



Apr. 2001 (Pre-Nourishment)



Nov. 2001 (1.5 months after nourishment)



Nov. 2002 (13.5 months after nourishment)

Oceanside Receiver Site, April 2001 through November 2002



2002 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

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**SANDAG
2002 REGIONAL BEACH
MONITORING PROGRAM**

ANNUAL REPORT

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SANDAG

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June 2003

EXECUTIVE SUMMARY

This report presents the findings of the SANDAG 2002 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 2002 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on 62 shore-perpendicular transects, semi-annual oblique aerial photography at the twelve RBSP receiver sites, and monthly beach width measurements at four 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 2000 through October 2001 was defined as the 2001 Monitoring Year, November 2001 through October 2002 as the 2002 Monitoring Year, and the combined period from November 2000 through October 2002 as the RBSP Monitoring Period. The principal study findings for the RBSP Monitoring Period are as follows:

1. Precipitation and streamflow were well below average during the two-year RBSP Monitoring Period, while the wave conditions were relatively mild. 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 stream flows 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 RBSP Monitoring Period was a miniscule 2,000 cy (1,000 cy/yr) at Moonlight Beach. As a result, 934,000 cy of the RBSP fill material (about 44%) served to compensate for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 1,170,000 cy, represented incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 1,048,000 cy (equivalent to 524,000 cy/yr over the two-year RBSP Monitoring Period). The Mission Beach Cell received an additional 148,000 cy (74,000 cy/yr), while the Silver Strand Cell incurred a deficit of 26,000 cy (13,000 cy/yr) due to the lack of nourishment activities other than the RBSP.
3. The sand bypass rates at Batiquitos and Agua Hedionda Lagoons during the RBSP Monitoring Period (23,000 and 215,000 cy/yr, respectively) were substantially higher than the average annual rates in prior years (2,000 and 143,000 cy/yr). These high rates were not caused by the RBSP, because the bypass work was conducted prior to or concurrent with the April 2001 start of the nourishment activities. The sand bypass rate at Oceanside Harbor during the RBSP Monitoring Period, 240,000 cy/yr, approached the average of 252,000 cy/yr in prior years. The implications are twofold: (1) the beaches adjacent to the Batiquitos and Agua Hedionda Lagoon entrances benefited from the increased bypass rates at these sites; and (2) the beaches at Oceanside and North Carlsbad were neutrally impacted by the near-typical bypass rate at Oceanside Harbor.
4. The combination of beach fills and mild wave conditions during the RBSP Monitoring Period proved to be extremely favorable for the San Diego County coast. Although the twelve receiver sites tended to experience shoreline and volume losses subsequent to fill placement, many of the adjacent beaches benefited as the material was dispersed along the coast. As a result, wider beaches resulted in all three littoral cells: at 59% of the transects with data predating the RBSP, the beach width measured in Fall 2002 exceeded that noted in Fall 2000. The greatest increases occurred in the Oceanside Cell, where more than 85% of the RBSP nourishment material was deposited.
5. Shorezone sediment volume changes were mixed during the 2002 Monitoring Year. Over the entire RBSP Monitoring Period, however, shorezone volume gains predominated in all three littoral cells. As in the case of shoreline advance, the most substantial volume gains occurred in the Oceanside Cell. In the absence of other

nourishment programs and of significant riverine input, the increase in shorezone volume may be attributed primarily to the RBSP.

6. The initial performance of the individual RBSP fills varied considerably. Based on the use of a single indicator transect, the beaches with the greatest shorezone volume gains in Fall 2002 relative to Spring 2001 consisted of Oceanside (54 cy/ft), Leucadia (42 cy/ft) and North Carlsbad (36 cy/ft).
7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange throughout the RBSP Monitoring Period. Of the three unstabilized entrance channels, San Elijo and San Dieguito closed twice while Los Peñasquitos closed three times. Nevertheless, the closure frequencies of these channels were less than or similar to the closure frequencies that preceded the RBSP. In addition, mechanical intervention to restore or enhance tidal exchange was required on fewer occasions than in the recent past.

