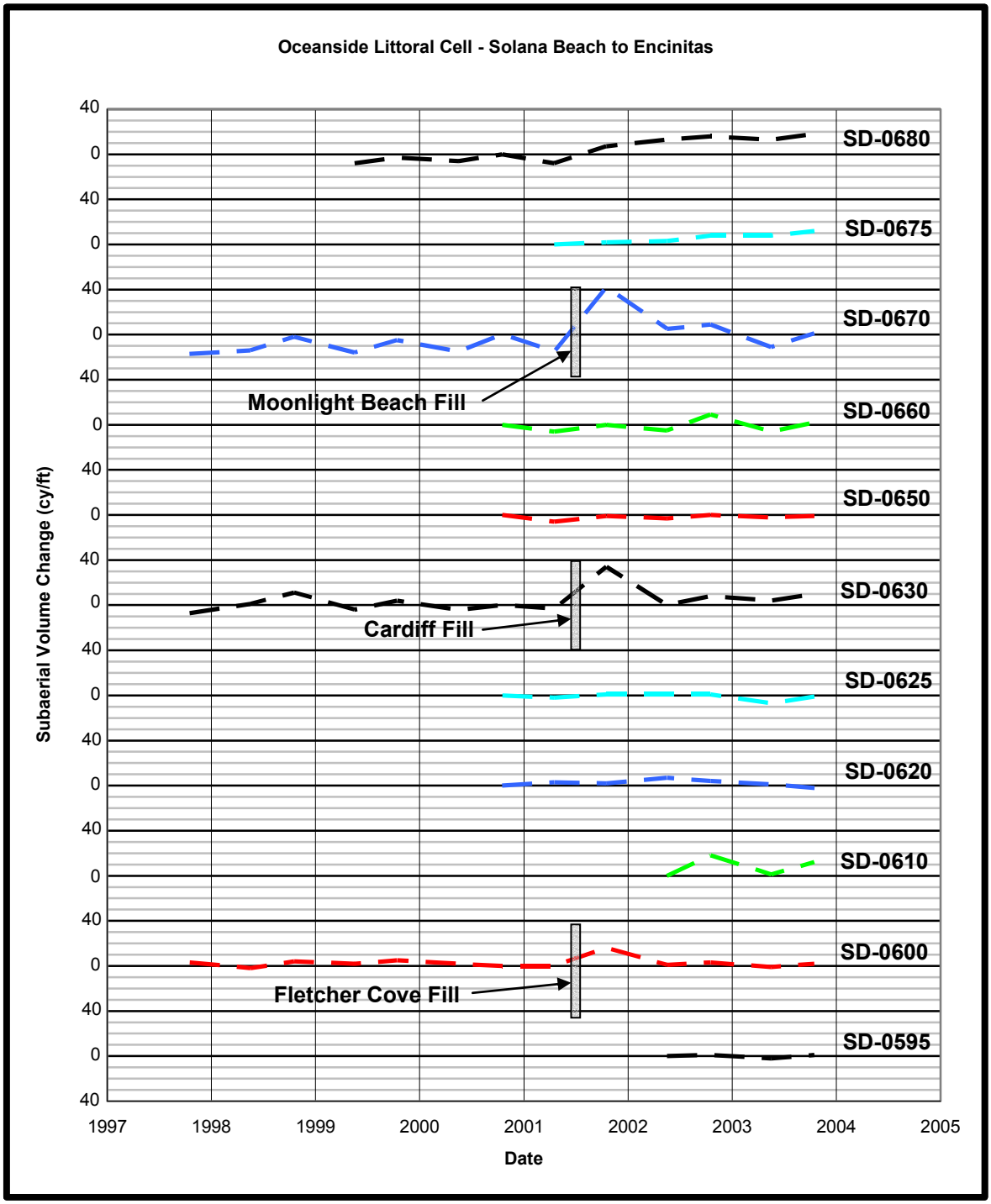
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13b. Time Series of Subaerial Volume Change in the Mission Beach Littoral Cell



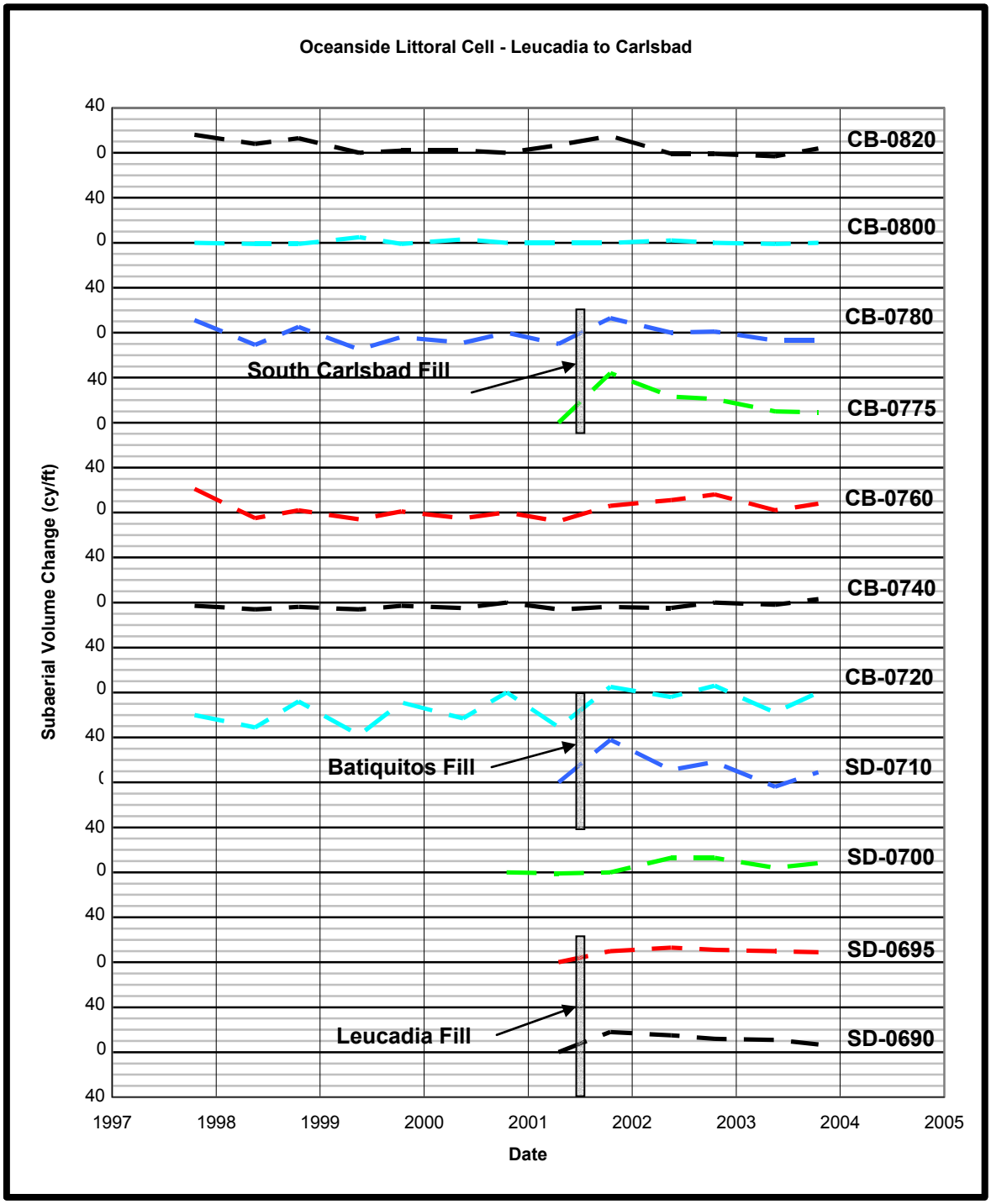
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 1 of 4)



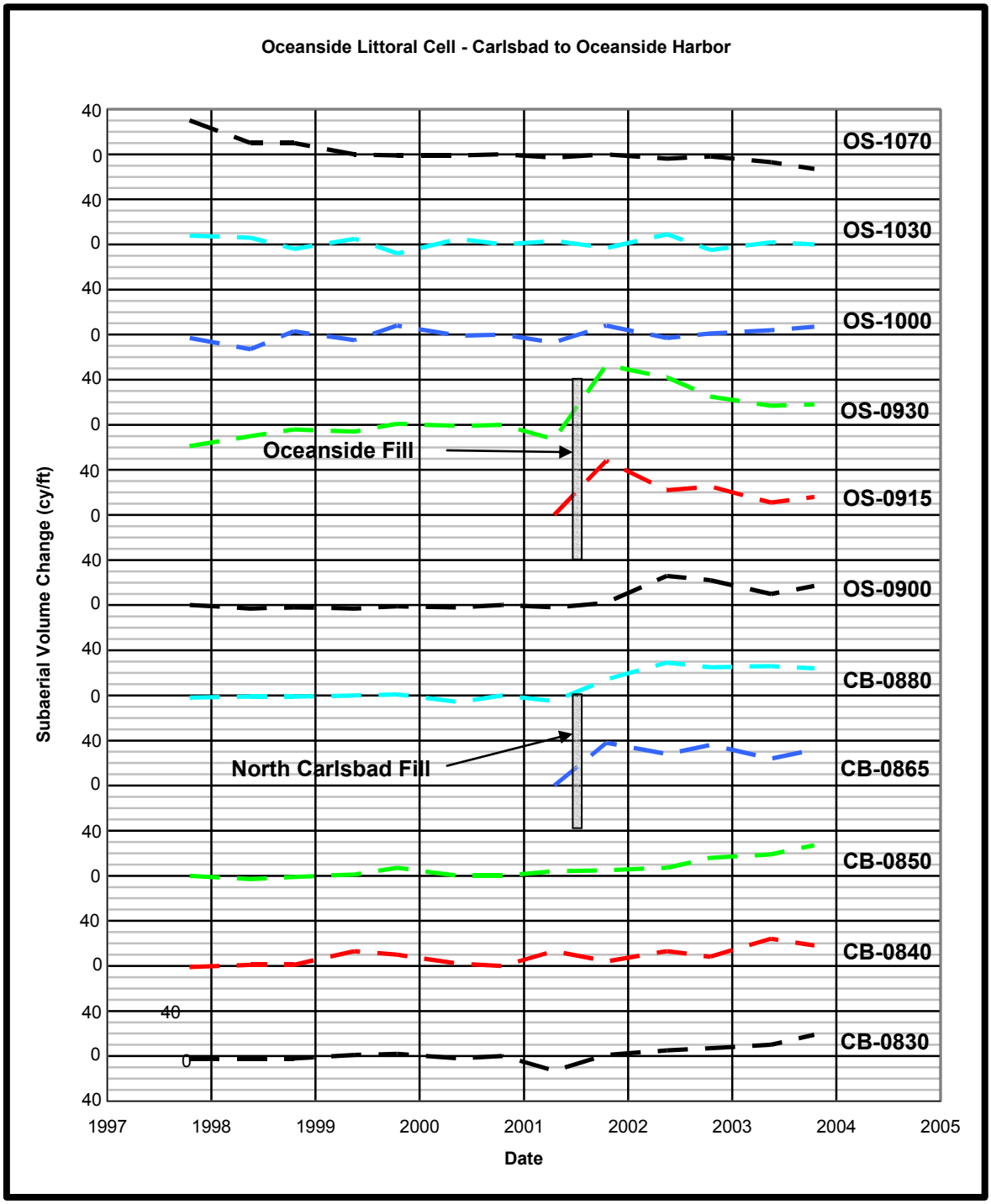
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 2 of 4)



Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 3 of 4)



Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 13c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 4 of 4)

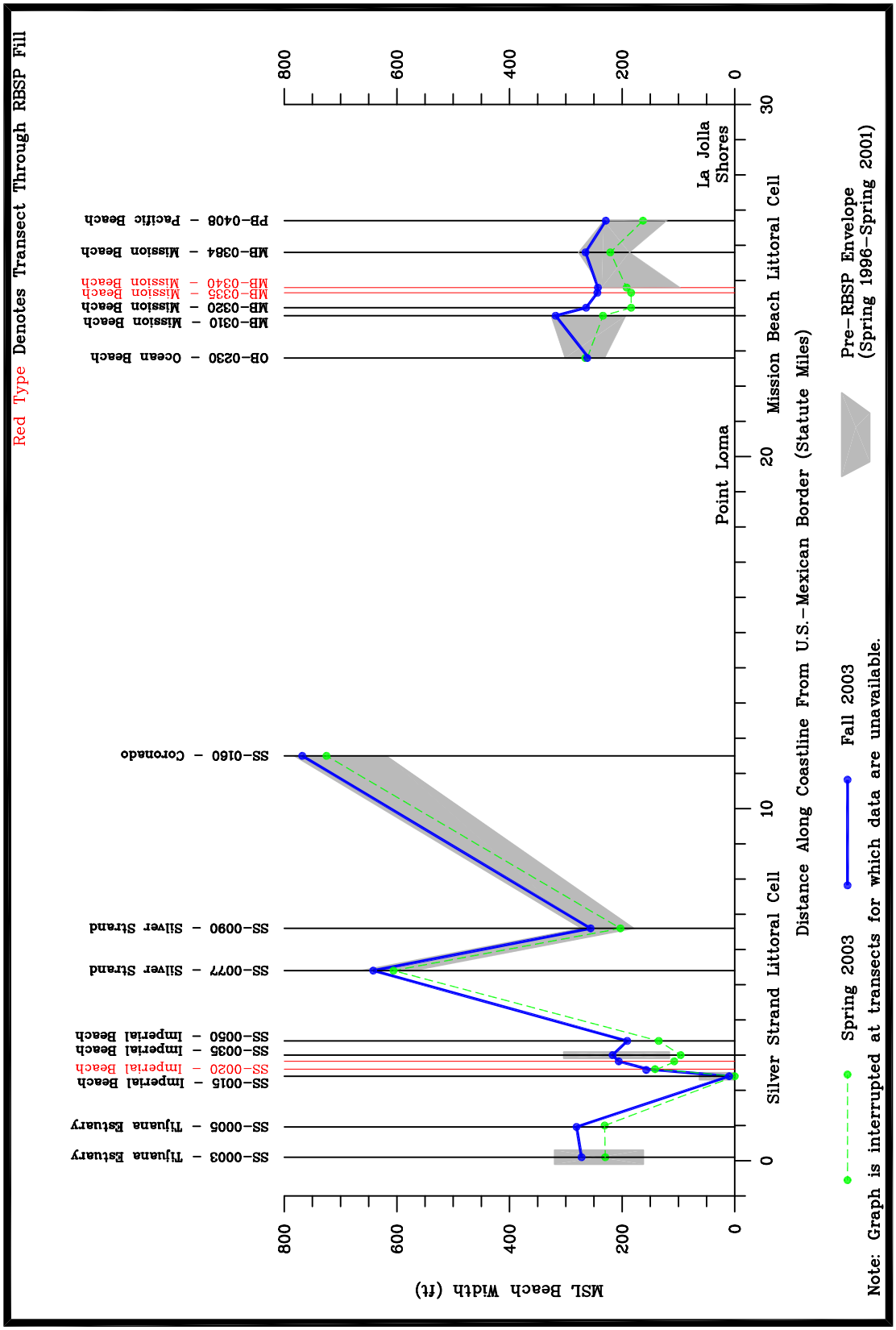


Figure 14a. Comparison of 2003 MSL Beach Widths with Pre-RBSP Envelope in the Silver Strand and Mission Beach Littoral Cells

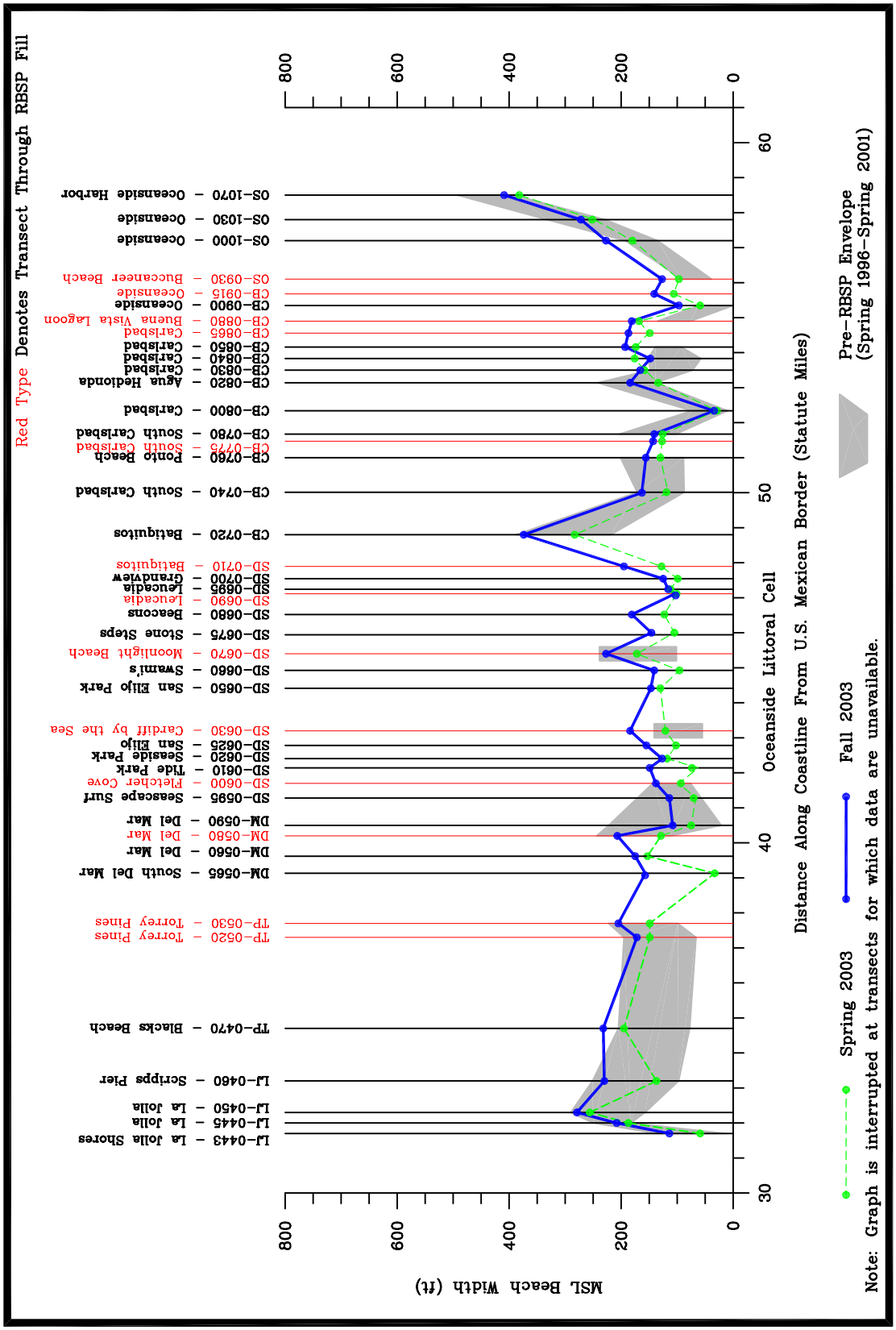


Figure 14b. Comparison of 2003 MSL Beach Widths with Pre-RBSP Envelope in the Oceanside Littoral Cell

5.1.3. Shorezone Volume Changes

Figure 15 and Table 14 present the volume changes that occurred in the shorezone (inside the range of closure) during the 2003 Monitoring Year and the entire RBSP Monitoring Period. The supporting data are provided in Appendix F.

During the 2003 Monitoring Year, gains and losses in shorezone volume were equally balanced among the 44 transects that pre-dated the RBSP Monitoring Period. The net result was an average loss of 1 cy/ft in the each of the Mission Beach and Oceanside Cells, and 7 cy/ft in the Silver Strand Cell. This finding is not surprising considering that in the absence of nourishment activities, major rainstorms, and severe storm events, significant quantities of material were neither added to nor removed from the shorezone.

This lack of change during the past year contrasts with the net increase in shorezone volume that occurred over the entire RBSP Monitoring Period. When the three littoral cells are considered together, the breakdown of volume changes during the three-year period is as follows:

- 24 transects (54%) exhibited gains in excess of 10 cy/ft;
- 13 transects (30%) exhibited essentially no change (10 cy/ft or less);
- 7 transects (16%) exhibited losses in excess of 10 cy/ft.

The average change in shorezone volume during this period was a gain of 15 cy/ft, reflecting average gains of 20 cy/ft in the Oceanside Cell and 12 cy/ft in the Mission Beach Cell along with a loss of 10 cy/ft in the Silver Strand Cell. The disparate results in the three cells may be explained, at least in part, by the average annual nourishment rates presented in Table 8. Whereas the nourishment rates in the Oceanside and Mission Beach Cells during the RBSP Monitoring Period exceeded the pre-RBSP rates by 219,000 and 48,000 cy/yr, respectively, the RBSP rate in the Silver Strand Cell was 33,000 cy/yr less than the pre-RBSP rate. As explained in Section 2, this deficit in the Silver Strand Cell arose from the cessation of all nourishment activities other than the RBSP.

It is noteworthy that the average shorezone volume increase of 15 cy/ft (Table 14) and average shoreline advance of 17 ft (Table 13) that occurred during the RBSP Monitoring Period are in substantial agreement with the "CERC Rule". This empirical rule-of-thumb states that an increase of one cubic yard in shorezone volume is accompanied by an increase of one foot in beach width.