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SANDAG
2002 REGIONAL BEACH
MONITORING PROGRAM

ANNUAL REPORT

1. INTRODUCTION

This report presents the findings of the SANDAG 2002 Regional Beach Monitoring Program. As in the case of six prior annual monitoring programs conducted between 1996 and 2001, the 2002 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 2002 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 2002 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on approximately 60 shore-perpendicular transects (60 in Spring and 61 in Fall), semi-annual oblique aerial photography at the twelve RBSP receiver sites, and monthly beach width measurements at four 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 (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 2002 Monitoring Program was sponsored by SANDAG, beach profile data for selected transects were provided by the Cities of Carlsbad, Encinitas, and

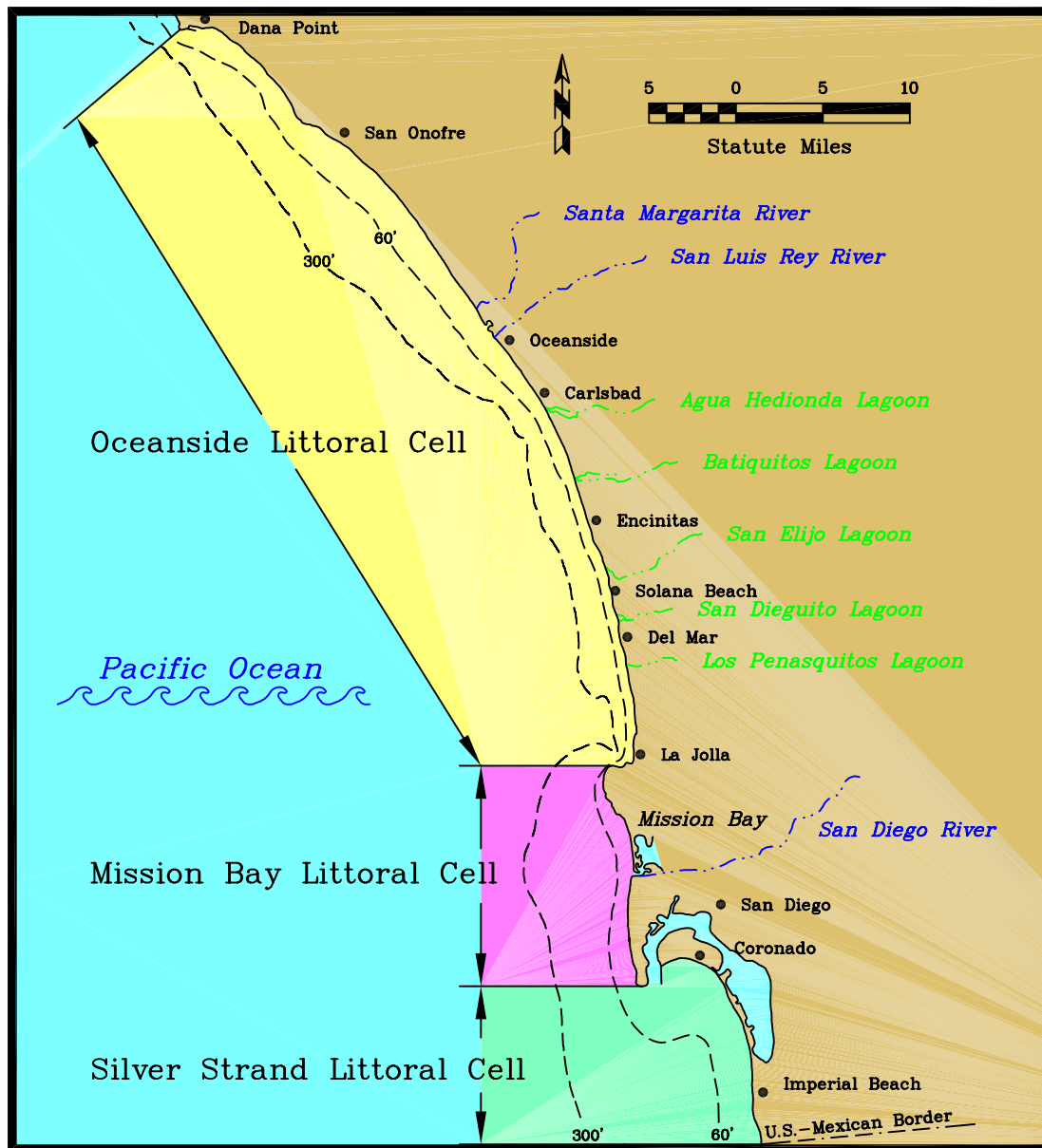


Figure 1. The Coast of San Diego County

Solana Beach. In addition, beach width measurements were provided by the Cities of Carlsbad, Encinitas, San Diego, 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;

RBSP Monitoring Period: November 2000 through October 2002.

Although the primary focus of this report is the 2002 Monitoring Year, considerable emphasis also is placed on the two-year RBSP Monitoring Period.

The remainder of this report provides a detailed account of the 2002 Regional Beach Monitoring Program, and summarizes the performance of the twelve RBSP beach fills. 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 2.75 ft below Mean Sea Level (MSL).

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 prevailed during 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 2001 Monitoring Year, for example, extends from November 1, 2000 through October 31, 2001.

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 climate control the rate of coastal sediment transport, with particular importance attached to 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 2002. 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

only 3.3 inches. This quantity is about 70% less than the long-term average, and represents the lowest total recorded during the 88-year period of record.

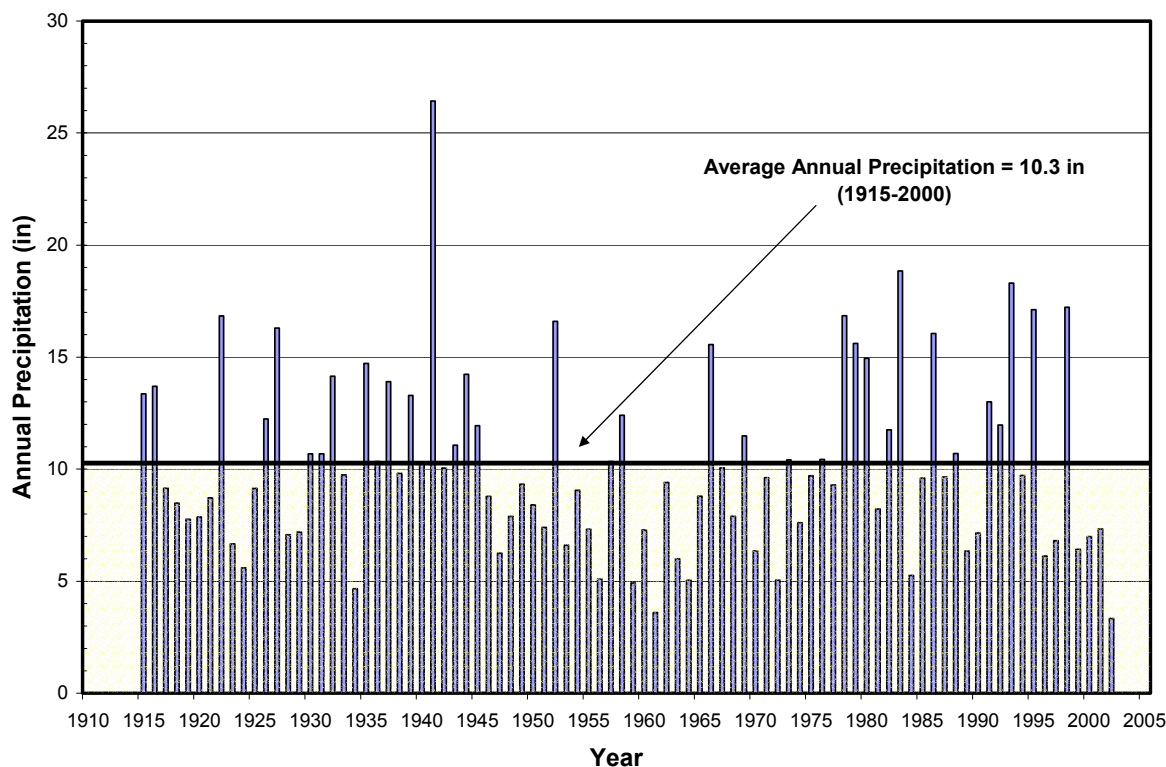


Figure 2. Annual Precipitation at Lindberg Field, 1915-2002

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 four consecutive years of below-average rainfall that have followed the 1997-98 El Niño event suggest the onset of another dry period.