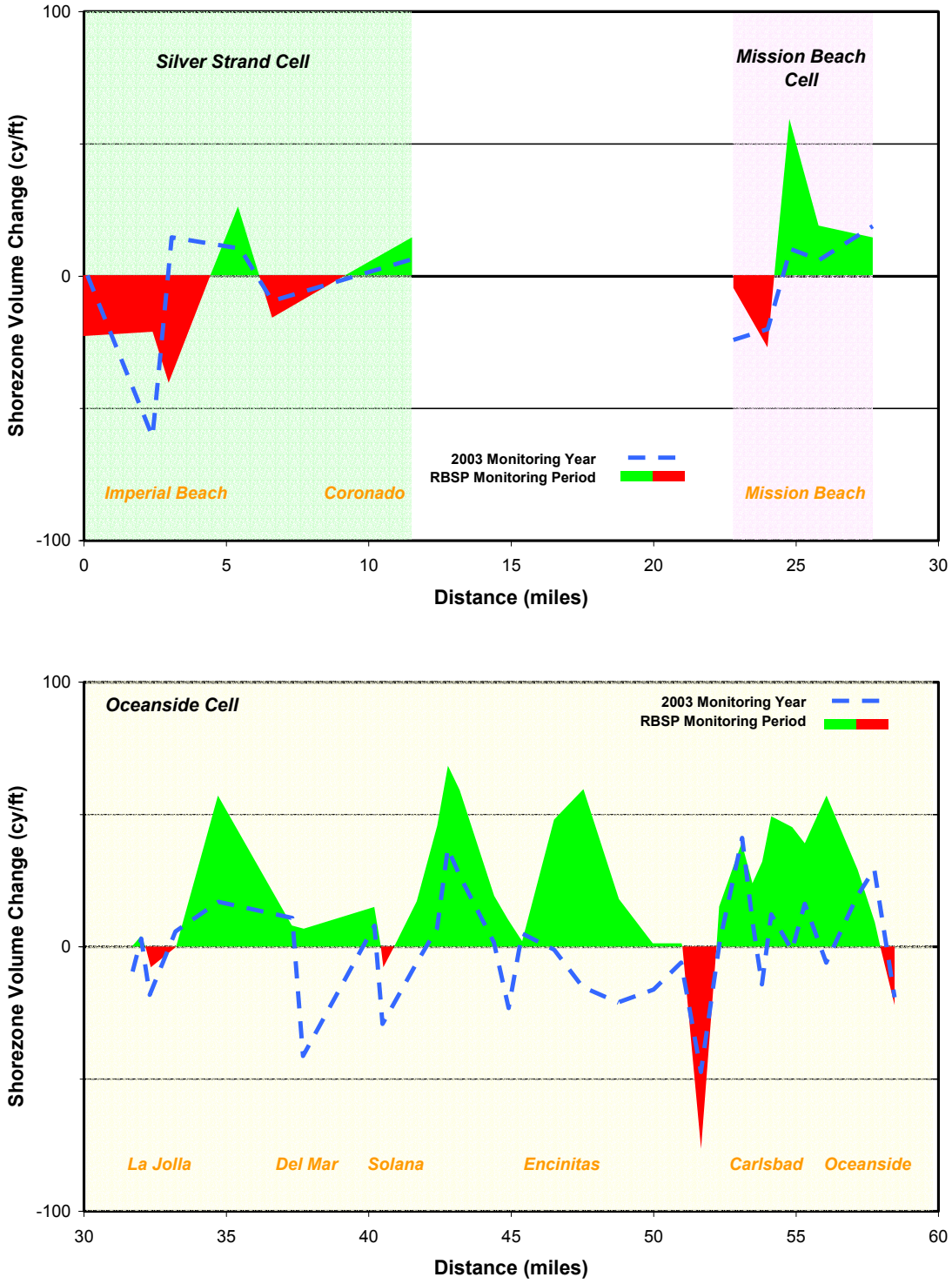


Figure 15. Shorezone Volume Changes during the 2003 Monitoring Year and RBSP Monitoring Period

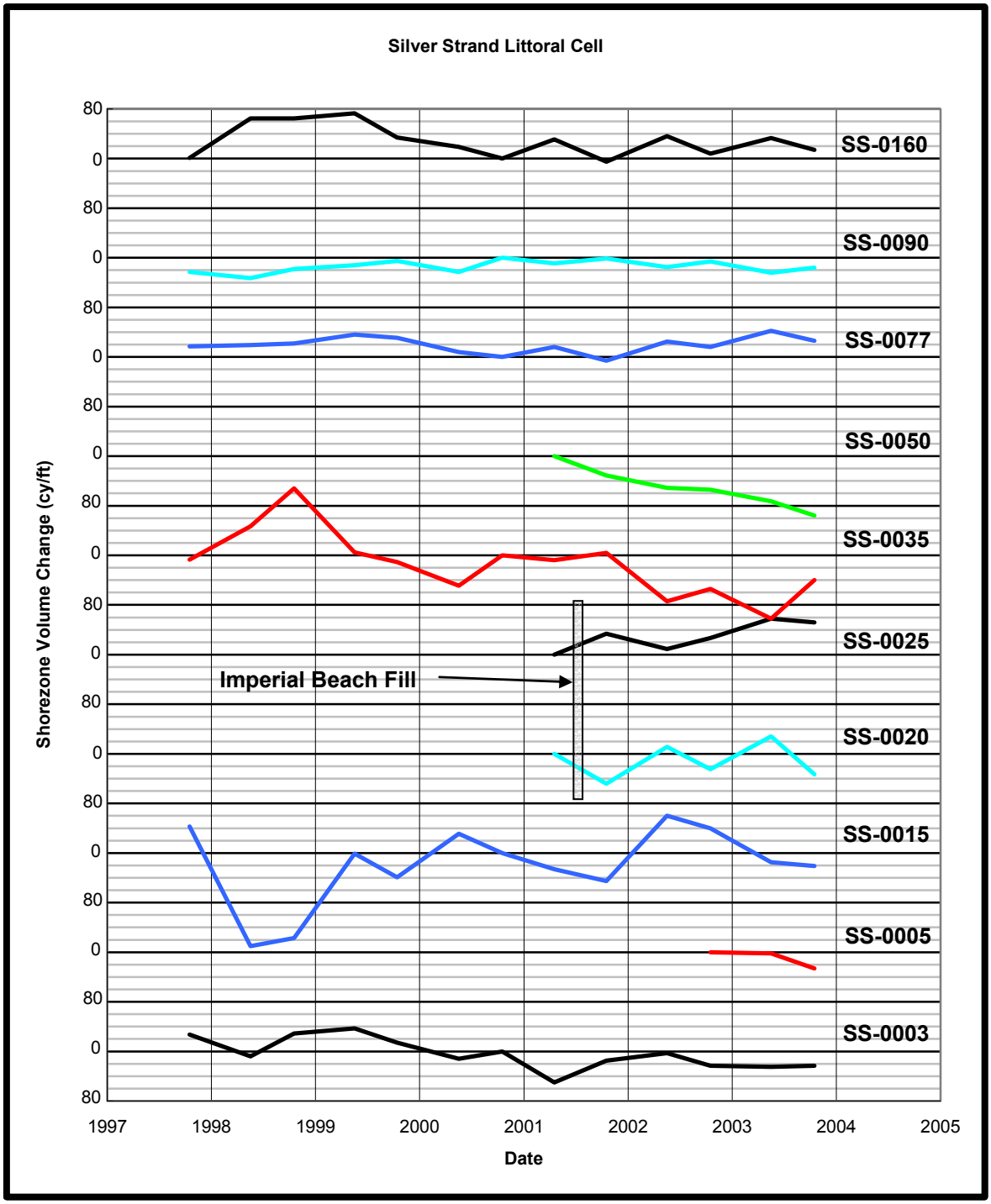
Table 14. Shorezone Volume Changes during the 2003 Monitoring Year and RBSP Monitoring Period[1]

Littoral Cell	Shoreline Volume Change (no. of transects)			Average Change (cy/ft)
	Increase	No Change[2]	Decrease	
Silver Strand Cell				
2003 Mon. Year	1	4	1	-7
RBSP Mon. Period[3]	2	0	4	-10
Mission Beach Cell				
2003 Mon. Year	2	1	2	-1
RBSP Mon. Period[3]	3	1	1	12
Oceanside Cell				
2003 Mon. Year	9	14	10	-1
RBSP Mon. Period[3]	19	12	2	20
All Cells Combined				
2003 Mon. Year	12	19	13	-1
RBSP Mon. Period[3]	24	13	7	15

Note: [1] Volume change statistics are derived from the 44 transects with measurements dating back to Fall 2000.
[2] "No Change" indicates a volume change of 10 cy/ft or less.
[3] RBSP Monitoring Period extends from November 2000 through October 2003.

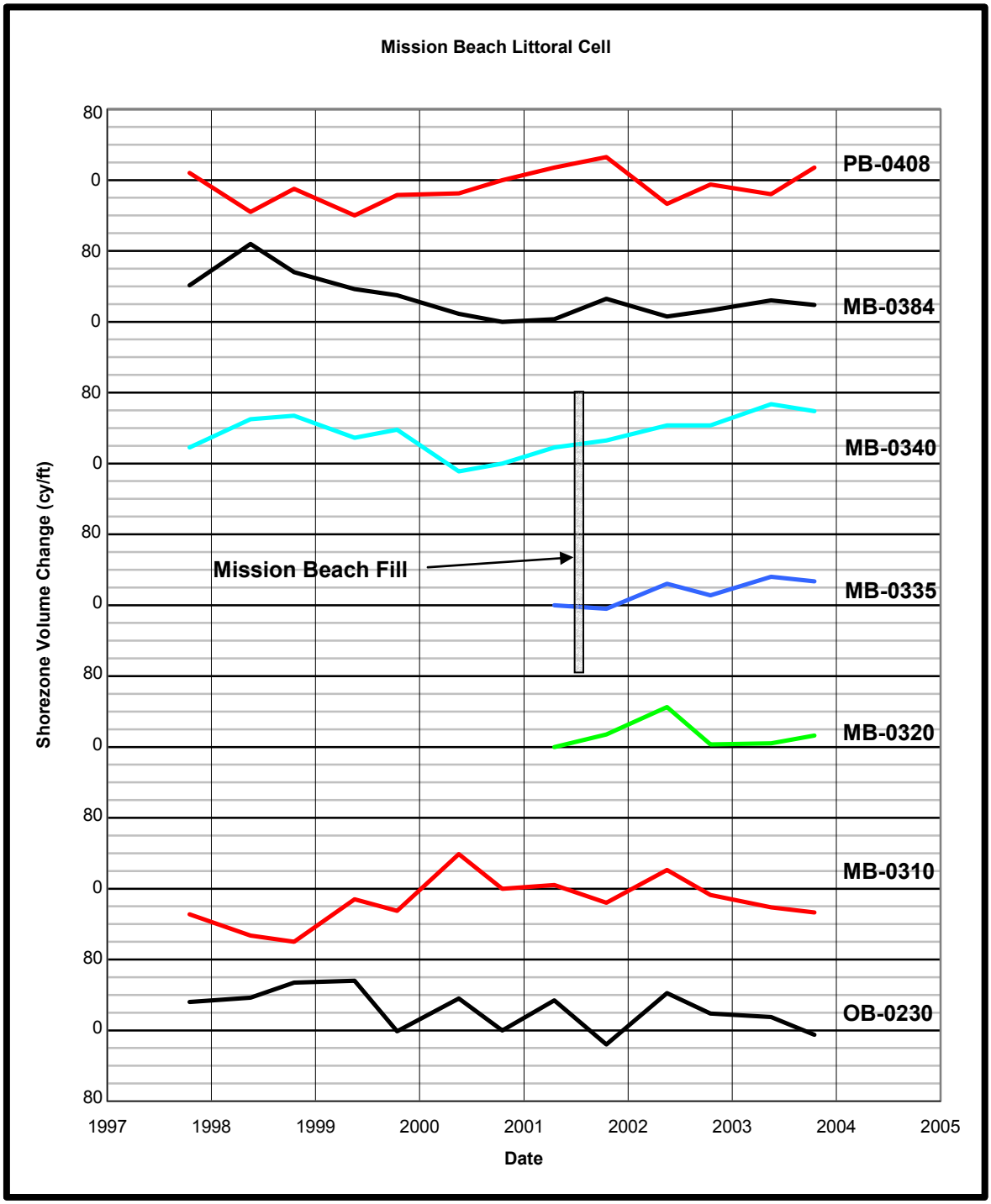
Figures 16a, b, and c present time series of the changes in shorezone sediment volume that occurred between Fall 1997 and Fall 2003. As in the case of Figures 13a, b, and c, the changes were reckoned from the volumes that prevailed at the beginning of the RBSP Monitoring Period (Fall 2000) whenever possible, or from the volumes that prevailed at the time of the initial survey for transects first profiled after Fall 2000. Key points are summarized below:

- A significant increase in shorezone volume occurred at the time of fill placement at each of the twelve RBSP receiver sites. At some of these beaches, such as Del Mar, Moonlight, and South Carlsbad, the gains were short-lived. At others, such as Mission Beach and Oceanside, the gains persisted through the time of the Fall 2003 survey.



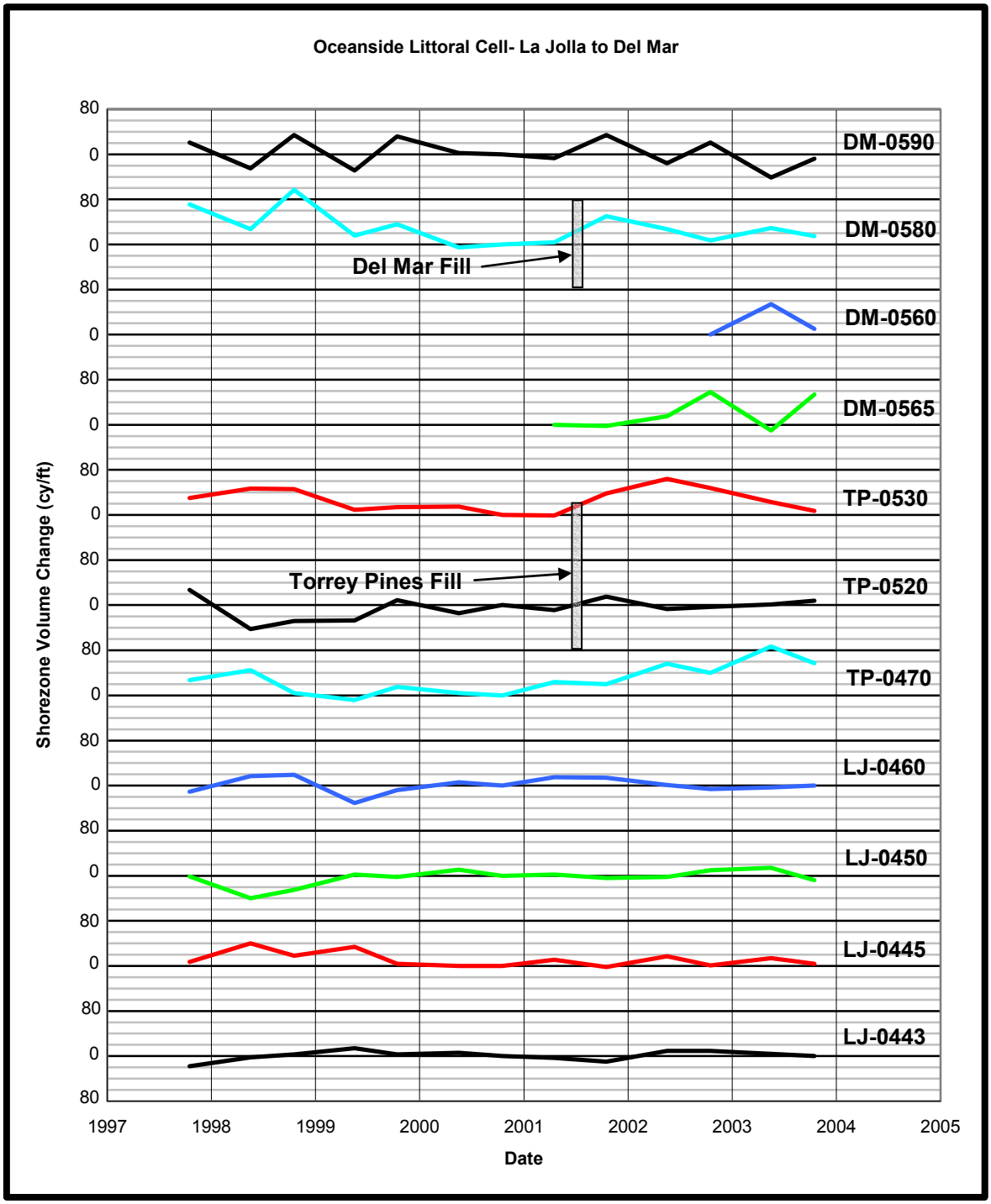
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16a. Time Series of Shorezone Volume Change in the Silver Strand Littoral Cell



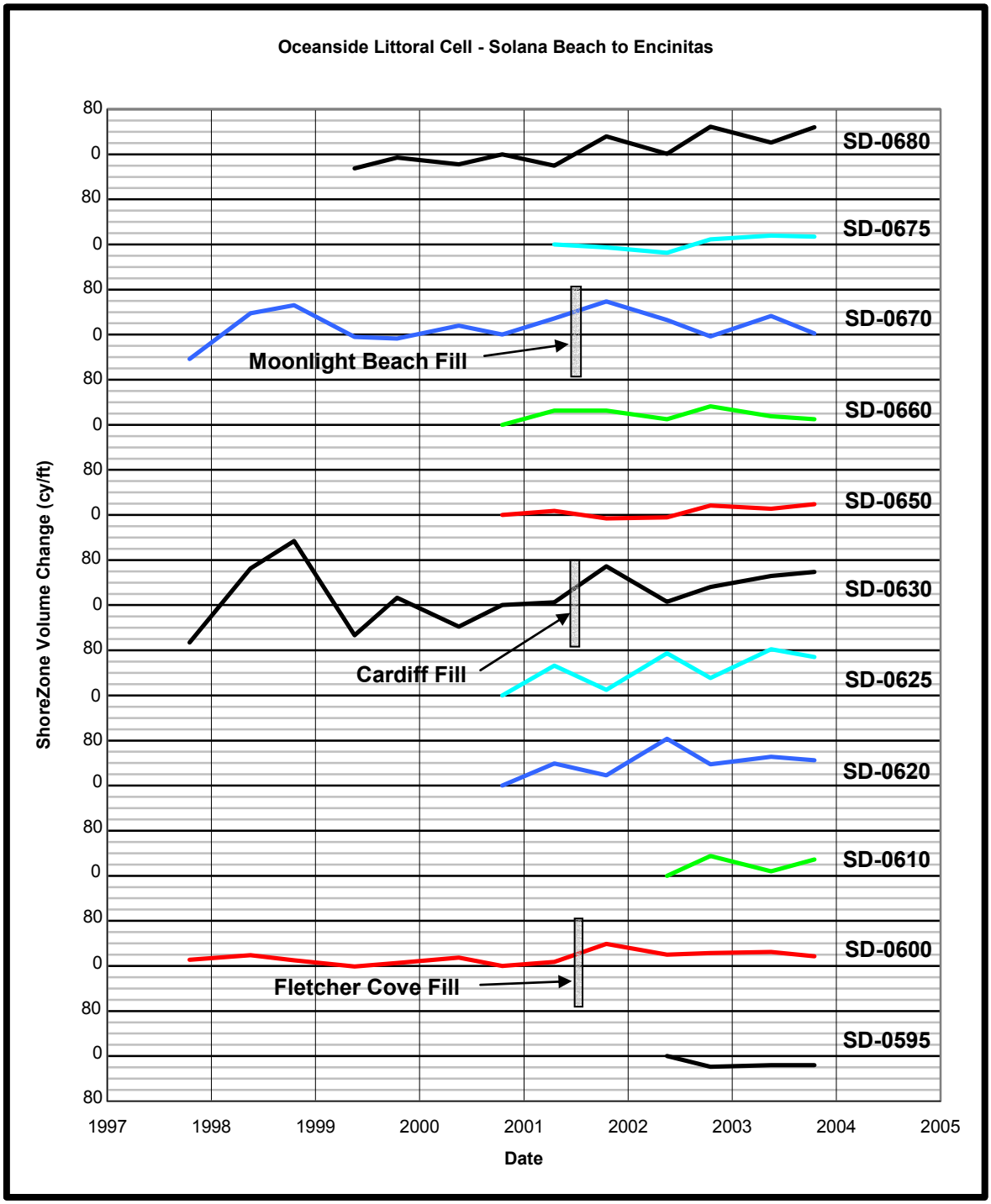
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16b. Time Series of Shorezone Volume Change in the Mission Beach Littoral Cell



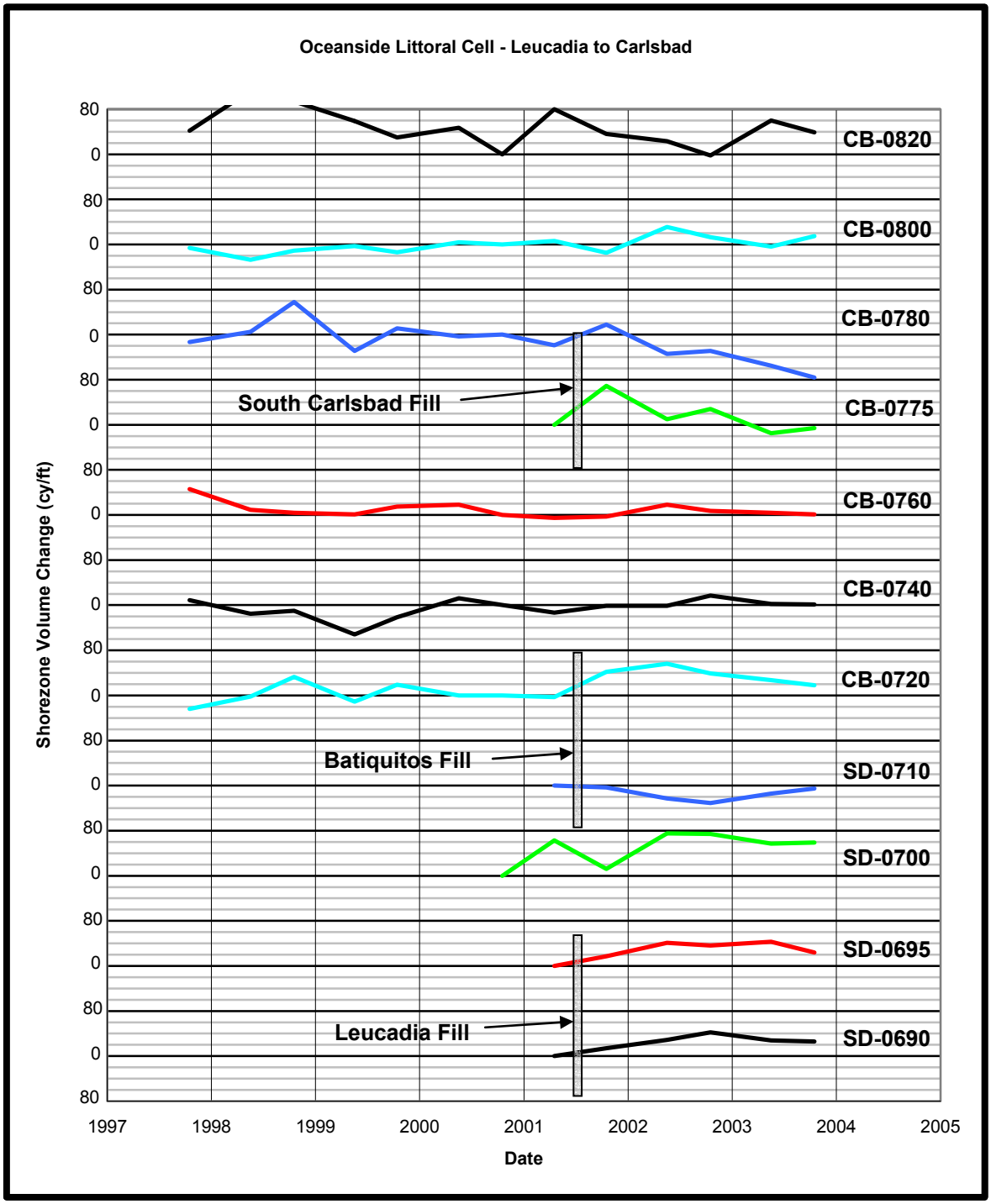
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 1 of 4)