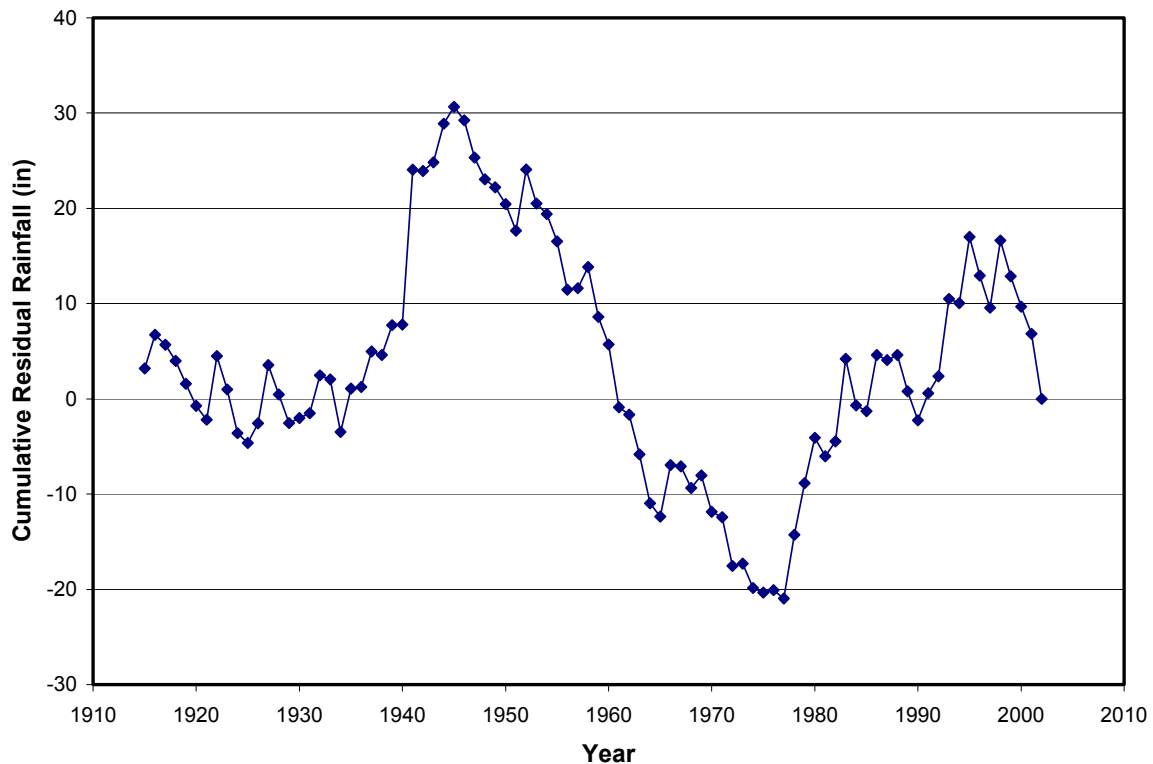


Figure 3. Cumulative Residual Rainfall at Lindberg Field, 1915-2002

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). 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 2001 and 2002 Monitoring Years.

Figure 4 presents the annual mean streamflow measured in each river between 1983 and 2002. In keeping with the rainfall data discussed in Section 2.1.1, the flow has been well below average since the 1997-98 El Niño event. During the 2002 Monitoring Year, the annual mean streamflow in each river was the lowest recorded during the 20-year period. 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

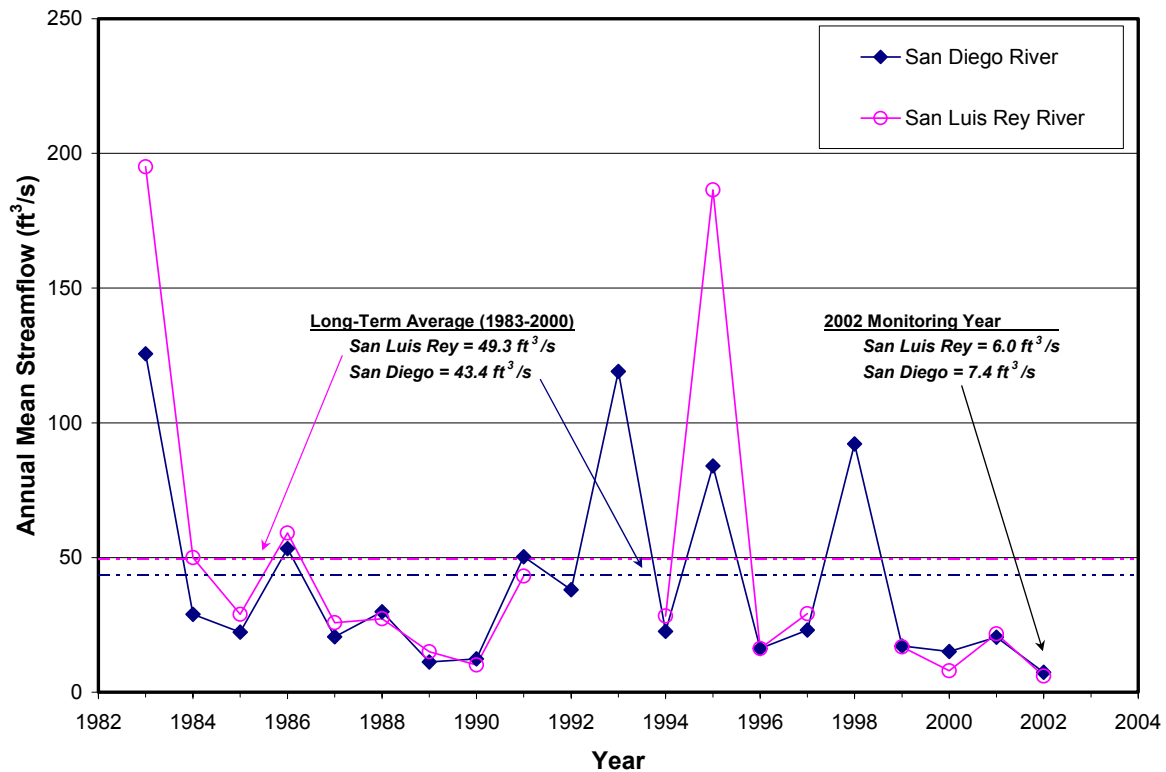


Figure 4. Annual Mean Streamflow in the San Luis Rey and San Diego Rivers, 1983-2002

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 and 2002 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 both years were characterized by below-average flow rates. 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.

2.1.3. Wave Climate

Two measures of the wave climate were used to compare the potential for sediment transport in 2001 and 2002 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.