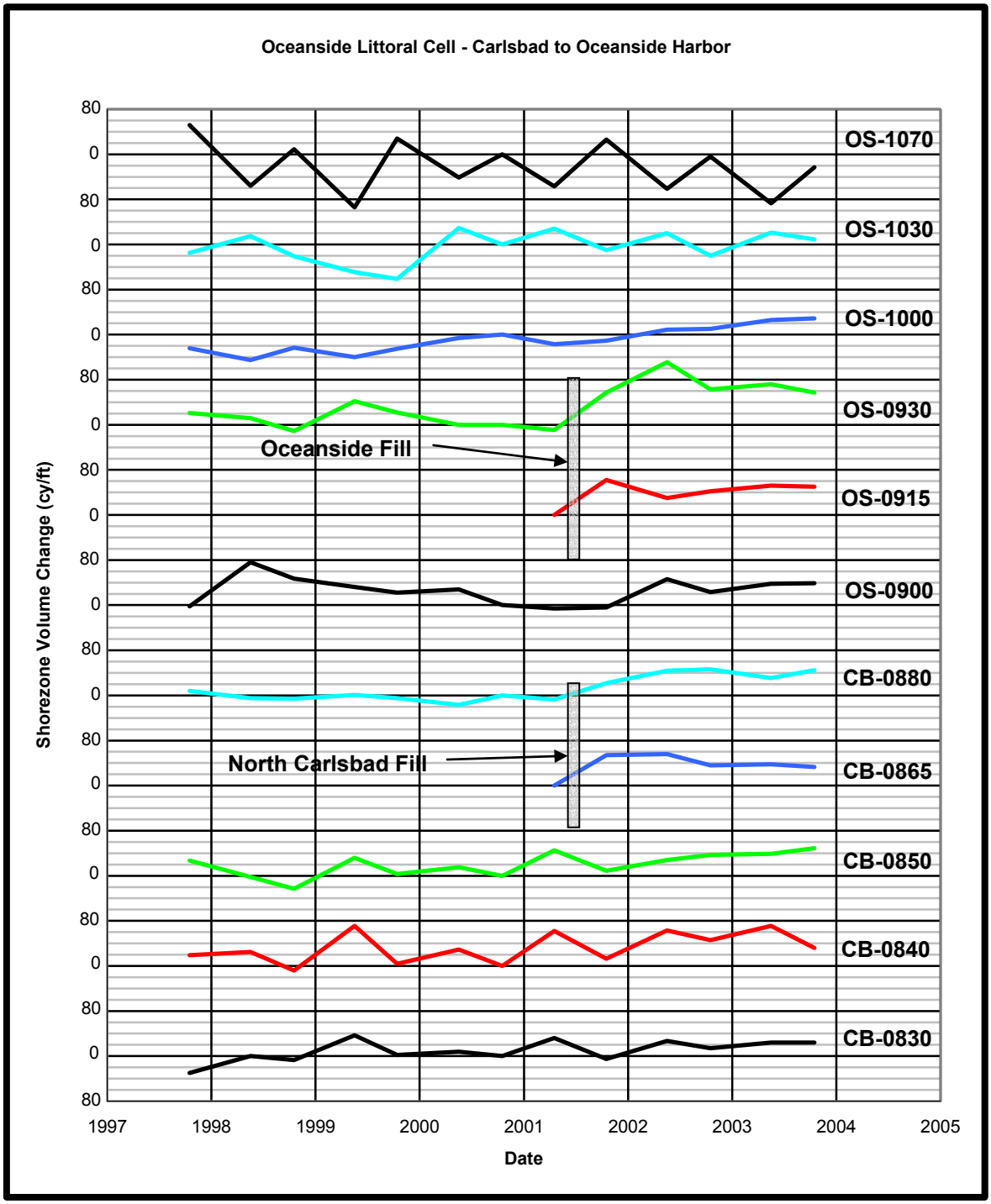
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 2 of 4)



Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 3 of 4)



Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 16c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 4 of 4)

- Shorezone volume gains occurred at many of the beaches adjacent to the receiver sites, reflecting lateral dispersal of the fill material. Representative examples include Transects SD-0625 and SD-0620, which are located adjacent to the Cardiff fill, and Transect SD-0680, which is located adjacent to the Leucadia fill.
- The positive impact of the RBSP fill material is most evident in the Oceanside-North Carlsbad area, where prolonged volume gains were recorded on the nine consecutive transects bounded by OS-1000 and CB-0830. These gains suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally along a stretch of coast that extends for more than two miles.

5.2. RBSP Beach Fill Performance

The subsections that follow assess the performance of each of the twelve RBSP beach fills. The locations of the fills, along with those of all beach profile transects in the vicinity, are shown in Figures 17 through 22.

Table 15 provides the MSL shoreline change and shorezone volume change that occurred between Spring 2001 and Fall 2003 on an indicator transect selected to characterize each fill site. In those instances where more than one transect crossed the fill, the transect that received the greatest nourishment (as indicated by the Post-Nourishment profile) was adopted as the indicator. To provide a reference against which individual fill performance can be measured, the table includes the average, maximum, and minimum values of each parameter.

It should be noted that the MSL shoreline changes in Table 15 reflect not only the effects of the nourishment program, but also a seasonal bias introduced by comparing shoreline positions from Spring (2001) and Fall (2003). Because the shoreline tends to advance during the summer wave season, the gains shown in the table are larger than they would have been without the seasonal bias. The Spring-to-Fall comparison is necessary, however, to bracket the life of the beach fills. The shorezone volumes shown in the table do not reflect a comparable seasonal bias, in that the shorezone encompasses the entire region in which seasonal cross-shore sediment transport may be expected to occur.

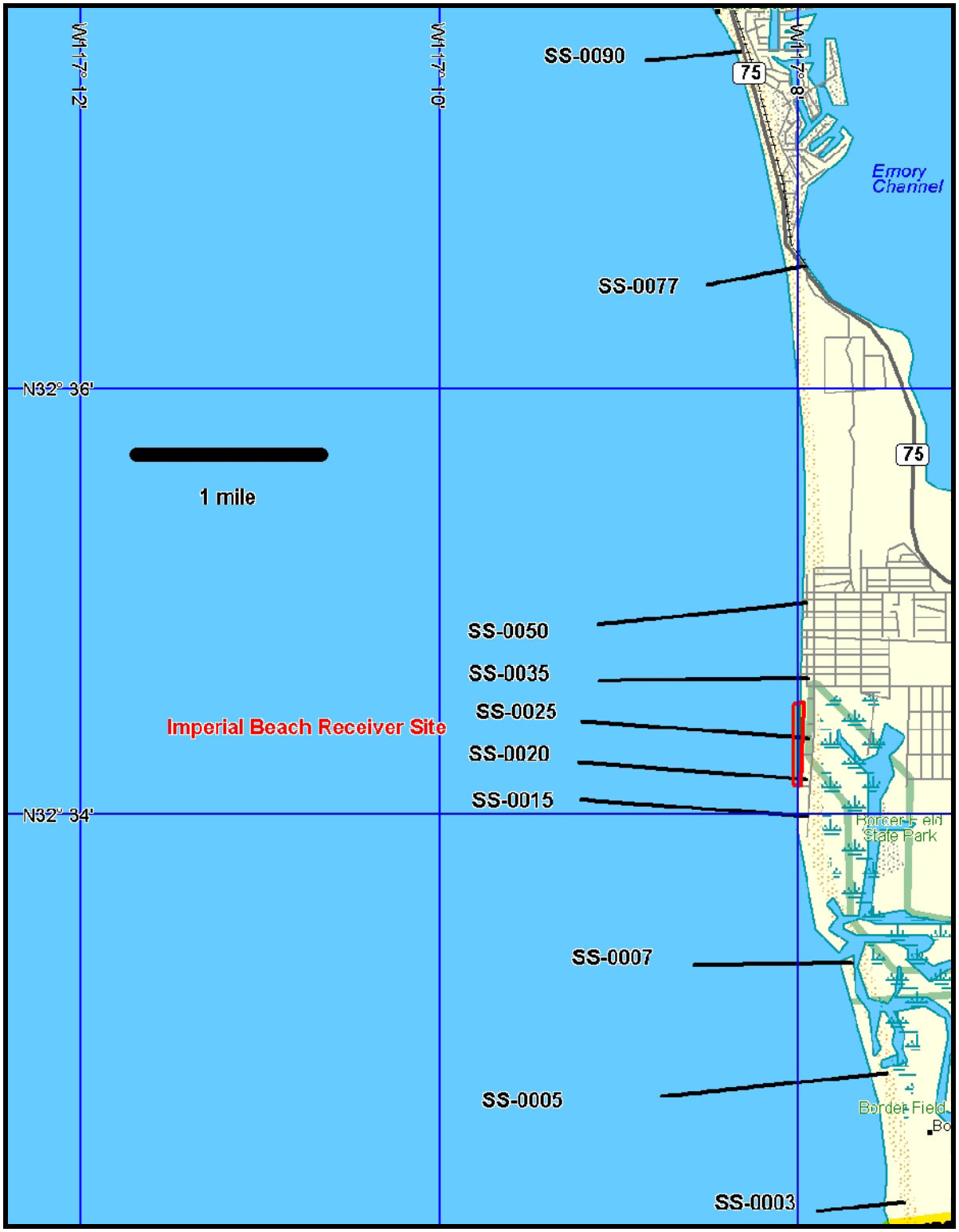


Figure 17. Location Map for Imperial Beach Receiver Site

Figure 18. Location Map for Mission Beach Receiver Site

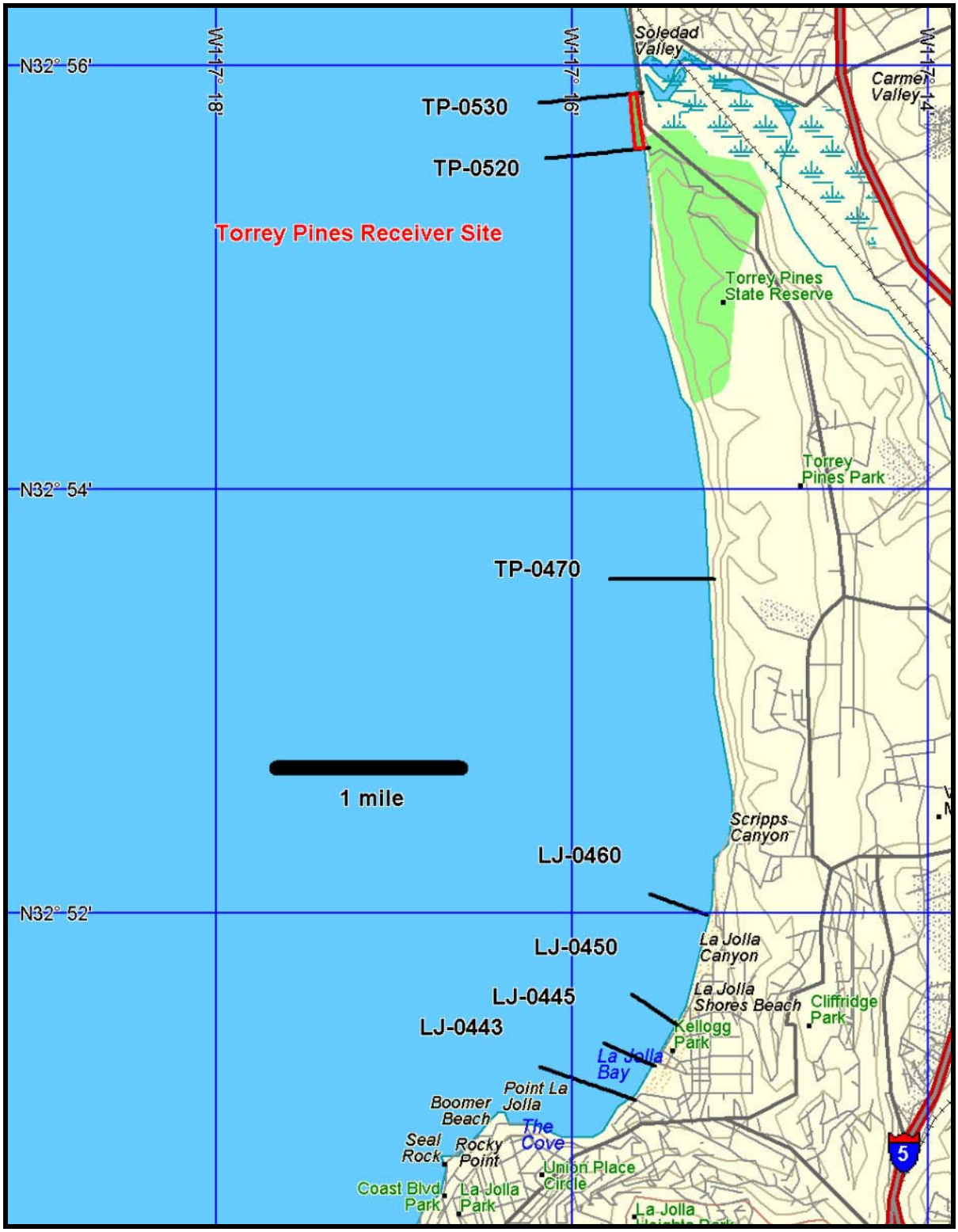


Figure 19. Location Map for Torrey Pines Receiver Site

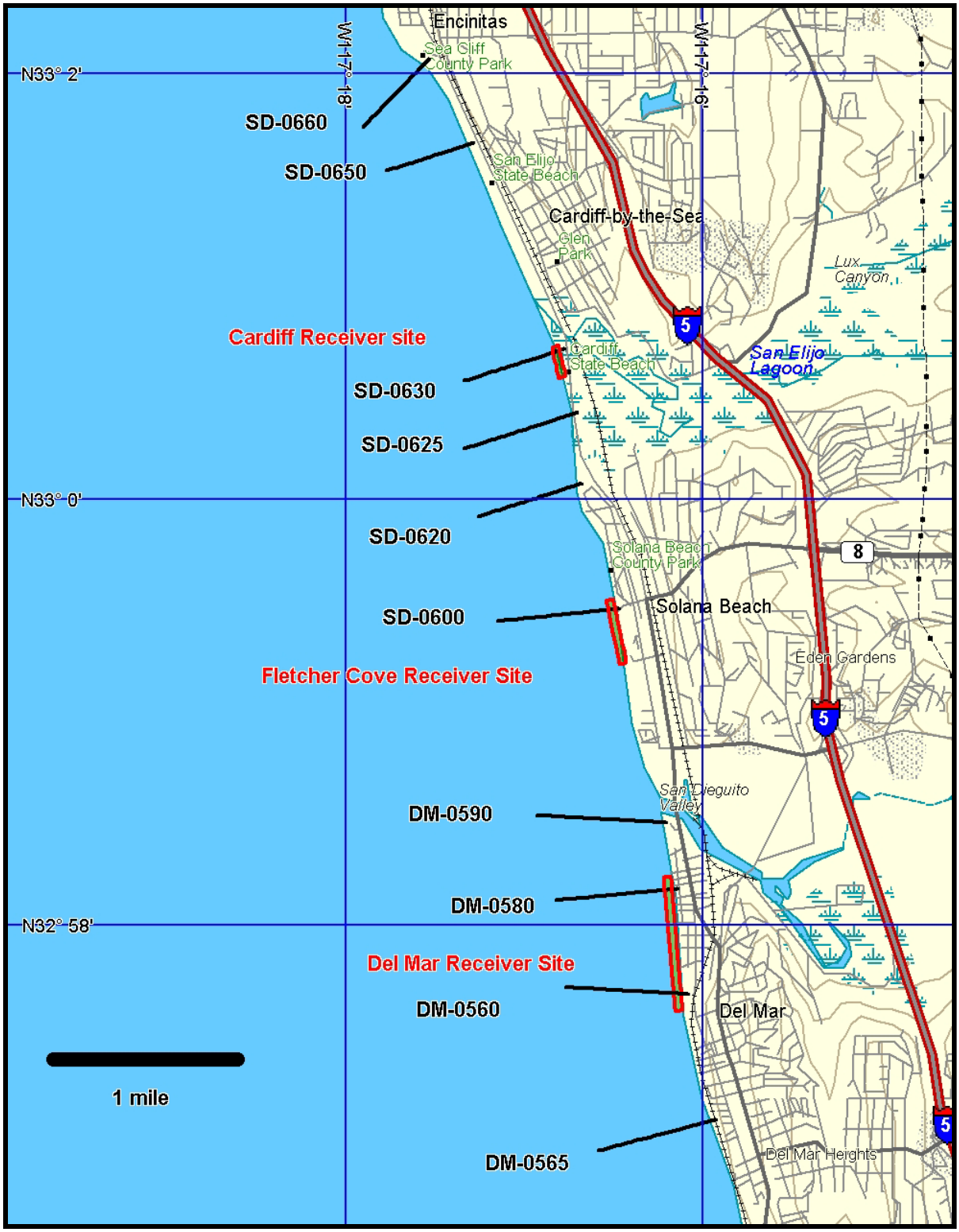


Figure 20. Location Map for Del Mar, Fletcher Cove, and Cardiff Receiver Sites

Figure 21. Location Map for Moonlight Beach, Leucadia, Batiquitos, and South Carlsbad Receiver Sites

Figure 22. Location Map for North Carlsbad and Oceanside Receiver Sites

Table 15. RBSP Beach Fill Performance

Receiver Beach	Indicator Transect	MSL Shoreline Change, Spring 01–Fall 03 (ft)	Shorezone Volume Change, Spring 01–Fall 03 (cy/ft)
Imperial Beach	SS-0025	137	52
Mission Beach	MB-0340	91	41
Torrey Pines	TP-0520	73	17
Del Mar	DM-0580	96	11
Fletcher Cove	SD-0600	48	10
Cardiff	SD-0630	97	54
Moonlight Beach	SD-0670	103	-27
Leucadia	SD-0690	28	26
Batiquitos	SD-0710	55	-5
S. Carlsbad	CB-0775	31	-6
N. Carlsbad	CB-0865	105	33
Oceanside	OS-0930	72	66
Average		***78***	***23***
Maximum		***137***	***66***
Minimum		***28***	***-27***

5.2.1. Imperial Beach (Figure 17)

The Imperial Beach fill, consisting primarily of coarse sand, was constructed from May 22 to June 5, 2001 (Table 1). At 120,000 cy, it was among the smallest fills in the RBSP. Pre-and post-nourishment views of the receiver beach are provided in Plate 1.

Profiles obtained on Transect SS-0025 between Spring 2001 and Fall 2003 are presented in Figure 23. During the initial year following the fill placement (Fall 2001 to Fall 2002), the oversteepened beach face adjusted to a more stable configuration, evidenced by above-water erosion and profile flattening. The profile changes during the 2003 Monitoring Year were consistent with the anticipated seasonal trends in cross-shore transport: offshore in winter (Fall 2002 to Spring 2003) and onshore in summer (Spring 2003 to Fall 2003). The extent of the above-water accretion was unusually large during Summer 2003, however, with the Fall 2003 profile closely resembling the Post-Nourishment beach condition.

Plate 1. Imperial Beach Receiver Site, April 2001 through November 2003

Between Spring 2001 and Fall 2003, the net result of the profile changes on Transect SS-0025 was a shoreline advance of 137 ft and a shorezone volume increase of 52 cy/ft. The shoreline advance was the largest recorded among the twelve RBSP receiver sites, while the volume increase was considerably higher than the average value of 23 cy/ft. As discussed below, this positive outcome resulted not only from the fill material but also from the arrival of sediment from the north.

Figure 16a indicates a trend of increasing shorezone volume at the two transects located within the fill (SS-0025 and SS-0020) following the nourishment operations. While the initial increase is attributable to the fill, the gains realized in subsequent years may have resulted from an influx of sediment from the north – a conclusion suggested by the losses that occurred on Transects SS-0050 and SS-0035 starting in Fall 2001.

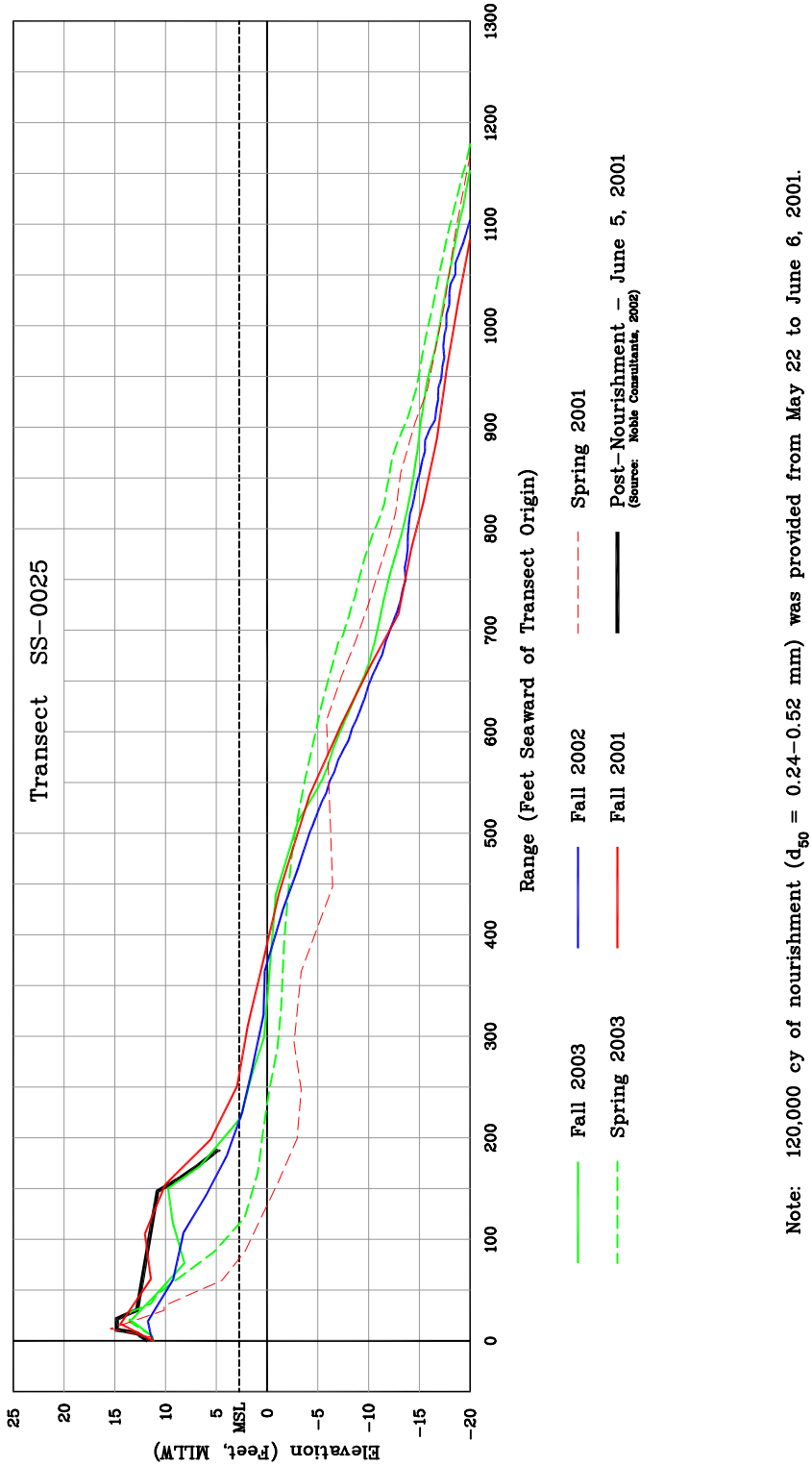


Figure 23. Transect SS-0025 at Imperial Beach Receiver Site

5.2.2. Mission Beach (Figure 18)

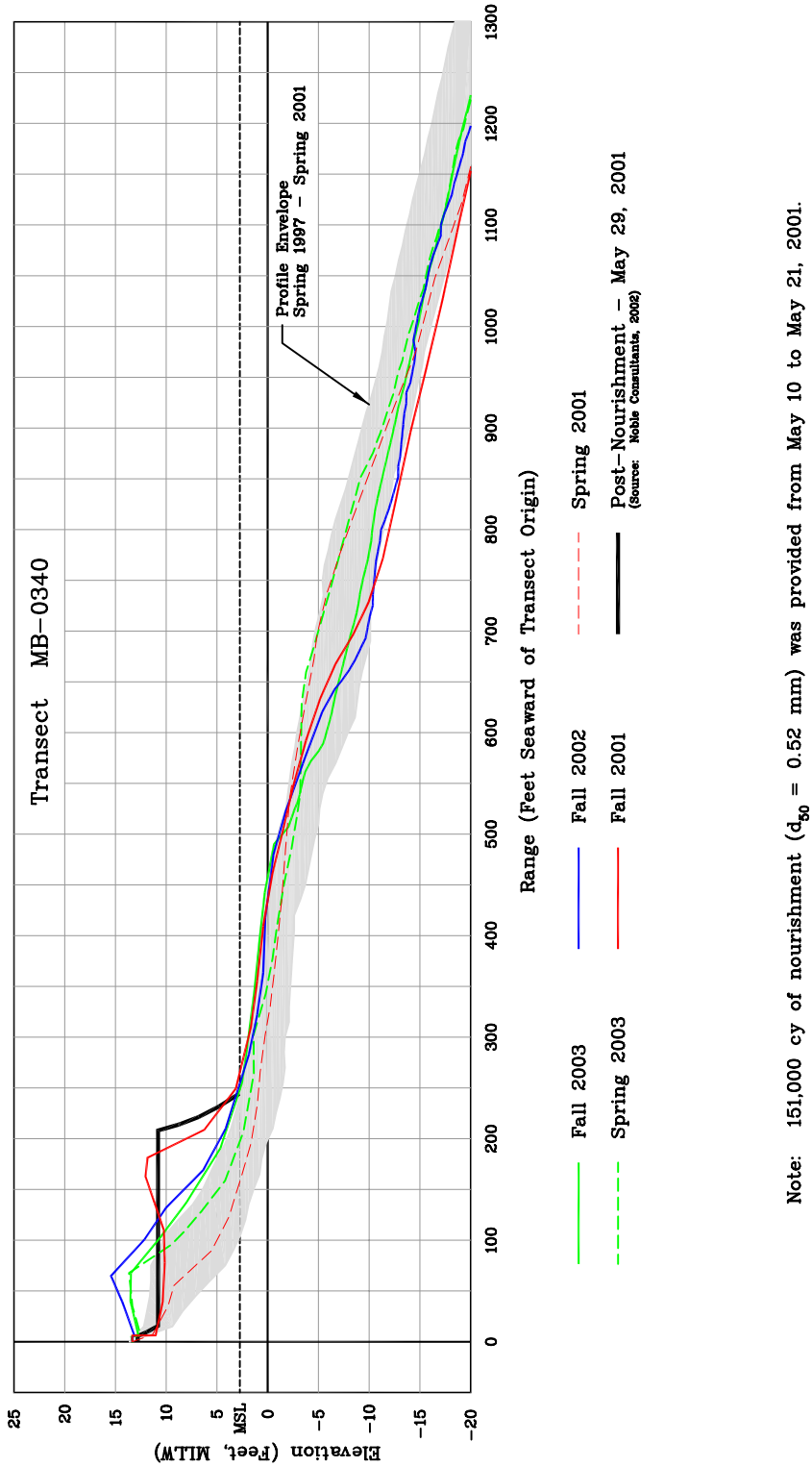
The Mission Beach fill consisted of 151,000 cy of coarse sand placed from May 10 to May 21, 2001. Pre-and post nourishment photographs are shown in Plate 2, while profiles obtained on Transect MB-0340 are plotted in Figure 24.

April 2001 (Pre-RBSP) *November 2001 (6 months after nourishment)*

May 2002 (12 months after nourishment) *November 2003 (29.5 months after nourishment)*

Plate 2. Mission Beach Receiver Site, April 2001 through November 2003

The consecutive Fall profiles shown in Figure 24 indicate progressive erosion of the above-water beach and flattening of the beach face following the placement of the RBSP fill. At the time of the Fall 2003 Survey, however, the beach profile remained above the pre-RBSP envelope between the back beach and MSL, suggesting an enduring benefit from the nourishment material. The prominent berm evident in these profiles resulted not from natural processes, but rather from mechanical grading undertaken to eliminate ponding



Note: 151,000 cy of nourishment (d_{50} = 0.52 mm) was provided from May 10 to May 21, 2001.

Figure 24. Transect MB-0340 at Mission Beach Receiver Site

in the back beach that occurred after placement of the nourishment material (Rennie, 2003; Boudreau, 2003). A similar feature is evident on Transect MB-0335 (Appendix D), which also crosses the fill site.

Between Spring 2001 and Fall 2003, the MSL shoreline advanced 91 ft and the shorezone volume increased by 41 cy/ft on Transect MB-0340. Both of these values exceeded the respective averages for the RBSP receiver sites.

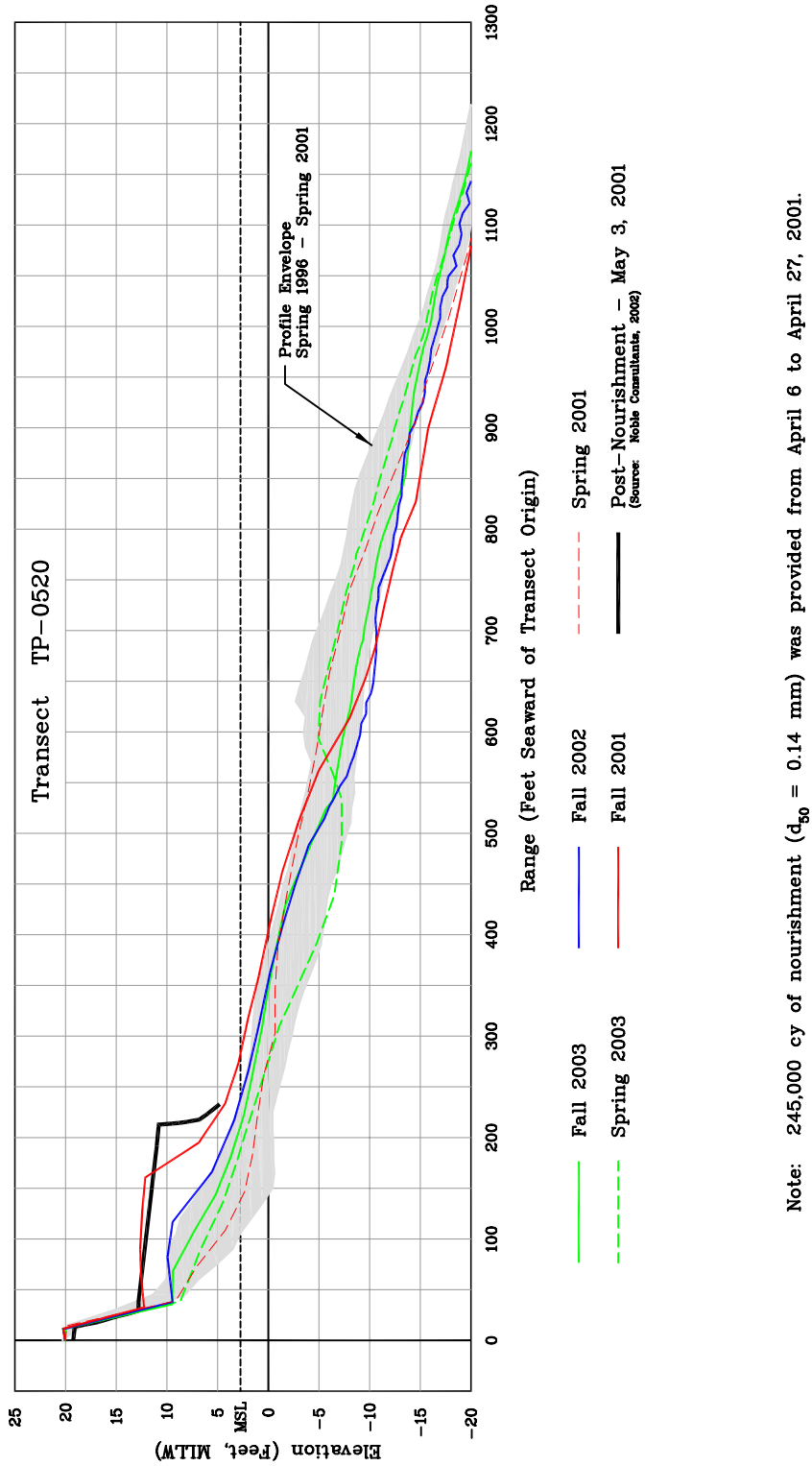
Figures 13b and 16b documents subaerial and shorezone volume changes on the five Mission Beach transects. As implied by the profile data, considerable subaerial volume gains occurred on the two transects crossing the fill (MB-0340 and MB-0035) immediately after nourishment. Despite seasonal fluctuations, the subaerial volume has remained remarkably stable at both locations, and represents a significant improvement over the pre-nourishment condition. When the entire shorezone is considered (Figure 16b), both transects exhibit a trend of steadily increasing volumes since the RBSP. Similar trends are not evident on adjacent transects, suggesting that alongshore dispersal of the fill material has been minimal.

5.2.3. Torrey Pines (Figure 19)

At Torrey Pines, the beach fill was composed of 245,000 cy of fine sand placed from April 6 to April 27, 2001. Among the twelve RBSP fills, this quantity was exceeded only by the 421,000 cy supplied at Oceanside. Successive profiles on Transect TP-0520 are shown in Figure 25, while pre- and post-nourishment photographs are provided in Plate 3.

Noteworthy aspects of the profile data on Transect TP-0520 include progressive erosion of the above-water beach and flattening of the beach face following fill placement. At the time of the Fall 2003 Survey, the beach profile no longer exceeded the pre-RBSP envelope, indicating that the fill had been largely dispersed. Nevertheless, when integrated over the 30-month period between Spring 2001 and Fall 2003, these changes produced a sizeable shoreline advance of 73 ft and a modest shorezone volume gain of 17 cy/ft.

Similar to the profile data, the time series of subaerial volume change (Figure 13c) show sizeable gains immediately after nourishment on the two transects crossing the Torrey Pines fill (TP-0530 and TP-0520). A trend of declining volumes then persisted for the remainder of the RBSP Monitoring Period, indicating a gradual dispersal of the fill.



Note: 245,000 cy of nourishment (d_{50} = 0.14 mm) was provided from April 6 to April 27, 2001.

Figure 25. Transect TP-0520 at Torrey Pines Receiver Site

Plate 3. Torrey Pines Receiver Site, April 2001 through November 2003

Shorezone volume gains (Figure 16c) were short-lived, as losses during the initial winter reduced the volumes to pre-RBSP levels. Approximately 2 miles south of the Torrey Pines receiver site, however, a trend of increasing shorezone volume is evident on Transect TP-0470. Although a considerable distance from the fill site, the gain may have resulted, at least in part, from downcoast transport of the Torrey Pines nourishment material.

Additional information on the performance of the Torrey Pines fill can be obtained from the Southern California Beach Processes Study. The study findings are presented in a series of quarterly reports available at http://cdip/ucsd.edu (e.g., Guza, *et al*., 2002).

5.2.4. Del Mar (Figure 20)

The Del Mar fill (Plate 4) consisted of 183,000 cy of fine sand placed from April 27 to May 10, 2001. As illustrated in Figure 26, the beach face flattened in the initial year

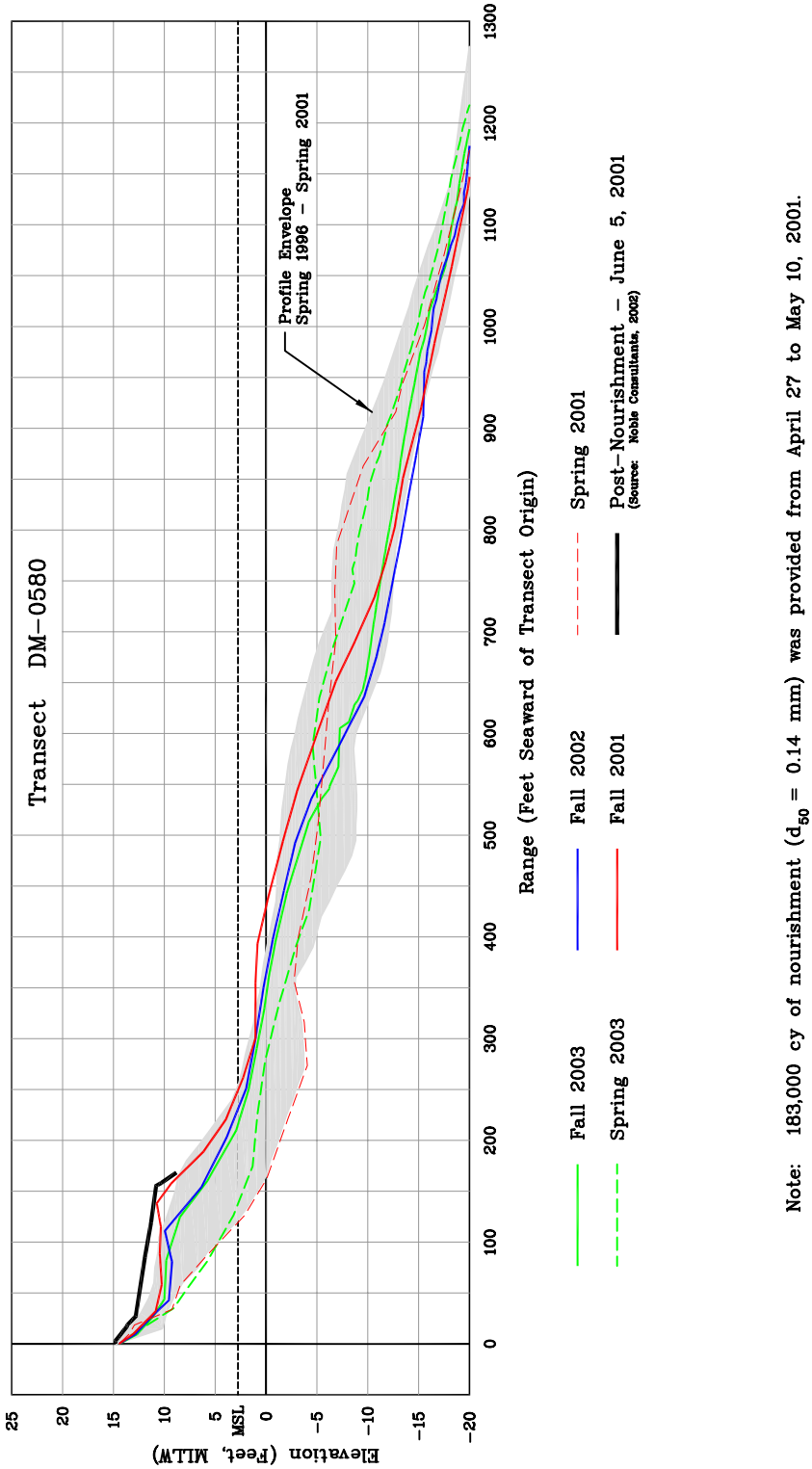
April 2001 (Pre-RBSP)

November 2001 (6 months after nourishment)

November 2002 (18 months after nourishment)

November 2003 (30 months after nourishment)

Plate 4. Del Mar Receiver Site, April 2001 through November 2003



Note: 183,000 cy of nourishment (d_{50} = 0.14 mm) was provided from April 27 to May 10, 2001.

Figure 26. Transect DM-0580 at Del Mar Receiver Site

following nourishment (Fall 2001 to Fall 2002). Changes were modest during the 2003 Monitoring Year, however, with the Fall 2003 profile closely approximating the Fall 2002 profile. When the 30-month period between Spring 2001 and Fall 2003 is considered, these changes produced a sizeable shoreline advance of 96 ft with a modest shorezone volume gain of 11 cy/ft.

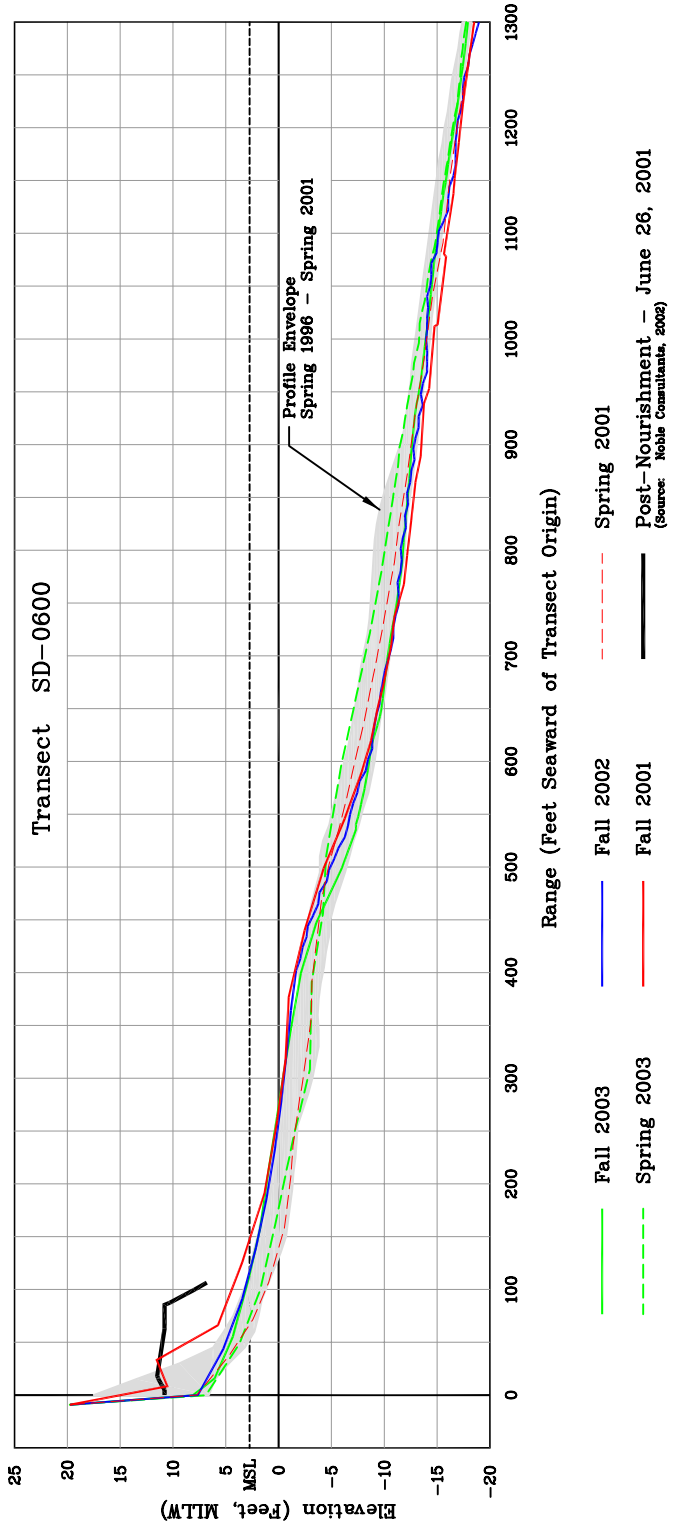
As suggested by the profile data, the time series of shorezone volume change at Transect DM-0580 (Figures 16c) indicates that the nourishment material produced a relatively minor gain immediately after placement. The volume then began to decline as the fill material was dispersed. Approximately 3,400 ft south of the receiver site, at Transect DM-0565, increasing shorezone volume during the same period suggests that the fill material was transported downcoast.

5.2.5. Fletcher Cove (Figure 20)

The Fletcher Cove fill, placed from June 15 to 24, 2001, consisted of 146,000 cy of fine sand. Figure 27 displays the Spring 2001 and Post-Nourishment profiles on Transect SD-0600, along with the profiles acquired in Fall 2001, Fall 2002, Spring 2003, and Fall 2003. Pre-and post nourishment photographs are provided in Plate 5.

The profile data at SD-0600 indicate that the majority of the nourishment material placed at the site in June 2001 had been lost from the above-water beach by Fall 2002. However, the Fall 2002 and Fall 2003 profiles both exceed the upper boundary of the pre-RBSP envelope near the waterline, suggesting stability during the past year as well as a slight improvement over the pre-nourishment condition. In the 30-month period between the Spring 2001 and Fall 2003 surveys, the shoreline position advanced 48 ft while the shorezone volume increased by 10 cy/ft.

In accordance with the profile data, a modest increase in subaerial volume is evident at Transect SD-0600 at the time of the Fall 2001 Survey (Figure 13c). The gain was short-lived, however, with the above-water volumes approximating the pre-RBSP condition by Spring 2002. When the shorezone volume is considered (Figure 16c), a similar increase is noted shortly after nourishment. Although a loss occurred during the initial winter, a small net shorezone volume gain persisted through the remainder of the RBSP Monitoring Period.



Note: 146,000 cy of nourishment (d_{50} = 0.14 mm) was provided from June 15 to June 24, 2001.

Figure 27. Transect SD-0600 at Fletcher Cove Receiver Site

April 2001 (Pre-RBSP)

November 2001 (4.5 months after nourishment)

November 2002 (15 months after nourishment)

November 2003 (28.5 months after nourishment)

Plate 5. Fletcher Cove Receiver Site, April 2001 through November 2003

5.2.6. Cardiff (Figure 20)

Cardiff received the smallest nourishment quantity among the RBSP receiver sites, 101,000 cy of medium sand. The fill was placed from August 2 to 10, 2001. Successive profiles on Transect SD-0630 are shown in Figure 28, while pre- and post-nourishment photographs are provided in Plate 6.

Figure 28 indicates that substantial above-water erosion occurred at the Cardiff receiver site during the first year following fill placement (Fall 2001 to Fall 2002). Subsequent changes were modest, with the Fall 2002 and Fall 2003 profiles almost identical. The Fall 2003 profile exceeded the upper boundary of the pre-RBSP envelope between elevations of +6 ft and -5 ft, suggesting that some of the nourishment material still remained in the area.