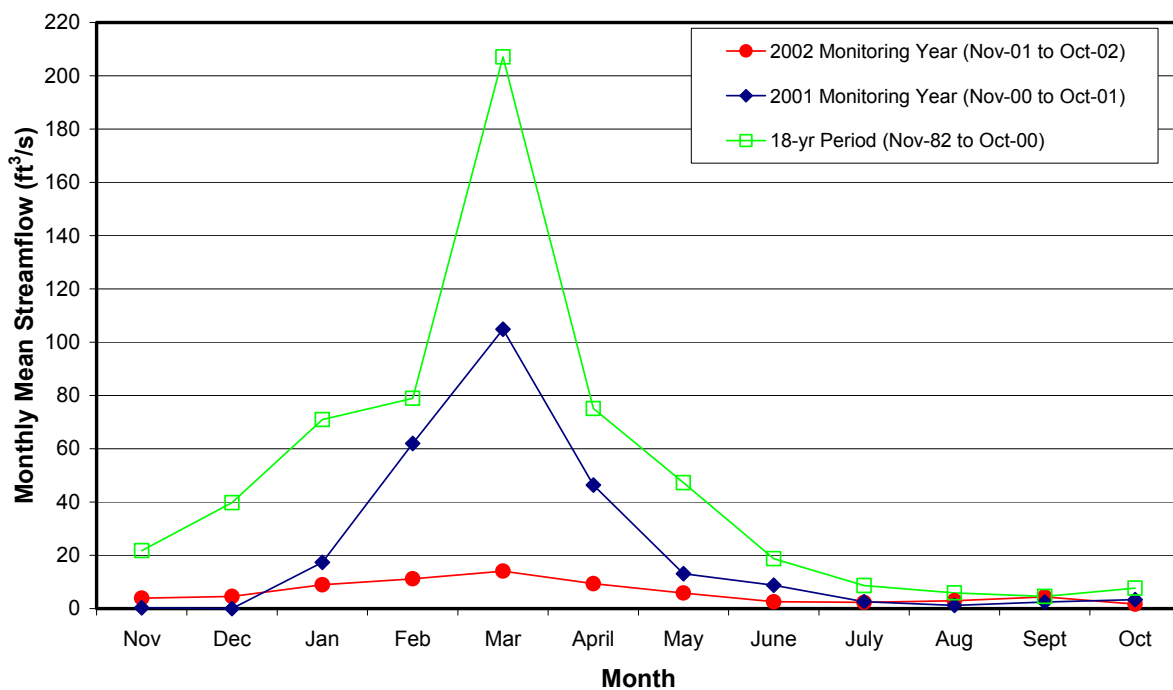


Figure 5. Monthly Mean Streamflow in the San Luis Rey River

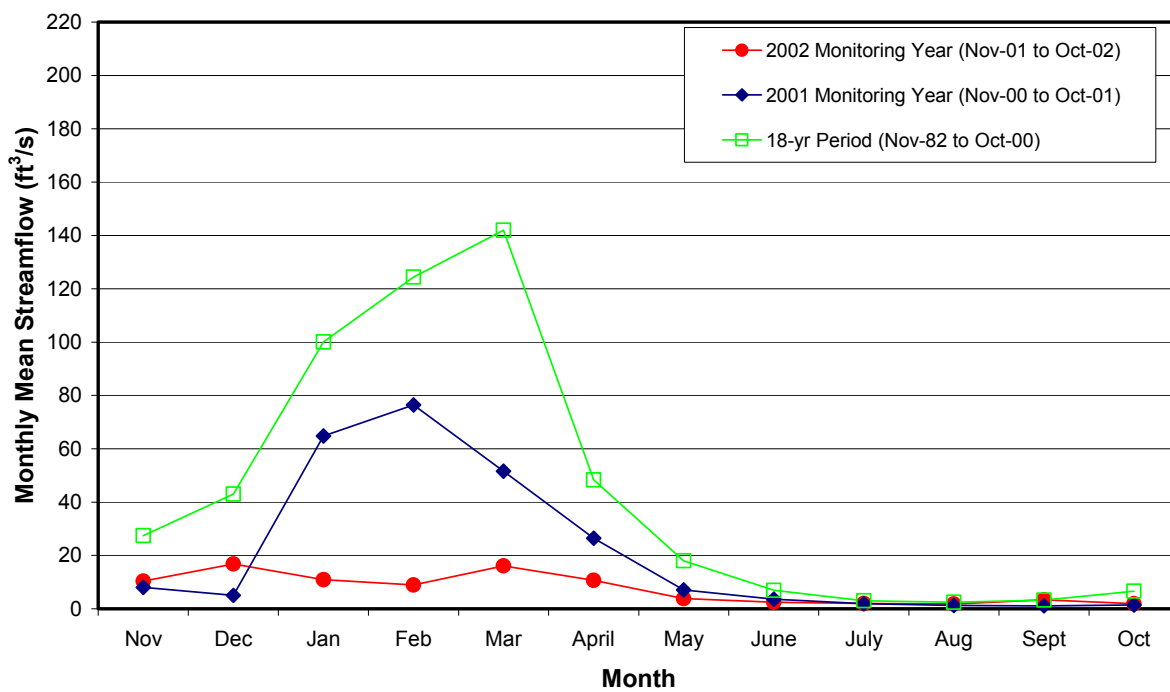


Figure 6. Monthly Mean Streamflow in the San Diego River

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 (2003). 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 2002 Monitoring Year are presented as time series in Figure 7. Consistent with the seasonal wave climate in Southern California, southerly swell predominated from April through mid-October. The anticipated predominance of northerly swell during the winter months occurred only from mid-December to mid-January, however, with the remainder of the year (mid-October through mid-December and mid-January through March) characterized by a mixture of northerly and southerly swell. The three most severe storms occurred in December, March, and September.

The total wave energy in each monitoring year from 1998 through 2002 was compared using the Relative Incident Energy Index (E_r) introduced 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):

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

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

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

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:

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

The computed values of E_r 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 with each successive year, dropping to 87 in 2002.

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). Once again, the most severe conditions occurred in 1998, when H_s exceeded 7 ft on sixteen occasions and 10 ft on