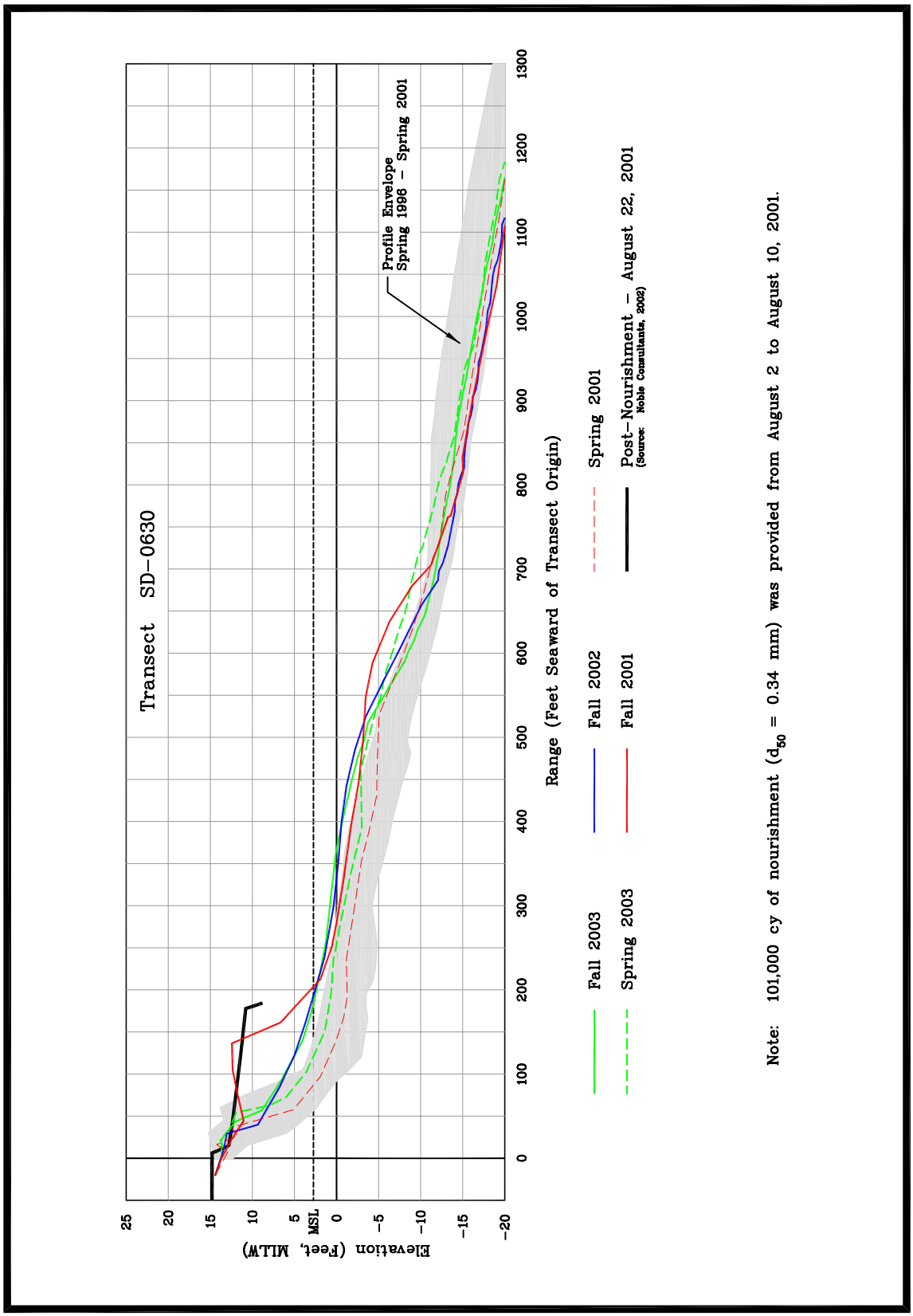


Figure 28. Transect SD-0630 at Cardiff Receiver Site

April 2001 (Pre-RBSP)

November 2001 (3 months after nourishment)

November 2002 (15 months after nourishment)

November 2003 (27 months after nourishment)

Plate 6. Cardiff Receiver Site, April 2001 through November 2003

Between Spring 2001 and Fall 2003, the net result of these profile changes on Transect SD-0630 was a shoreline advance of 97 ft and a shorezone volume increase of 54 cy/ft. The fact that both of these values exceed the respective RBSP averages is surprising when the small size of the fill is taken into consideration.

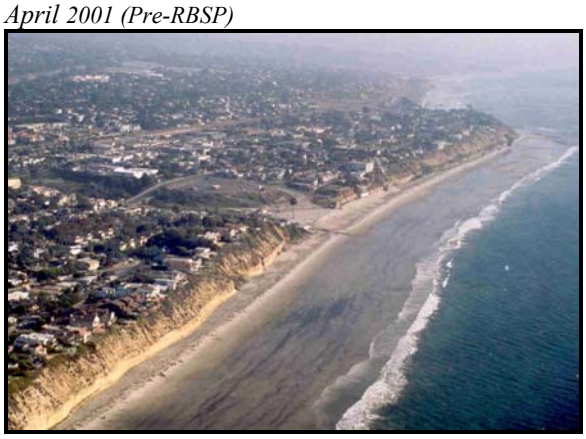
As suggested by the profile data, significant subaerial and shorezone volume gains occurred at Transect SD-0630 immediately after nourishment (Figures 13c and 16c). Losses during the following winter (2001-2002) reduced the volumes to pre-RBSP levels. While the subaerial volume remained stable through the remainder of the RBSP Monitoring Period, the shorezone volume registered a substantial gain. A trend of increasing shorezone volume also is evident at Transect SD-0625 and SD-0620, suggesting downcoast transport of the fill material.

5.2.7. Moonlight Beach (Figure 21)

The Moonlight Beach fill, consisting primarily of coarse sand, was placed from August 10 to 16, 2001. Although the quantity was small, at 105,000 cy, the design fill width of 180 ft was among the largest of the twelve RBSP sites (Table 1). Pre-and post-nourishment photographs are shown in Plate 7; profiles on Transect SD-0670 are provided in Figure 29.

April 2001 (Pre-RBSP)

November 2001 (3 months after nourishment)



November 2002 (15 months after nourishment)

November 2003 (26.5 months after nourishment)

Plate 7. Moonlight Beach Receiver Site, April 2001 through November 2003

The successive Fall profiles shown in Figure 24 indicate rapid erosion of the above-water beach and flattening of the beach face slope following the placement of the RBSP fill. As a result, the subaerial volume gains that occurred at the Moonlight Beach receiver site following the nourishment diminished relatively quickly. At the time of the Fall 2003 Survey, the profile at SD-0670 approximated the upper boundary of the pre-RBSP envelope between the back beach and -2 ft, but dropped to the lower boundary seaward of

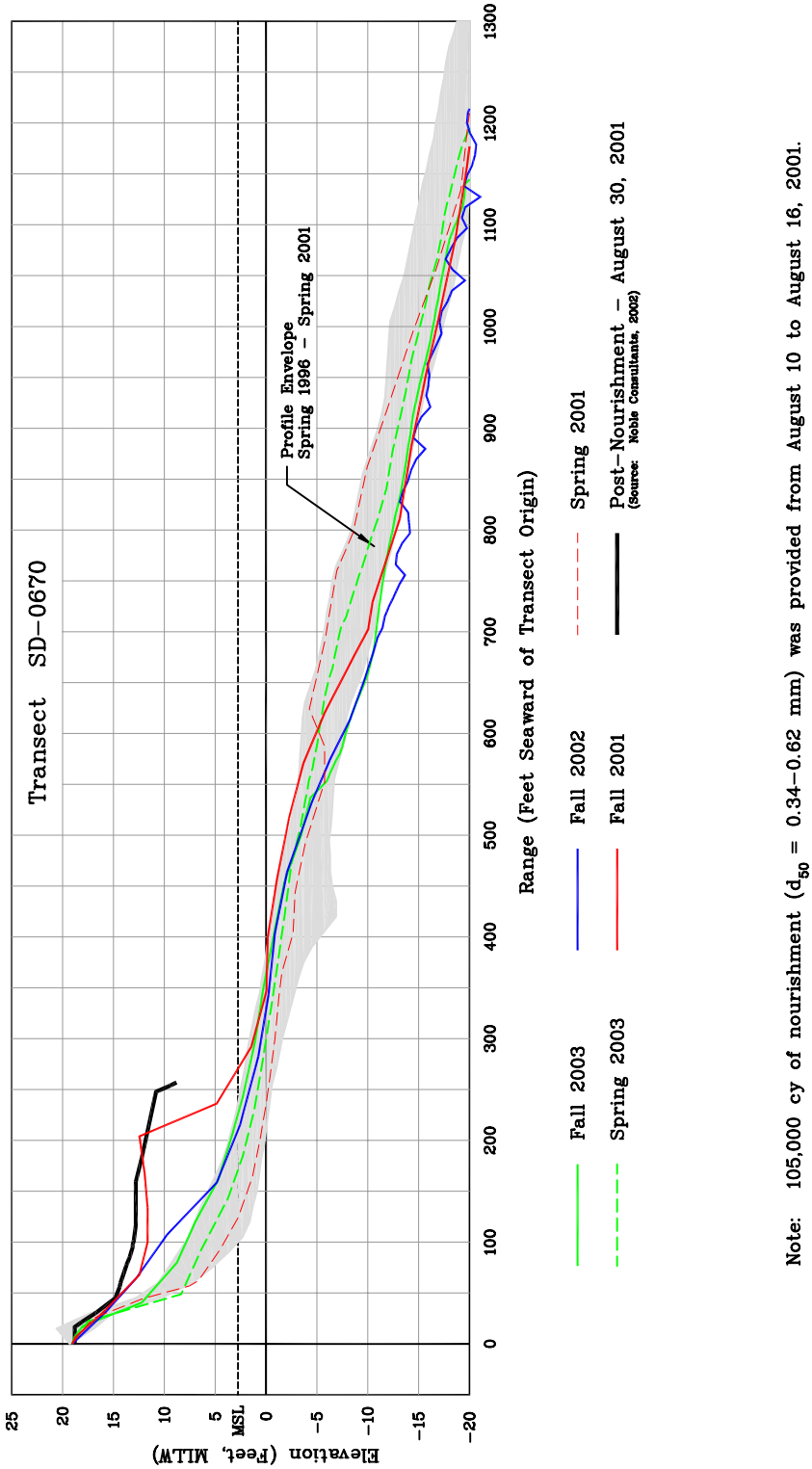


Figure 29. Transect SD-0670 at Moonlight Beach Receiver Site

the -7 ft isobath. Integrating these changes over the 30-month period between the Spring 2001 and Fall 2003 surveys, the shoreline position advanced 103 ft, but the shorezone volume decreased by 27 cy/ft.

Similar trends are evident in Figures 13c and 16c, which display time series of the subaerial and shorezone volume changes. Volume gains attributable to the nourishment are apparent in Fall 2001, followed by a trend of diminishing volumes through the remainder of the RBSP Monitoring Period. As no survey transects exist immediately to the south of the Moonlight Beach receiver site, the extent to which the nourishment material benefited the downcoast beaches cannot be quantified.

5.2.8. Leucadia (Figure 21)

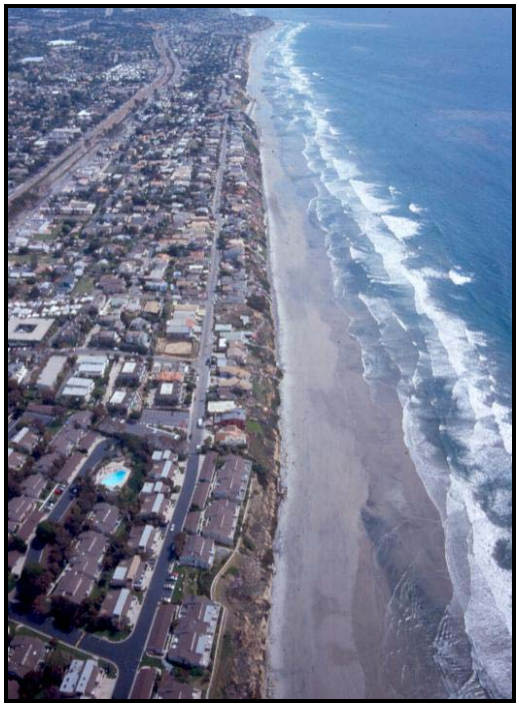
The Leucadia fill (Plate 8) consisted of 132,000 cy of coarse sand. A relatively long, narrow fill with a nominal width of 120 ft, it was placed from June 4 to 15, 2001. Survey profiles on Transect SD-0690 are provided in Figure 30.

The profile data indicate above-water erosion following the placement of the fill. However, during the past year (Fall 2002 to Fall 2003), the rate of change slowed. As a result, the beach width increased by 28 ft since the Spring 2001 survey. Although the shorezone volume increased by 26 cy/ft, this modest gain appears to have resulted more from the enhanced mapping of offshore reefs that commenced in Fall 2002 (Section 4.1.1) than from actual sediment accretion (Figure 30).

The subaerial and shorezone volumes at the Leucadia receiver site declined gradually following nourishment in 2001 (Figures 13c and 16c). This relative stability may have resulted from an influx of material from the Batiquitos fill, located less than 1 mile to the north. Similarly, downcoast transport of the Leucadia fill material appears to have benefited the adjacent beaches to the south. To this end, the subaerial and shorezone volumes increased steadily at Transects SD-0680 and SD-0675 subsequent to the RBSP.

5.2.9. Batiquitos (Figure 21)

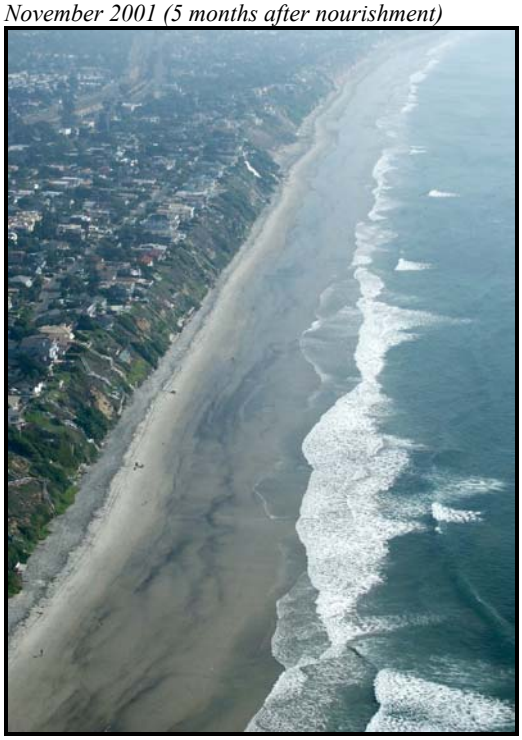
At the Batiquitos receiver site, 117,000 cy of coarse sand were provided from August 16 to 23, 2001 (Plate 9). Profile data for Transect SD-0710 are shown in Figure 31.



April 2001 (Pre-RBSP)

November 2001 (5 months after nourishment)

November 2002 (17 months after nourishment)



November 2003 (29 months after nourishment)

Plate 8. Leucadia Receiver Site, April 2001 through November 2003

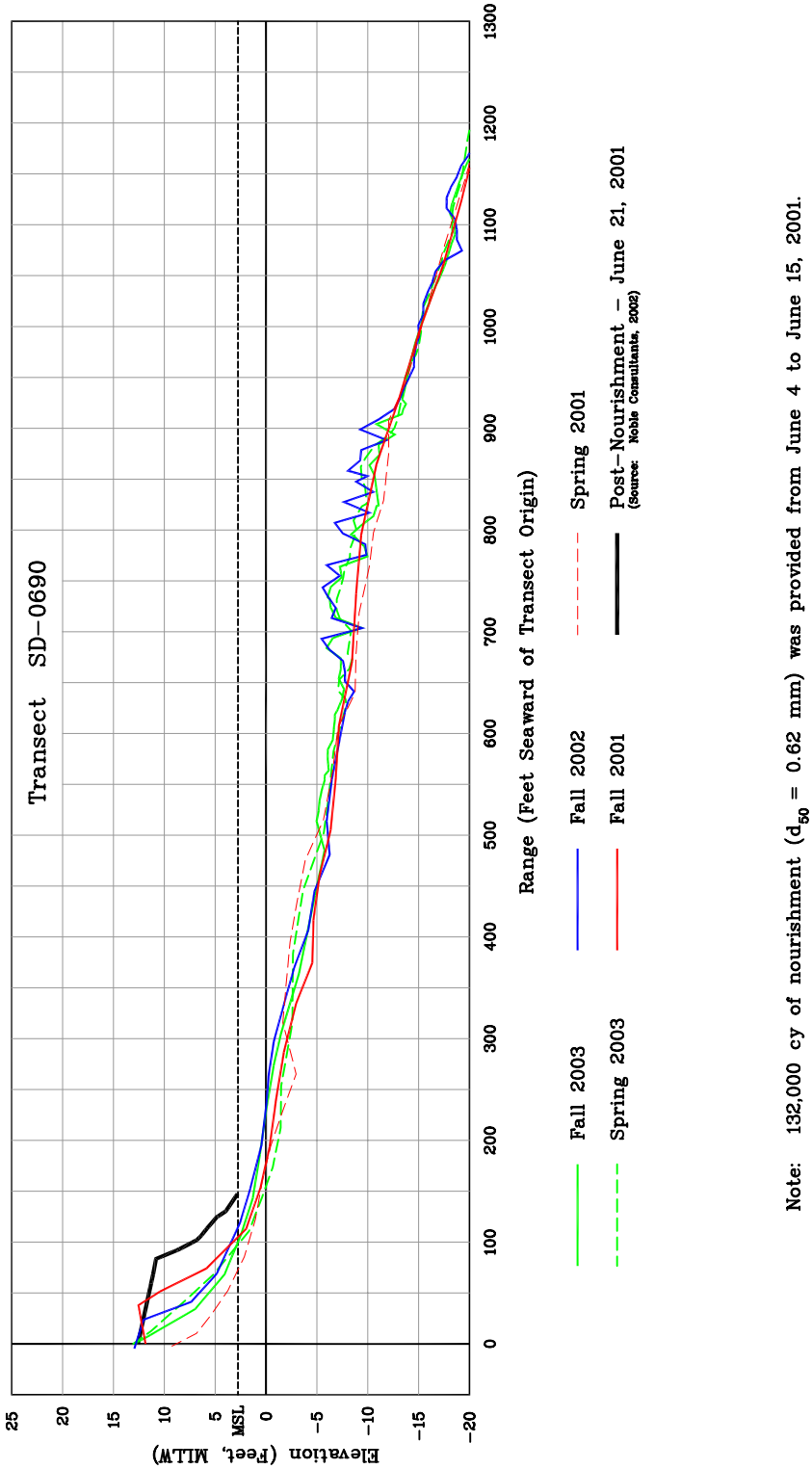


Figure 30. Transect SD-0690 at Leucadia Receiver Site

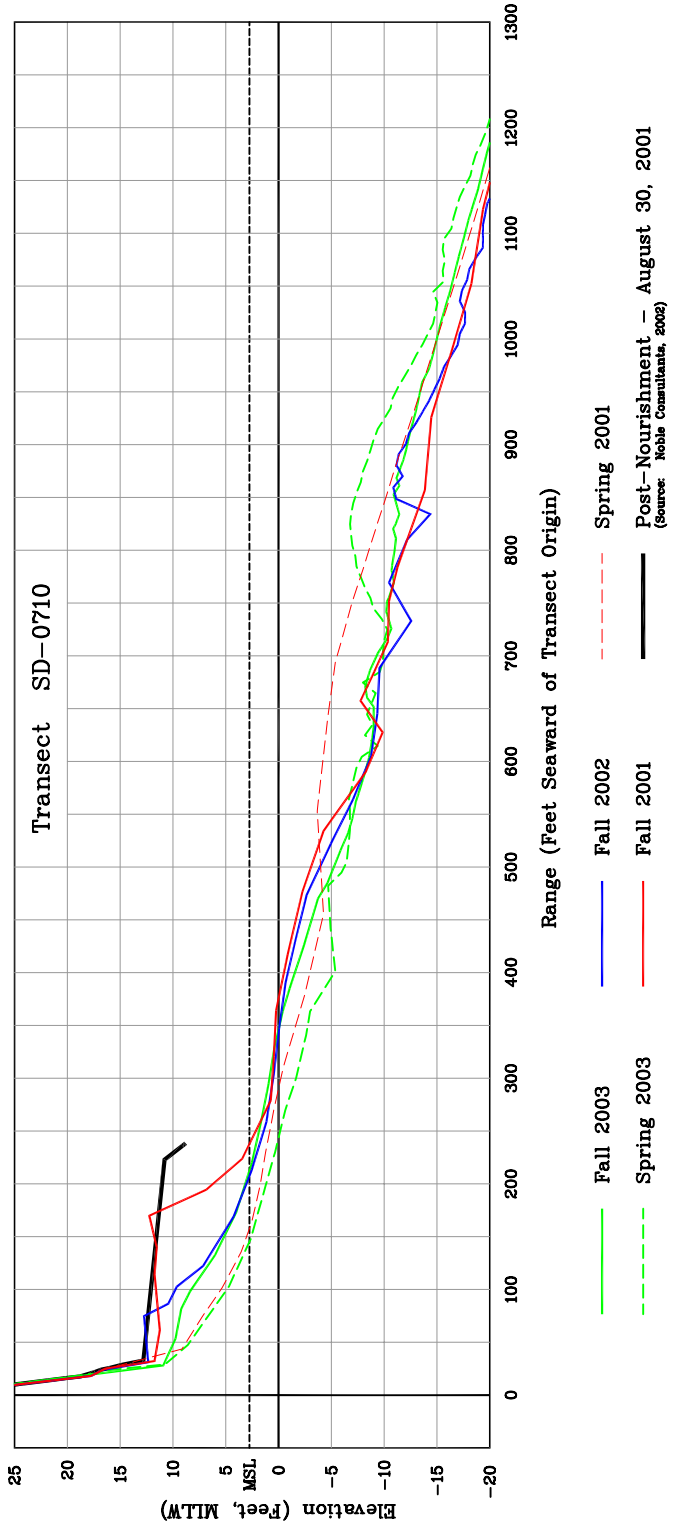
April 2001 (Pre-RBSP)

November 2001 (2.5 months after nourishment)

November 2002 (14.5 months after nourishment)

November 2003 (26.5 months after nourishment)

Plate 9. Batiquitos Receiver Site, April 2001 through November 2003



Note: 117,000 cy of nourishment (d_{50} = 0.62 mm) was provided from August 16 to August 23, 2001.

Figure 31. Transect SD-0710 at Batiquitos Receiver Site

The profile data for the Batiquitos fill indicate a sequence of events similar to that recorded at Leucadia: above-water erosion and profile flattening concentrated in the period between the time of fill placement and Fall 2002, followed by relative stability thereafter. The net outcome over the 30-month span between Spring 2001 and Fall 2003 was a shoreline advance of 55 ft accompanied by a shorezone volume decrease of 5 cy/ft. As in the case of Moonlight Beach, which also registered a decrease in shorezone volume during this period, the loss stemmed from pronounced erosion in water depths of -4 ft to -20 ft.

In keeping with the profile changes, Figures 13c and 16c indicate subaerial and shorezone volume losses following fill placement. The loss of nourishment material from the Batiquitos site appears to have produced gains at the adjacent beaches to the south. At Transect SD-0700, located 1,100 ft to the south of the Batiquitos receiver site, subaerial and shorezone volumes increased during Winter 2001-2002. Furthermore, these gains persisted through Fall 2003. As indicated in Section 5.2.8, the Leucadia site also appears to have benefited from the downcoast dispersal of the Batiquitos fill. These findings suggest that the two fills have merged.

5.2.10. South Carlsbad (Figure 21)

South Carlsbad received 158,000 cy of coarse sand from June 25 to July 6, 2001 (Plate 10). Successive survey profiles obtained between Spring 2001 and Fall 2003 on Transect CB-0775 are shown in Figure 32.

Like many of the other RBSP nourishment sites, the South Carlsbad fill experienced progressive above-water erosion and profile flattening following placement. In contrast to the other sites, however, the consecutive Fall profiles show a trend of persistent and substantial erosion of the nearshore bar between elevations of -2 ft and -10 ft subsequent to the RBSP. The net result was a shoreline advance of 63 ft and a shorezone volume loss of 6 cy/ft between Spring 2001 and Fall 2003.

While significant subaerial and shoreline volume gains were realized on Transects CB-0780 and CB-0775 just after fill placement, the remainder of the RBSP Monitoring Period was characterized by declining volumes. As indicated in Figures 13c and 16c, virtually all of the fill material had been dispersed prior to the Fall 2003 survey. Downdrift, at Transect CB-0760, the dispersal produced only modest, transient increases in the subaerial and shorezone volumes (Figures 13c and 16c)

April 2001 (Pre-RBSP)

November 2001 (4.5 months after nourishment)

November 2002 (16.5 months after nourishment)

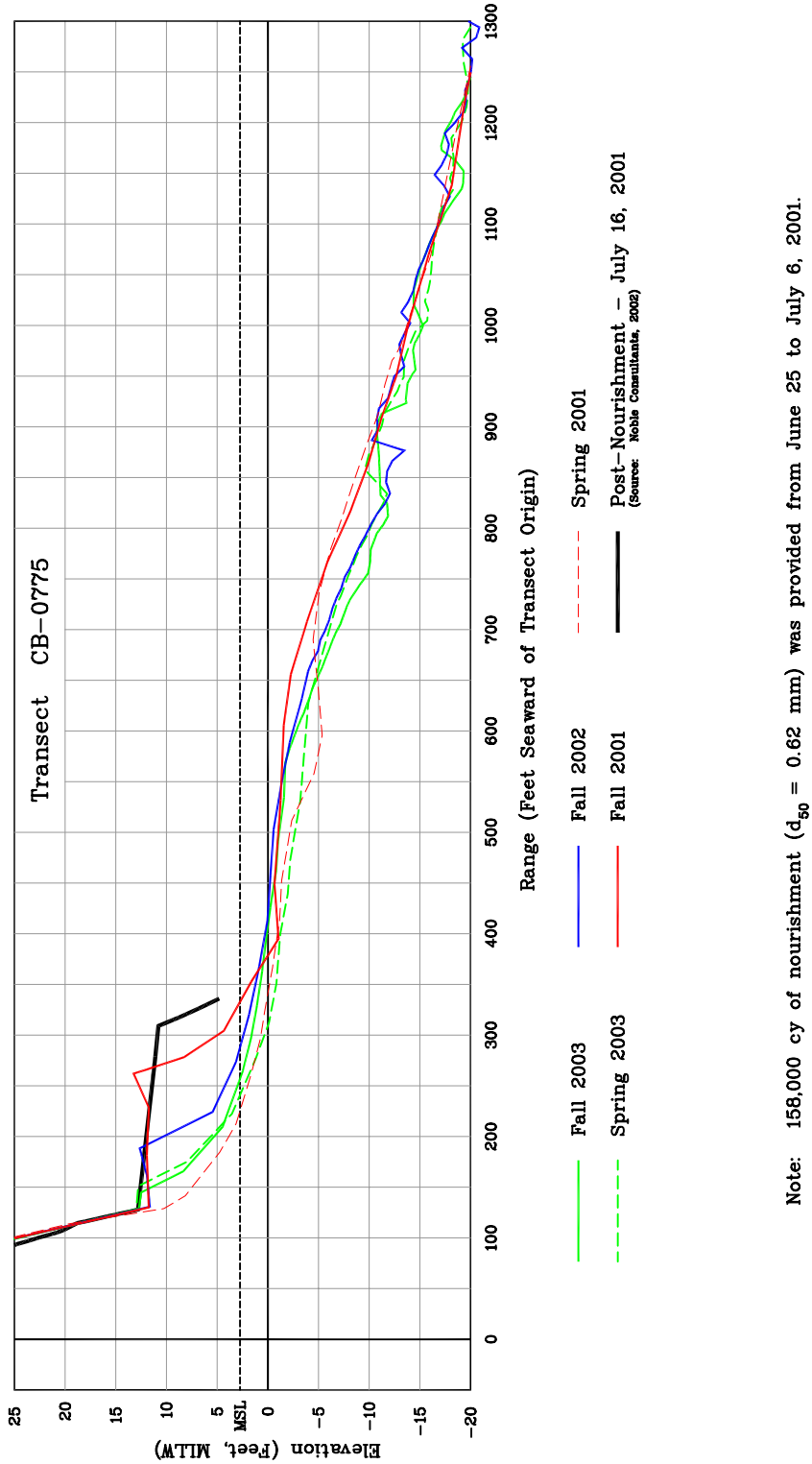
November 2003 (28 months after nourishment)

Plate 10. South Carlsbad Receiver Site, April 2001 through November 2003

5.2.11. North Carlsbad (Figure 22)

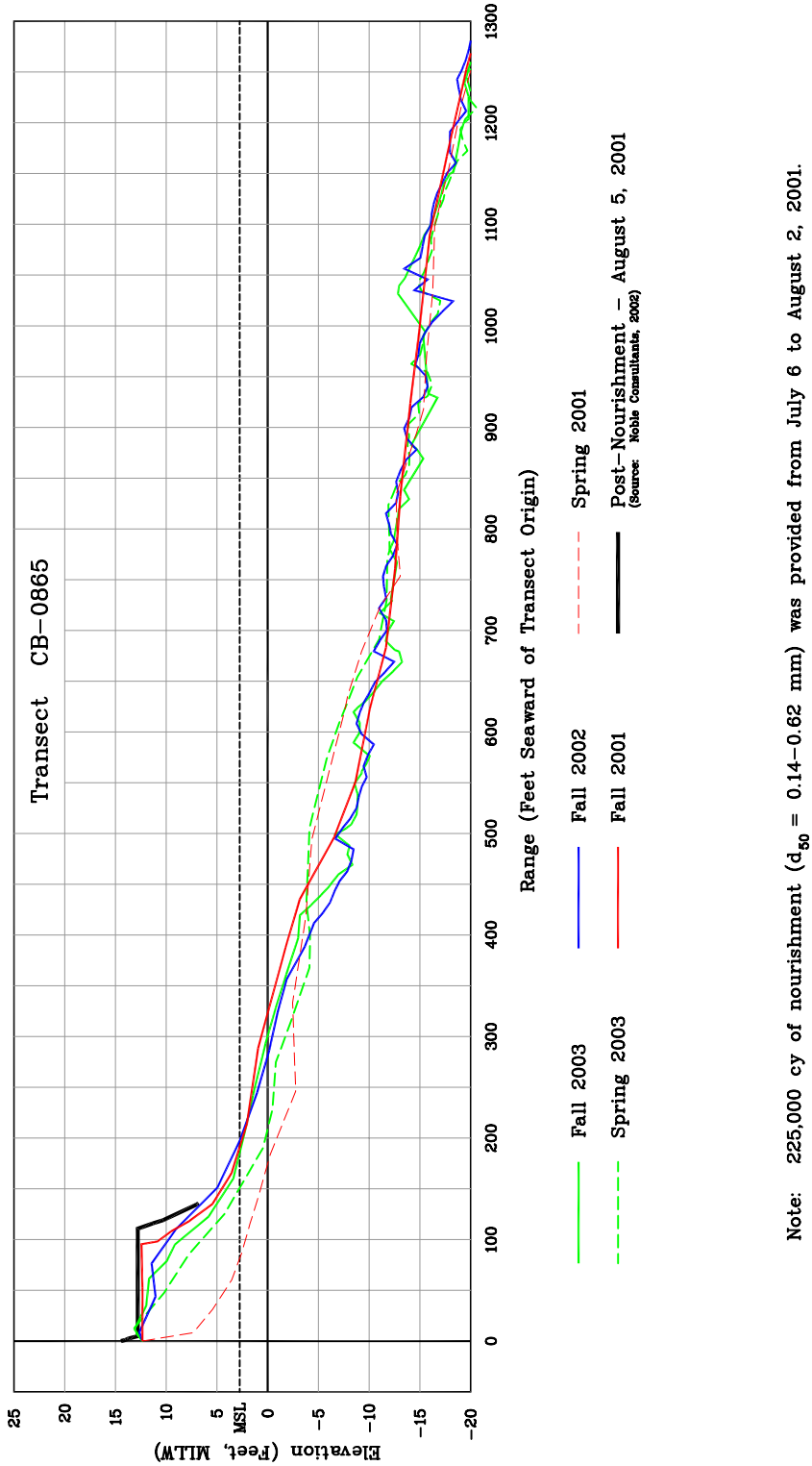
The 225,000 cy North Carlsbad fill was the third largest constructed under the RBSP. Placed from July 6 to August 2, 2001, it consisted of a mixture of coarse (21%), medium (2%) and fine (77%) sand. Beach profiles obtained on Transect CB-0865 are shown in Figure 33, while pre- and post-nourishment photographs are provided in Plate 11.

Although the beach face became progressively flatter after the RBSP, the above-water erosion at North Carlsbad was modest compared to that which occurred at most of the other receiver sites. The resulting shoreline advance of 105 ft and shorezone volume increase of 33 cy/ft that occurred between Spring 2001 and Fall 2003 exceed the corresponding RBSP average values by large margins.



Note: 158,000 cy of nourishment (d_{50} = 0.62 mm) was provided from June 25 to July 6, 2001.

Figure 32. Transect CB-0775 at South Carlsbad Receiver Site



Note: 225,000 cy of nourishment (d_{50} = 0.14-0.62 mm) was provided from July 6 to August 2, 2001.

Figure 33. Transect CB-0865 at North Carlsbad Receiver Site

April 2001 (Pre-RBSP)

November 2001 (3.5 months after nourishment)

November 2002 (15.5 months after nourishment)

November 2003 (27 months after nourishment)

Plate 11. North Carlsbad Receiver Site, April 2001 through November 2003

The time series of subaerial and shorezone volume changes at Transect CB-0880 (Figures 13c and 16c) parallel the profile changes. The substantial volume gains that occurred immediately after nourishment persisted through Fall 2003 with only modest losses. This result is somewhat surprising in light of the high percentage of fine sand contained in the fill material (77%).

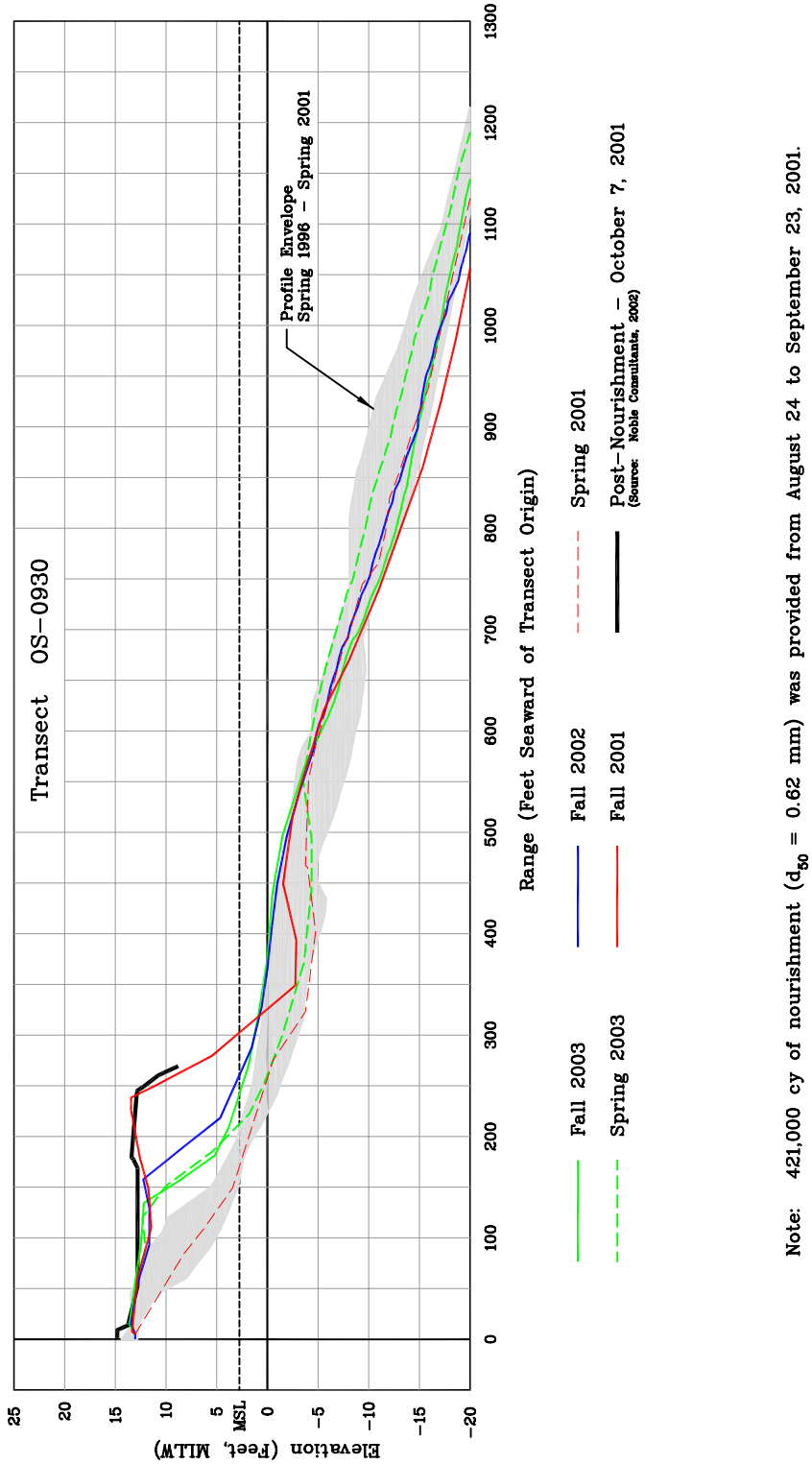
The most likely explanation for the exceptional performance of the beach at North Carlsbad is the arrival of fill from the Oceanside receiver site due to southerly transport. The volume changes at Transects CB-0850, CB-0840, and CB-0830 (all of which lie within 5,000 ft of the North Carlsbad site) suggest that even as material was arriving from the north, a portion of the North Carlsbad fill was moving downcoast to benefit the adjacent beaches. At these locations, a trend of steadily increasing subaerial and shorezone volumes is apparent since the RBSP (Figures 13c and 16c).

5.2.12. Oceanside (Figure 22)

The Oceanside fill (Plate 12) was the largest (421,000 cy) and longest (4,400 ft) of the RBSP fills. Comprised entirely of coarse sand, it also was the last to be constructed (August 24-September 23, 2001). Profiles obtained on Transect OS-0930 are presented in Figure 34.

Plate 12. Oceanside Receiver Site, April 2001 through November 2003

The profile data indicate that the nourished beach face became progressively flatter between fill placement and Fall 2003. The rate of above-water volume loss decreased with time, however, evidenced by only modest changes between the Fall 2003 and Fall 2002 profiles. Volume gains from the waterline to -22 ft suggest that the material eroded from the beach face moved offshore. The result was extremely favorable: a shoreline advance of 72 ft and a shorezone volume increase of 66 cy/ft between Spring 2001 and Fall 2003. While the increase in beach width was about average for the RBSP fills, the shorezone volume gain was the maximum recorded.



Note: 421,000 cy of nourishment (d_{50} = 0.62 mm) was provided from August 24 to September 23, 2001.

Figure 34. Transect OS-0930 at Oceanside Receiver Site

As suggested by the profile changes, the subaerial volume data at Transects OS-0930 and OS-0900 (Figure 13c) indicate a gradual dispersal of the fill material following the initial post-nourishment gains. However, a significant percentage of the shorezone volume gains at these locations persisted through Fall 2003 (Figure 16c). As described in the preceding section, the volume changes shown in Figures 13c and 16c suggest that a portion of the Oceanside fill nourished the downcoast beaches and coalesced with the North Carlsbad fill. The net result was a significant improvement over the pre-RBSP condition along more than 2 miles of coast between Transects OS-1000 (Oceanside) and CB-0830 (Carlsbad).

Possible reasons for the exemplary performance of the Oceanside fill include the large volume of nourishment and the coarse grain size. In addition, the sand bypassing rate at Oceanside Harbor during the RBSP Monitoring Period has been slightly higher than the pre-RBSP rate (Section 2.3). Hence, this material may be contributing to the improved condition of the beaches in Oceanside and Carlsbad as it moves downcoast.

6. LAGOON ENTRANCE CONDITION

Section 6 evaluates the condition of five lagoon entrances in the Oceanside Littoral Cell during the RBSP Monitoring Period (November 2000-October 2003). An overview is provided in Section 6.1, followed by a discussion of each entrance in Section 6.2. The location of each entrance is indicated in Figure 1.

6.1. Overview

Lagoon entrances in the Oceanside Cell are influenced by a combination of coastal processes, fluvial processes, and human activities. The entrance channels can close when littoral drift overwhelms the capacity of tidal currents and river discharge to remove the arriving sediment. Conversely, tidal exchange can be restored or enhanced during periods of high rainfall, when sediment is flushed from the channels by increased river discharge. The desire for sustained or enhanced tidal exchange also has lead to human intervention, consisting primarily of inlet stabilization and mechanical excavation.

Using a probabilistic approach, Elwany, *et al. (*1998), estimated that San Dieguito, a typical southern California lagoon, would remain open to tidal exchange only 34% of the time under natural conditions. The percent varies with the climatic cycle, however, increasing to 66% during periods of above-average precipitation and decreasing to only 12% during periods of below-average precipitation.

Elwany asserts that the duration of the period that a lagoon remains open is highly dependent on the condition of the inner channels. When the inner channels become deep and relatively free of sand following a period of heavy precipitation and strong river flows, the tidal prism often is sufficient to maintain an ocean outlet with limited human intervention. Conversely, during prolonged dry periods, the interior channels often fill with sand, constricting the tidal prism and the ability to maintain an ocean outlet. In the case of San Dieguito Lagoon, Elwany estimates that the interior channels must be flushed free of sand by strong river flows every three to five years in order for the lagoon to remain open to tidal exchange with minimal maintenance.

As discussed in Section 2, five consecutive years of below-average to average rainfall have followed the 1997-98 El Niño event. This would suggest a relatively high probability of prolonged lagoon closures and an increased propensity for the lagoons to re-close following mechanical opening during the RBSP Monitoring Period.

Figure 35 shows the average percentage of time that each of the five lagoons remained open to tidal exchange prior to the RBSP and during the RBSP Monitoring Period. As indicated in the figure, the pre-RBSP period of record for each lagoon varies from three to 45 years in accordance with the available data. Prior to the RBSP, the two jetty-stabilized entrances, Agua Hedionda and Batiquitos, never closed. In contrast, the three unstabilized entrances closed periodically despite efforts to maintain tidal exchange. The percentage of time open varied widely among these lagoons, with values of 39% at San Elijo, 76% at San Dieguito, and 92% at Los Peñasquitos.

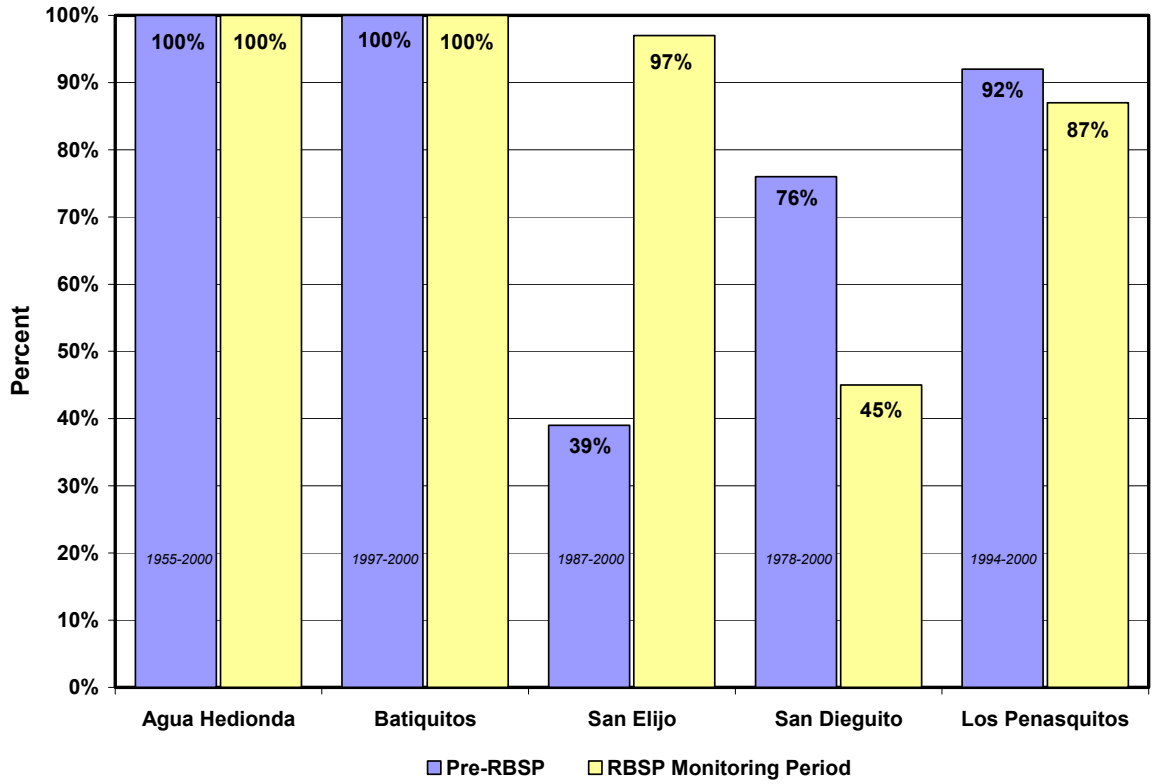


Figure 35. Percentage of Time Lagoon Entrances Open to Tidal Exchange preceding the RBSP and during the RBSP Monitoring Period

During the RBSP Monitoring Period, the two jetty-stabilized entrance channels remained open to the full range of tidal exchange with only minor variations in water depth. As indicated in Figure 36, the unstabilized entrance channels at Los Peñasquitos and San Dieguito closed on seven and six occasions, respectively. At San Elijo, the unstabilized channel closed on only three occasions during the RBSP Monitoring Period. The entrance channel was open to tidal exchange more than the historical average at San Elijo (97% vs. 39%), less at San Dieguito (45% vs. 76%), and essentially the same at Los Peñasquitos (87% vs. 92%).

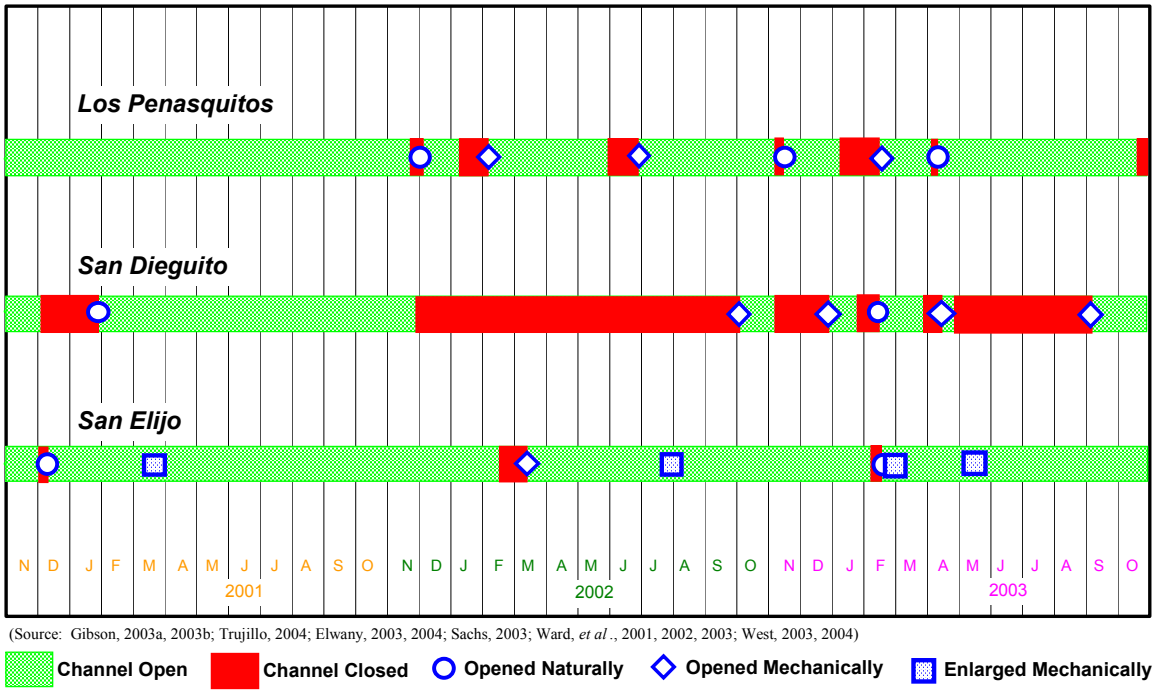


Figure 36. Condition of Unstabilized Lagoon Entrances during RBSP Monitoring Period

6.2. Lagoon Entrance Performance

The performance of each lagoon entrance during the RBSP Monitoring Period is evaluated below. To provide a basis for comparison, the pre-RBSP performance also is summarized. Supporting topographic data are provided in Appendix H, while ground photographs of the three unstabilized channels appear in Appendix I.