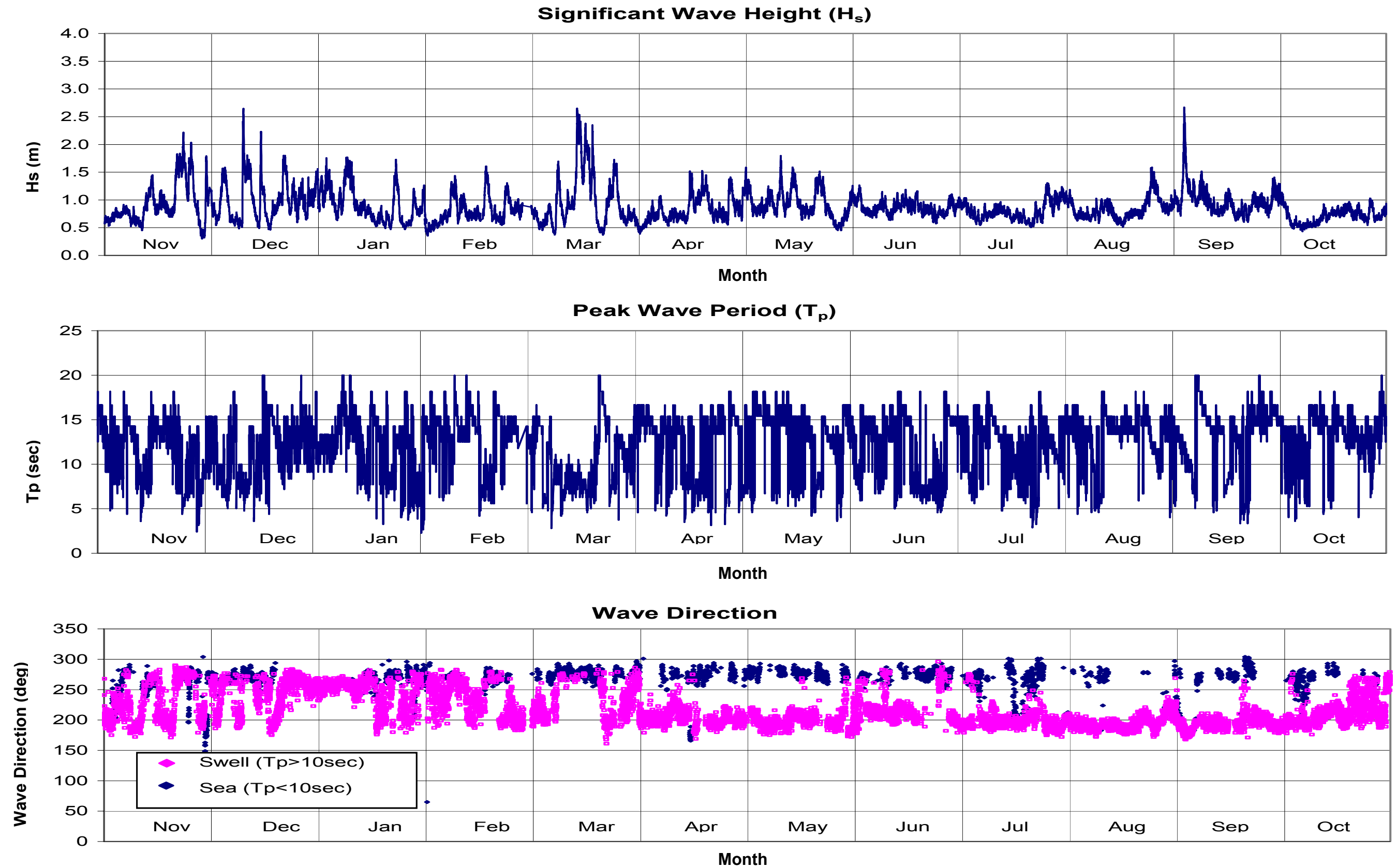


Figure 7. Wave Characteristics at the Oceanside Buoy, 2002 Monitoring Year

six occasions. During the 2001 Monitoring Year, H_s exceeded 7 ft on six occasions and 10 ft on two occasions. However, none of these events occurred subsequent to the April 6 initiation of the RBSP the nourishment activities. The 2002 Monitoring Year also was relatively mild, with H_s never reaching 