6.2.1. Agua Hedionda

The rubble mound jetties at the Agua Hedionda Lagoon entrance were constructed in 1954 to maintain a stable inlet for the Encina Power Plant seawater intake (Shaw, 1980). Extensive dredging was performed at the same time to create a cooling water basin. As a result of these modifications, and ongoing maintenance dredging, the lagoon entrance has been open to tidal exchange continuously since 1955.

Historically, maintenance dredging has been required at intervals of one to two years to remove a flood-tide shoal that forms in the cooling basin. Dredge quantities have ranged from 90,000 to 459,000 cy (Tucker, 2002). Over the 45-yr period preceding the RBSP

(1955-2000), an average of 241,000 cy/yr was removed from the lagoon and placed on the adjacent beaches. As discussed in Section 2.2, the dredging operation returns sediment to the littoral system that has been trapped in the interior basin, and therefore represents sand bypassing.

Maintenance dredging was conducted on two occasions during the RBSP Monitoring Period. Between November 2000 and April 2001, 429,084 cy were removed from the lagoon (Jenkins, *et al.*, 2003). Subsequently, 336,857 cy were removed between December 2002 and April 2003 (Hughes, 2003). It should be noted the 2000-2001 dredging program was completed prior to placement of the RBSP nourishment material in the Carlsbad area. Hence the unusually large quantity of material removed during this operation cannot be attributed to the RBSP.

Plate 13 displays the condition of the north entrance to Agua Hedionda Lagoon on a semi-annual basis from April 2001 to November 2003. In the April 2001 photo, a dredge is evident removing the flood tide shoal from the region landward of the jetties. The next three photos show the progressive return of the shoal, with the feature fully emergent in November 2002. The shoal is not evident in the May 2003, having been removed during the 2002-2003 dredge program. A faint trace of the reforming shoal is seen in the November 2003 photograph.

Figure 37 presents the controlling elevations that were measured in the north entrance channel on a semi-annual basis from Spring 1997 through Fall 2003. ("Controlling elevation" refers to the lowest elevation at which water can pass unobstructed between the ocean and the lagoon.) During the period that preceded the RBSP (Spring 1997-Spring 2001), the controlling elevations ranged from -4.3 to -6.2 ft (MLLW). Subsequent to the nourishment activities (Fall 2001 to Fall 2003), the controlling elevations were comparable: -4.9 to -5.7 ft.

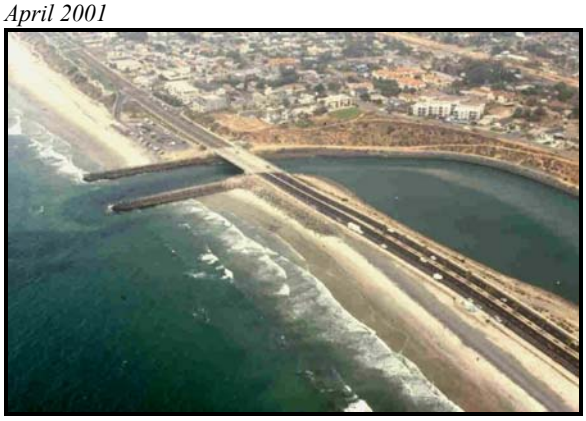
6.2.2. Batiquitos

Prior to 1994, the entrance to Batiquitos Lagoon was unstabilized and prone to frequent closure (SANDAG, 1999b). As part of the Batiquitos Lagoon Restoration Project, conducted between 1994 and 1997, two rubble mound jetties were constructed at the entrance and 1.8 million cy of sediment were dredged from the wetlands.

Since completion of the initial wetland restoration effort, the lagoon has remained open to tidal exchange. Periodic dredging has been required, however, to maintain the

April 2001

November 2001



May 2002

November 2002

May 2003

November 2003

Plate 13. Agua Hedionda Lagoon North Entrance, April 2001 through Novovember 2003

tidal prism. As indicated previously in Section 2.2.3, an average of 2,000 cy/yr was removed from the lagoon and placed on the adjacent beaches prior to the RBSP. This rate underestimates the long-term dredge requirement, because the major dredge activities associated with the lagoon restoration effort had just been completed.

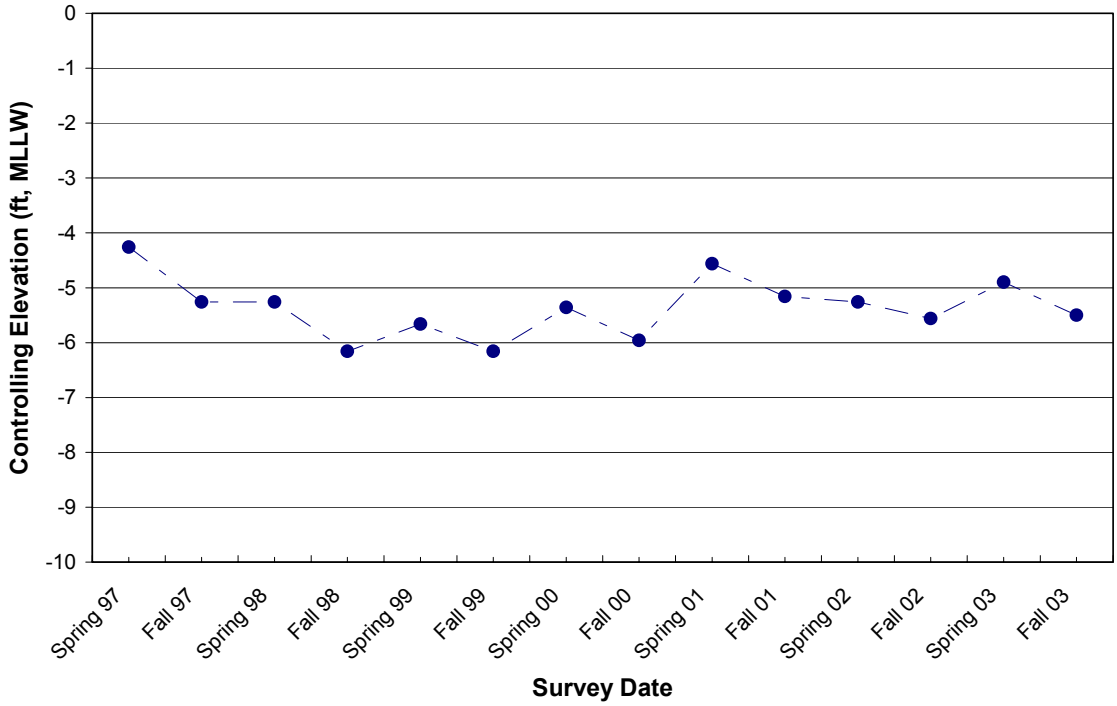


Figure 37. Controlling Elevation for Tidal Exchange in Agua Hedionda Lagoon

During the RBSP Monitoring Period, bypassing was undertaken only in 2001. Although the resulting average rate of 15,000 cy/yr during the RBSP Monitoring Period exceeded the pre-RBSP average of 2,000 cy/yr, the latter figure is anomalously low as explained above.

An additional 75,000 cy of sediment were dredged from the lagoon in 2003 but used to enhance least tern nesting sites within the lagoon rather than for bypassing (Dillingham, 2004). Hence, the bypass rate could have been substantially higher during the RBSP Monitoring Period if this material had been returned to the littoral system.

Plate 14 illustrates the condition of the Batiquitos Lagoon entrance channel between April 2001 and November 2003. Substantial shoals are evident in the outer and middle basins in all six photographs, with little change evident over the 32-month period despite the aforementioned dredge programs.

Between Spring 1997 and Spring 2001, the controlling elevations in the entrance channel varied between -5.3 and -6.6 ft (Figure 38). The elevations measured after placement of the RBSP nourishment material, -5.7 to -6.3 ft, were within this range.

Plate 14. Batiquitos Lagoon Entrance, April 2001 through November 2003

6.2.3. San Elijo

Based on records maintained by the San Elijo Lagoon Conservancy (Gibson, 2003b), San Elijo Lagoon was open to tidal exchange only 39% of the 14-year period preceding the RBSP (1987-2000). The average closure frequency during this period was 4.6 times per

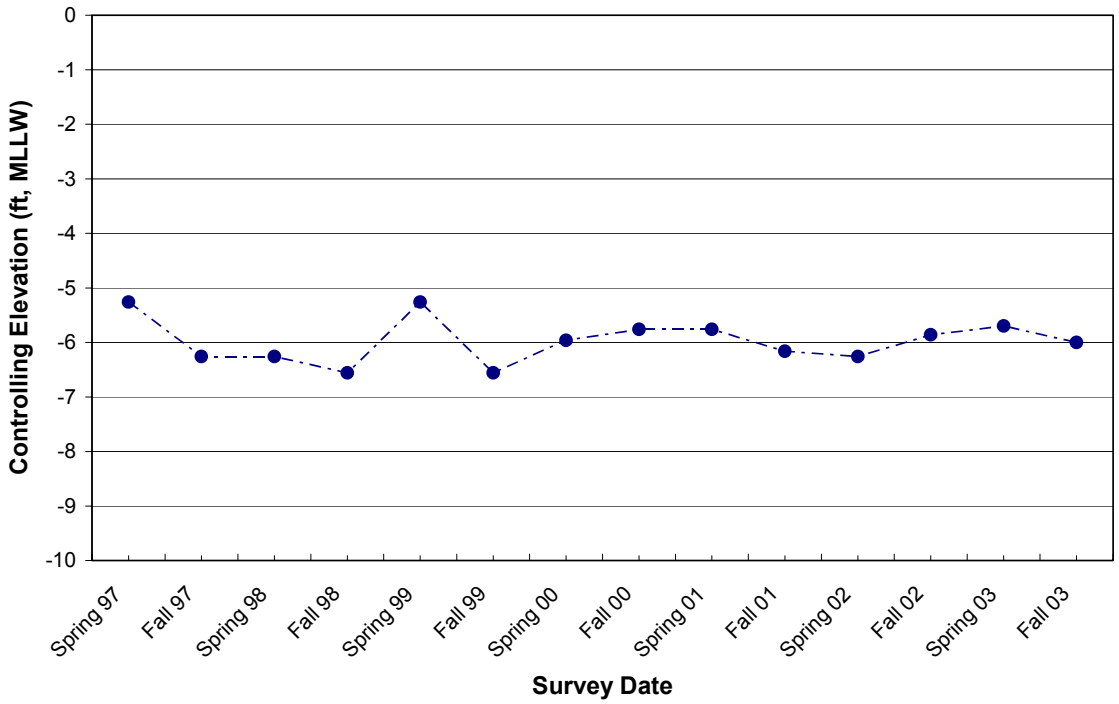


Figure 38. Controlling Elevation for Tidal Exchange in Batiquitos Lagoon

year, while the frequency of mechanical opening was 3.1 times per year. The difference between these two frequencies is attributable to natural opening of the entrance channel.

Plate 15 shows the condition of the San Elijo entrance channel between April 2001 and November 2003. In December 2000, the channel closed briefly before re-opening five days later (Figure 36). The lagoon then remained open to restricted tidal exchange for more than 14 months, aided by mechanical enlargement of the entrance in May 2001, before closing in February 2002. Tidal exchange was restored by mechanical means shortly thereafter, in March 2002. Mechanical enlargement of the channel was undertaken in July 2002 to increase the flow. During the 2003 Monitoring Year, the lagoon closed for eight days in early February before re-opening naturally. The entrance channel then remained open for the rest of the year, with mechanical enlargements conducted in February and May.

The February enlargement included not only the lagoon mouth, but also the 2,500-ft interior channel from the mouth to the railroad trestle (Trujillo, 2004). As discussed in Section 6.1, a lagoon's ability to remain open to tidal exchange is highly dependent on the condition of the interior channels. Hence, this increase in the tidal prism is likely to have reduced the channel's susceptibility to closure.

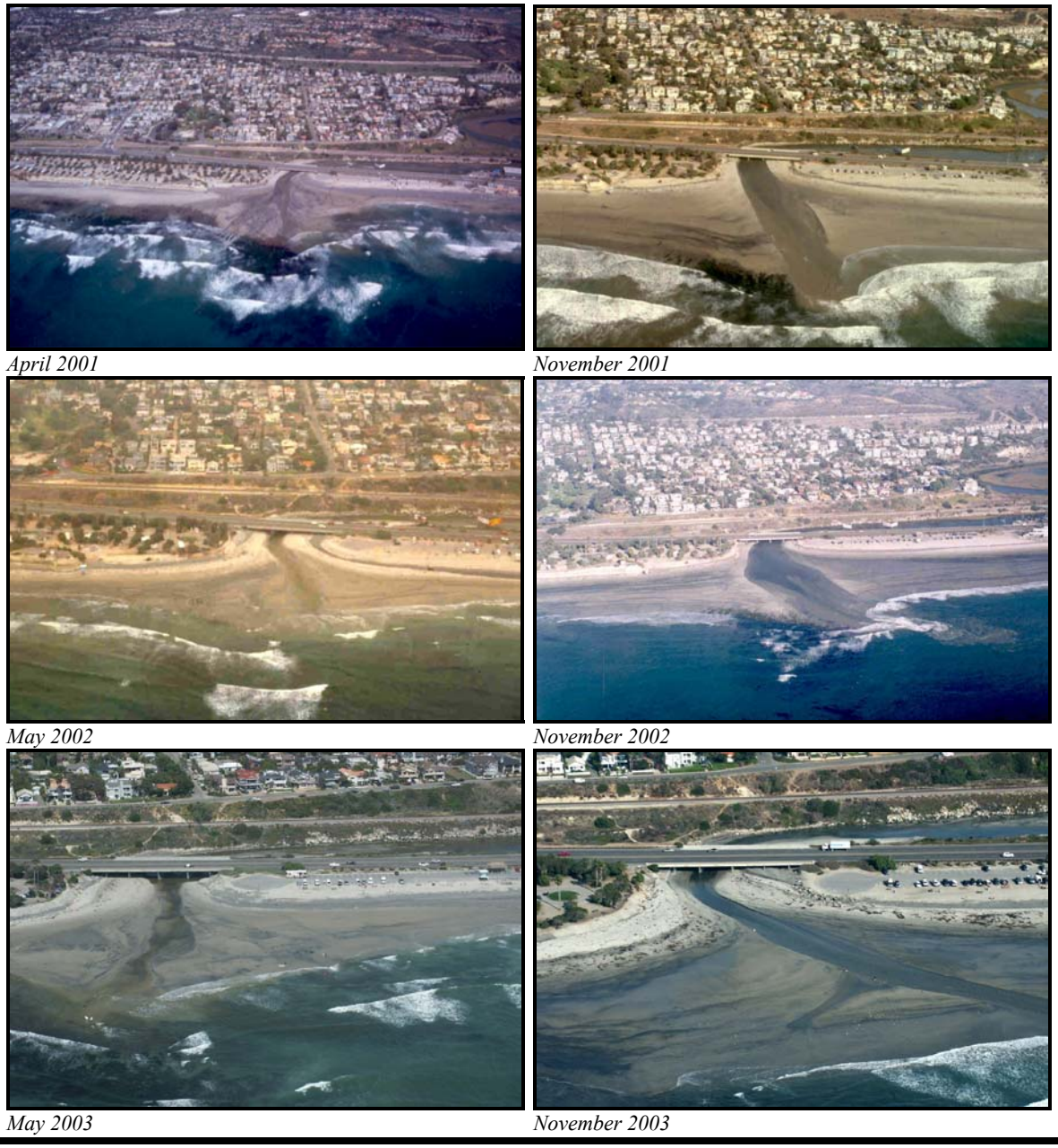


Plate 15. San Elijo Lagoon Entrance, April 2001 through November 2003

The lagoon was open 97% of the time during the RBSP Monitoring Period, greatly exceeding the historical average of 39%. The occurrence of only three closures between Fall 2000 and Fall 2003 (1.0 closures per year) also represents a significant improvement relative to the channel's past history of 4.6 closures per year. Similarly, the frequency of channel maintenance (mechanical openings and enlargements) during the RBSP Monitoring Period, 1.7 times per year, was well below the historical average of 3.1 times per year.

The controlling elevations noted subsequent to the RBSP nourishment activities (Fall 2001 to Fall 2003) ranged from +0.7 to +2.4 ft, near the bottom of the range that prevailed prior to the RBSP (+0.6 to +6.7 ft; Figure 39).

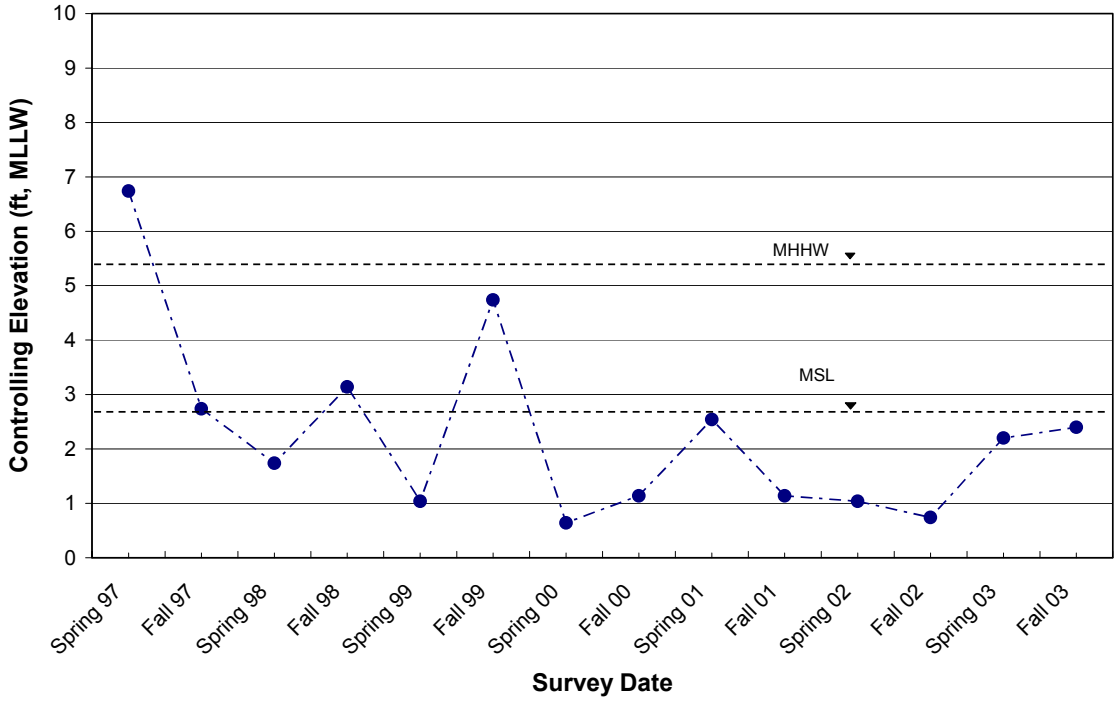


Figure 39. Controlling Elevation for Tidal Exchange in San Elijo Lagoon

Based on the elevation change data presented in Appendix H, the sediment volume in the entrance channel survey area decreased by 1,900 cy between Fall 2002 and Spring 2003, and increased by 9,600 cy between Spring 2003 and Fall 2003. The net change during the 2003 Monitoring Year was an increase of 7,700 cy. For the three-year RBSP Monitoring Period, the net volume increase in the entrance channel survey area was 4,800 cy.

6.2.4. San Dieguito

Based on data compiled by Elwany, *et al.* (1998; 2003), San Dieguito Lagoon was open to tidal exchange 76% of the time between 1979 and 2000. On average, the channel closed 0.5 times per year, and was opened mechanically 0.6 times per year. The relatively low closure frequency can be attributed in part to the above-average rainfall during the period of record.

The entrance channel (Plate 16) closed on six occasions during the RBSP Monitoring Period (Figure 36). The first occurred in December 2000, several months prior to the commencement of the RBSP. The channel re-opened naturally after a 2-month period, and remained open until late November 2001. The lagoon then was closed to tidal exchange for more than 10 months before mechanical intervention in October 2002. The blocked entrance channel is shown in the May 2002 photo. The entrance closed on four occasions during the 2003 Monitoring Year, requiring mechanical intervention to restore tidal exchange on three of those occasions (December 2002, April 2003, and September 2003). In one instance (February 2003), the entrance channel opened naturally following a period of high rainfall (Elwany, 2004).

The monitoring data suggest that the November 2001 closure was caused, at least in part, by the northerly transport of sediment from the nearby Del Mar receiver site. Of particular relevance is an accumulation of sediment noted at the waterline of Transect DM-0590 at the time of the Fall 2001 Survey (Section 5.2.4). This transect lies to the north of the Del Mar fill, and immediately south of the lagoon entrance channel (Figure 21). A similar accumulation was observed at the time of the Fall 2002 survey, but was absent in Fall 2003 – a finding that suggests the Del Mar fill has been dispersed to a large extent by waves and currents, and no longer exerts a significant impact on the condition of San Dieguito Lagoon.

The entrance to San Dieguito lagoon was open 45% of the time during the RBSP Monitoring Period, well below the historical average of 76%. This low percentage resulted in part from the fact that the lagoon was allowed to remain closed for nearly one year (November 2001 to October 2002). It is likely that climatic conditions also played an important role in the disparity between the two percentages, with the RBSP Monitoring Period characterized by below-average precipitation (Section 2.1.1). In contrast, the pre-RBSP average was derived from a period of above-average precipitation (1976-2000). As discussed in Section 6.1, Elwany, *et al.* (1998) estimated that San Dieguito Lagoon remains open 66% of the time during periods of above-average precipitation and only 12% of the time during periods of below-average precipitation.

The frequencies of channel closure (2.0 times per year) and mechanical opening (1.3 times per year) during the RBSP Monitoring Period exceeded the corresponding historical averages (0.5 and 0.6 times per year, respectively). It is noteworthy, however, that one of the six closures occurred several months prior to the placement of the RBSP nourishment material, and therefore cannot be attributed to the presence of that material.

April 2001

November 2001

May 2002

November 2002

May 2003

November 2003

Plate 16. San Dieguito Lagoon Entrance, April 2001 through November 2003

During the RBSP Monitoring Period, the controlling elevations in the entrance channel varied between +1.1 ft and +7.3 ft (Figure 40). Although large, this range lies within the elevations measured prior to the RBSP (+0.7 to +9.1 ft).

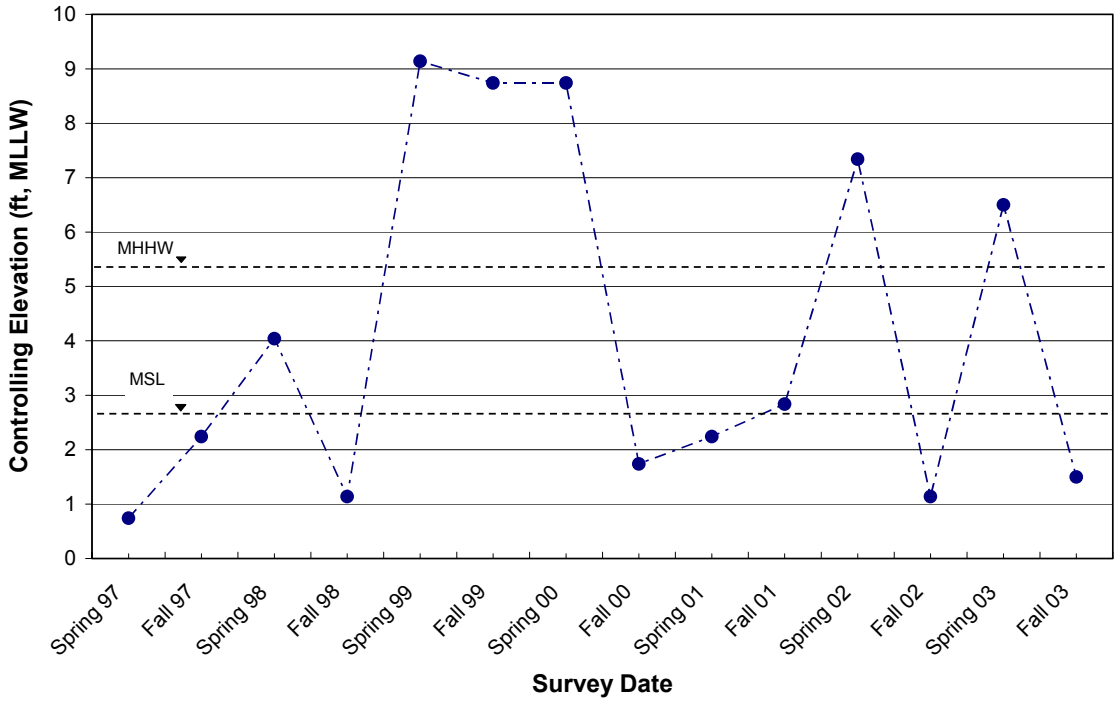


Figure 40. Controlling Elevation for Tidal Exchange in San Dieguito Lagoon

Between Fall 2002 and Spring 2003, a seasonal loss of 28,500 cy was experienced in the entrance channel survey area (Appendix H). This loss was followed by a seasonal gain of 20,000 cy between Spring and Fall 2003, producing a net loss of 8,500 cy for the 2003 Monitoring Year. For the three-year RBSP Monitoring Period, the net volume loss in the entrance channel survey area was 7,000 cy.

6.2.5. Los Peñasquitos

Prior to the RBSP, the unstabilized entrance to Los Peñasquitos Lagoon typically closed several times per year. Efforts to re-establish the entrance channel with earth moving equipment date back to the 1960's. Based on data compiled by the Los Peñasquitos Lagoon Foundation (West, 2003), the lagoon was open to tidal access about 50% of the time between 1965 and 1984.

More recently, the Los Peñasquitos Lagoon Foundation has funded a sustained effort to maintain tidal flow by mechanically opening or widening the channel several times each year (KEA Environmental, 2001). As a result, the lagoon was open to tidal exchange over 90% of the time between 1994 and 2000 (Williams, 1995; 1996; 1997; 1998; 1999; Ward,

2000; 2001; West, 2003). During this period, the entrance closed 2.6 times per year, and was mechanically opened or widened 1.9 times per year.

After providing restricted tidal exchange during the entire 2001 Monitoring Year, the Los Peñasquitos entrance channel closed on three occasions during the 2002 Monitoring Year and four occasions during the 2003 Monitoring Year (Figure 36). The channel opened naturally following three of these closures, but mechanical excavation was required to re-establish tidal exchange on three other occasions (February 2002, June 2002, and February 2003). The most recent closure occurred in late October 2003, and persisted through the end of the 2003 Monitoring Year. The channel condition at the time of the semi-annual overflights conducted between April 2001 and November 2003 is shown in Plate 17.

The lagoon was open 87% of the time during the RBSP Monitoring Period, closely approximating the historical average of 92%. However, the frequencies of channel closure and mechanical opening during this period (2.3 and 1.0 times per year, respectively) were both lower than the historical averages (2.6 and 1.9 times per year).

The controlling elevations in the entrance channel measured subsequent to the RBSP nourishment activities ranged from +1.5 to +3.8 ft. Prior to the RBSP, the values ranged from +1.5 to +7.1 ft (Figure 41). The elevation change data in Appendix H indicate that the entrance channel survey area lost 9,300 cy between Fall 2002 and Spring 2003, and gained 4,500 cy between Spring 2003 and Fall 2003. The total net loss for the year was 4,800 cy. For the three-year RBSP Monitoring Period, the entrance channel survey area lost 400 cy.

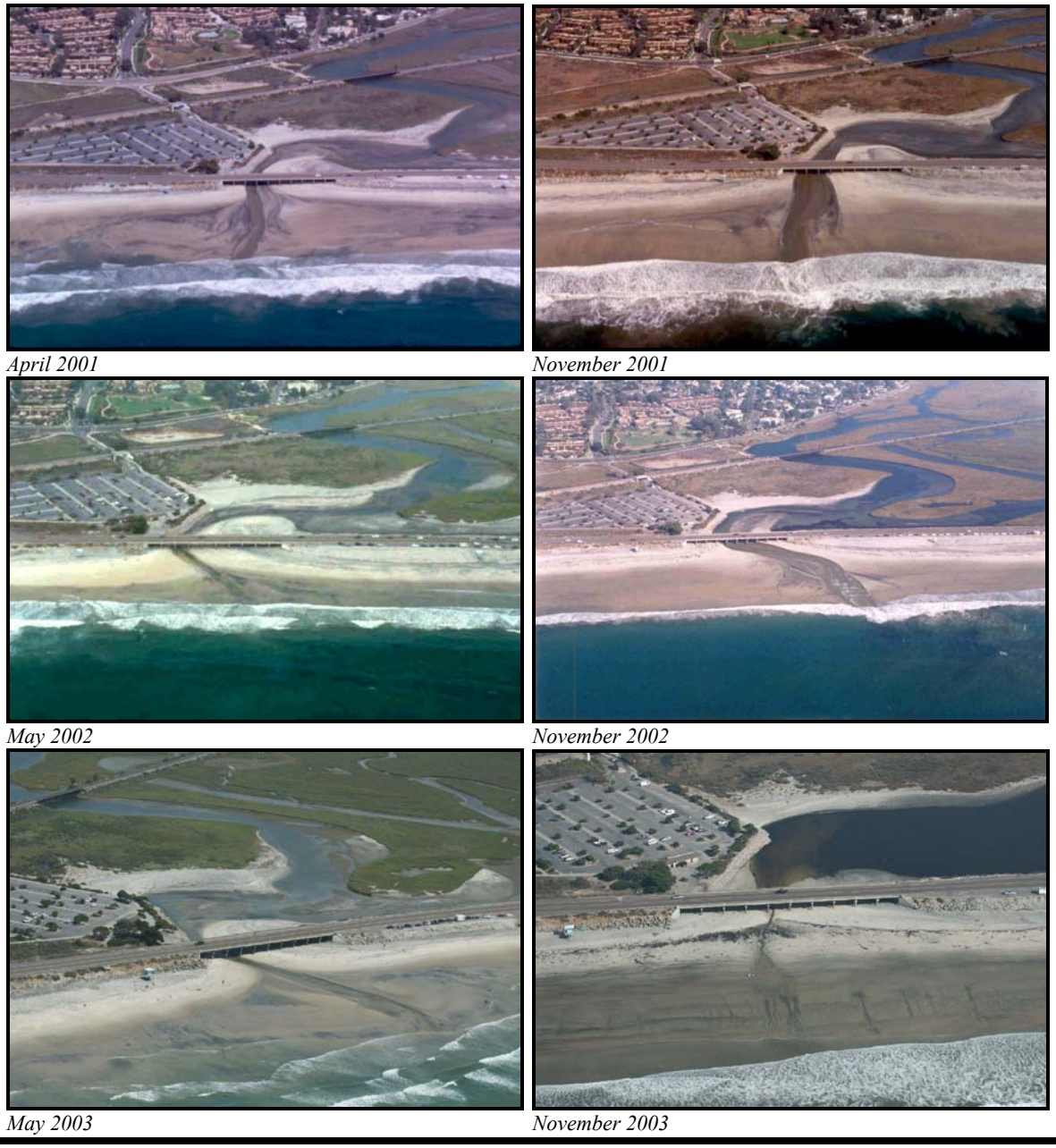


Plate 17. Los Peñasquitos Lagoon Entrance, April 2001 through November 2003

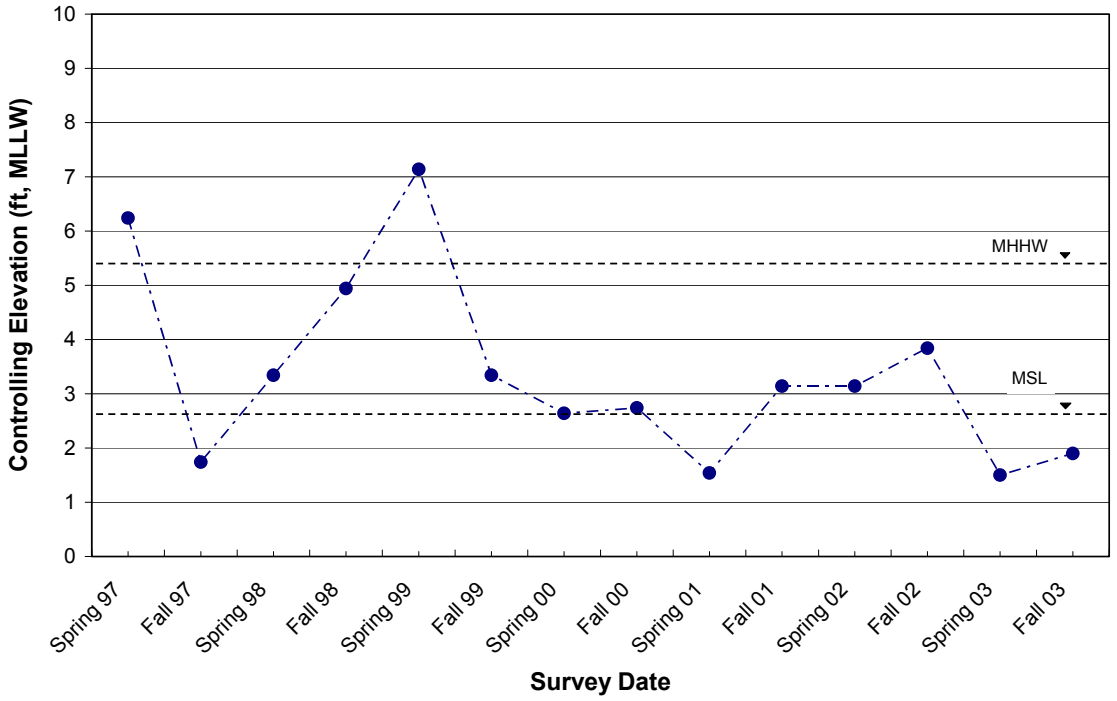


Figure 41. Controlling Elevation for Tidal Exchange in Los Peñasquitos Lagoon

7. CONCLUSIONS

Conclusions pertaining to the condition of San Diego County's beaches and the impacts of the RBSP beach fills are summarized below:

1. Precipitation, streamflow, wave energy and storm frequency all increased during the 2003 Monitoring Year relative to 2001 and 2002. Nevertheless, the average values of these parameters during the three-year RBSP Monitoring Period remained well below the pre-RBSP averages. The primary implications of these environmental conditions are threefold: (1) the absence of large wave events following the implementation of the RBSP helped to prolong the life of the beach fills; (2) the scant precipitation and low streamflows failed to deliver significant quantities of beach-quality sediment to the coast; and (3) the low streamflows failed to flush coastal sediment from the lagoon entrances in the Oceanside Cell.

2. The only non-RBSP nourishment provided during the entire RBSP Monitoring Period was 2,000 at Moonlight Beach. As a result, two thirds of the RBSP fill material (1,401,000 cy) may be regarded as compensating for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 702,000 cy, represents incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 657,000 cy (equivalent to 219,000 cy/yr over the three-year RBSP Monitoring Period). The Mission Beach Cell received an additional 144,000 cy (48,000 cy/yr), while the Silver Strand Cell incurred a deficit of 99,000 cy (33,000 cy/yr) due to the lack of nourishment activities other than the RBSP. No nourishment was provided in any of the three littoral cells during the 2003 Monitoring Year.

3. The sand bypass rates at Agua Hedionda and Oceanside Harbor during the RBSP Monitoring Period (192,000 and 306,000 cy/yr, respectively) exceeded the average annual rates in prior years by about 50,000 cy/yr. (Note: the average annual rate for Agua Hedionda was derived by assuming that the quantities dredged in 2001 and 2003 apply to the four-year period 2001-2005.) The increased bypassing rates at these two sites constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor and both north and south of Agua Hedionda. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the pre- and post-RBSP rates is not meaningful.

4. During the 2003 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, but the shoreline tended to retreat. This apparent paradox may be explained by the fact that sediment moved from the subaerial portion of the profile to the submerged portion, but remained within the shorezone. The predominance of shoreline retreat is attributable to four factors: (1) offshore dispersal of the RBSP fill material, (2) a lack of significant sediment input from rivers and streams, (3) an increase in wave energy relative to the past two years, and (4) a lack of beach nourishment activities. The stability of the shorezone sediment volume is consistent with the fact that, in the absence of nourishment activities, major rainstorms, and severe storm events, significant quantities of material were neither added to nor removed from the coast.

5. Notwithstanding the loss of dry beach that occurred in 2003, the condition of the County's beaches improved substantially during the RBSP Monitoring Period. Beach widths increased by an average of 17 ft during this period, while shorezone volumes increased by an average of 15 cy/ft. The greatest gains occurred in the Oceanside Cell, where more than 85% of the RBSP nourishment material was deposited. The primary reasons for this improvement in the state of the coast appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period. Although much of the RBSP fill material has been dispersed from the receiver sites, the residual benefits to the County's beaches include an increased area for recreational activities, and a more substantial buffer against storm-induced erosion.

6. The performance of the individual RBSP fills varied considerably. At some sites, such as Del Mar, Moonlight, and South Carlsbad, the gains in shorezone volume that occurred at the time of fill placement were short-lived. At others, such as Mission Beach and Oceanside, the gains persisted through the time of the Fall 2003 Survey. In many cases, dispersal of the fill material was accompanied by shorezone volume gains on the downdrift beaches. The positive impact of the RBSP was most evident in the Oceanside-North Carlsbad area, where the monitoring data suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally to benefit more than two miles of shoreline. A similar situation was observed in the Encinitas area involving the Batiquitos and Leucadia fills.

7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth during the RBSP Monitoring Period. Of the three unstabilized entrances, San Elijo closed on

three occasions, San Dieguito on six, and Los Peñasquitos on seven. This pronounced variation in closure frequency resulted in the San Elijo entrance channel remaining open to tidal exchange for a greater percentage of time than the historical average (97% vs. 39% historically), the San Dieguito channel remaining open for a lesser percentage of time (45% vs. 76% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (87% vs. 92% historically).

8. REFERENCES

Boudreau, R., 2003, personal communication, Moffatt and Nichol, Engineers, Long Beach, CA.

Coastal Frontiers Corporation, 1997, "SANDAG 1996 Regional Beach Monitoring Program – Compilation of Historical Beach Profile Data", Chatsworth, CA 10 PP. + app.

Coastal Frontiers Corporation, 1998, SANDAG 1997 Regional Beach Monitoring Program – Compilation of Historical and Recent Beach Profile Data", Chatsworth, CA, 9 pp. + app.

Coastal Frontiers Corporation, 1999, "SANDAG 1998 Regional Beach Monitoring Program – Compilation of Historical and Recent Beach Profile Data", Chatsworth, CA, 12 pp. + app.

Coastal Frontiers Corporation, 2000, "SANDAG 1999 Regional Beach Monitoring Program – Annual Report", Chatsworth, CA, 44 pp. + app.

Coastal Frontiers Corporation, 2001, "SANDAG 2000 Regional Beach Monitoring Program – Annual Report", Chatsworth, CA, 39 pp. + app.

Coastal Frontiers Corporation, 2002, "SANDAG 2001 Regional Beach Monitoring Program – Annual Report", Chatsworth, CA, 85 pp. + app.

Coastal Frontiers Corporation, 2003, "SANDAG 2002 Regional Beach Monitoring Program – Annual Report", Chatsworth, CA, 105 pp. + app.

Dillingham, T., 2002, personal communication, California Department of Fish and Game, San Diego, CA.

Dillingham, T., 2004, personal communication, California Department of Fish and Game, San Diego, CA.

Elwany, M.H.S., 2003, personal communication, Coastal Environments, La Jolla, CA.

Elwany, M.H.S., 2004, personal communication, Coastal Environments, La Jolla, CA.

Elwany, M.H.S., R. E. Flick, S. Aijaz, 1998, "Opening and Closure of a Marginal Southern California Lagoon Inlet", *Estuaries*, Vol. 21, No. 2, p. 246-254.

Frenken, J., 2002, personal communication, City of Encinitas, Encinitas, CA.

Jenkins, S. and J. Wasyl, 2003, "San Influx at Agua Hedionda Lagoon in the Aftermath of the San Diego Regional Beach Sand Project," Scott A. Jenkins Consulting, Poway, CA.

Gibson, D., 2003a, "Mitigation Funds from Inlet Maintenance," letter to Mr. Rob Rundle, SANDAG, from San Elijo Lagoon Conservancy, Carlsbad, CA.

Gibson, D., 2003b, personal communication, San Elijo Lagoon Conservancy, Encinitas, CA.

Guza, R.,T., W.C. O'Reilly, R.J. Seymour, and S.L. Elgar, 2002, "Southern California Beach Processes Study", 7th Quarterly Report, 30 November 2002, Scripps Institution of Oceanography, http://cdip.ucsd.edu.

Hughes, G., 2003, "Order 96-32: Second Quarter 2003 and Final Report for Monitoring Report Agua Hedionda Lagoon Dredging," letter to Mr. John Robertus, California Regional Water Quality Control Board, from NRG Cabrillo Power Operations Inc., Carlsbad, CA.

Inman, D.L., 1987, "Accretion and Erosion Waves on Beaches", *Shore and Beach*, Vol. 55, Nos. 3-4. p. 61-65.

Inman, D.L. and S.A. Jenkins, 1999, "Climate Change and the Episodicity of Sediment Flux of Small California Rivers", *Journal of Geology*, Vol. 107, p. 251-270.

Inman, D.L. and P. Masters, 1991, "Budget of Sediment and Prediction of the Future State of the Coast", in USACE, 1991, "State of the Coast Report, San Diego Region", U.S. Army Corps of Engineers, Los Angeles District, Coast of California Storm and Tidal Waves Study, Volume I – Main Report, Los Angeles, CA.

KEA Environmental, Inc., 2001, "Operations Procedures, Mitigation Monitoring and Contingency Measures Plan for the San Diego Regional Beach Sand Project", San Diego, CA, 12 pp. + app.

Keeley, B., 2003, personal communication, City of Encinitas, Encinitas, CA.

Keeley, B., 2004, personal communication, City of Encinitas, Encinitas, CA.

Leidersdorf, C.B., R.C. Hollar and S. Sachs, 1999, "Technology in Support of Policy: The SANDAG Regional Beach Monitoring Program", *Proc. Sand Rights '99*, ASCE, New York, p. 261-272.

Noble, R., 2002, "Beach Nourishment Construction at Twelve San Diego County, California Receiver Beach Sites," World Dredging, Mining, and Construction, February 2002, p. 7-20.

Noble Consultants, Inc., 2001, "Final Construction Management Documents, San Diego Regional Beach Sand Project", Irvine, CA.

Noble Consultants, Inc., 2002, personal communication, Irvine, CA.

Rennie, M., 2003, personal communication, City of San Diego, San Diego, CA.

Ryan, J., 2003, personal communication, U.S. Army Corps of Engineers, Los Angeles District, Los Angeles, CA.

Sachs, S., 2002, personal communication, San Diego Association of Governments (SANDAG), San Diego, CA.

Sachs, S., 2003, personal communication, San Diego Association of Governments (SANDAG), San Diego, CA.

SANDAG Staff, 1996, "Opportunistic Sand Projects – Year End Report", Memorandum to Shoreline Erosion Committee dated November 26, 1996, Sand Diego Association of Governments (SANDAG), San Diego, CA.

SANDAG Staff, 1999a, "Update of Opportunistic Sand Projects", Memorandum to Shoreline Erosion Committee dated August 30, 1999, Sand Diego Association of Governments (SANDAG), San Diego, CA.

SANDAG Staff, 1999b, Memorandum to Shoreline Erosion Committee dated September 27, 1997, Sand Diego Association of Governments (SANDAG), San Diego, CA.

Scripps Institution of Oceanography, 2004, "The Coastal Data Information Program", http://cdip.ucsd.edu.

Seymour, R.J., 1998. "Effects of El Niños on the West Coast Wave Climate", *Shore and Beach*, Vol. 66, No. 3. p. 3-6.

Shaw, Martha J., 1980, "Artificial Sediment Transport and Structures in Coastal Southern California", University of California, San Diego, Scripps Institute of Oceanography, SIO Reference No. 80-41, La Jolla, CA, 109pp.

Trujillo, A., 2004, personal communication, San Elijo Lagoon Conservancy, Encinitas, CA.

Tucker, S., 2002, personal communication, San Diego Association of Governments (SANDAG), San Diego, CA.

United States Geological Survey, 2004, http://waterdata.usgs.gov.

Ward, K.M., M. Cordrey, and J. West, 2000, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 20 September 1998-20 September 1999", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Ward, K.M., J. West, and M. Cordrey, 2001, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 21 September 2000-20 September 2001", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Ward, K.M., J. West, and M. Cordrey, 2003, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report: September 17, 2002 - September 16, 2003", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Webb, C., 2004, personal communication, Moffatt and Nichol, Engineers, Long Beach, CA.

West, J., 2003, personal communication, Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

West, J., 2004, personal communication, PERL, San Diego State University, San Diego, CA.

Western Regional Climate Center, 2004, http://wrcc.dri.edu.

Williams, G.D., 1996, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 20 September 1995-20 September 1996", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Williams, G.D., 1997, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 20 September 1996-20 September 1997", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Williams, G.D., and D. Gibson, 1995, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 20 September 1994-20 September 1995", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Williams, G.D., G. Noe, and J. Desmond, 1998, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 20 September 1997-20 September 1998", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.

Williams, G.D., J. West, M. Cordrey, and K. Ward, 1999, "The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon, Annual Report, 21 September 1998-20 September 1999", Pacific Estuarine Research Laboratory (PERL), San Diego State University, San Diego, CA.