10 ft and exceeding 7 ft on seven occasions. The maximum significant wave height in 2002, 8.8 ft (2.67 m), occurred on September 4 during a southerly swell event. Significant wave heights of 8.7 ft (2.65 m) resulted from short-period northerly seas on two occasions: December 10 and March 14.

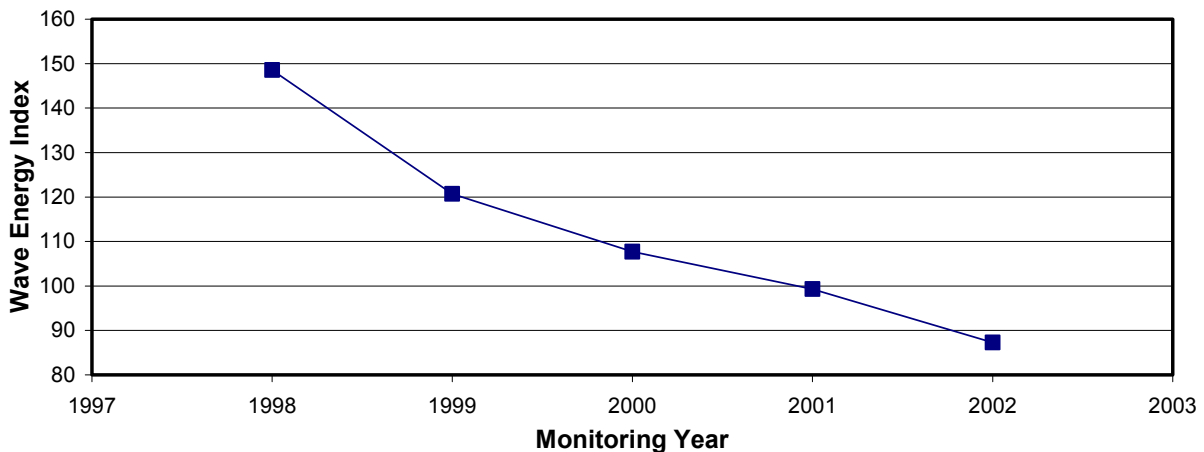


Figure 8. Relative Incident Energy Index at the CDIP Oceanside Buoy, 1998-2002

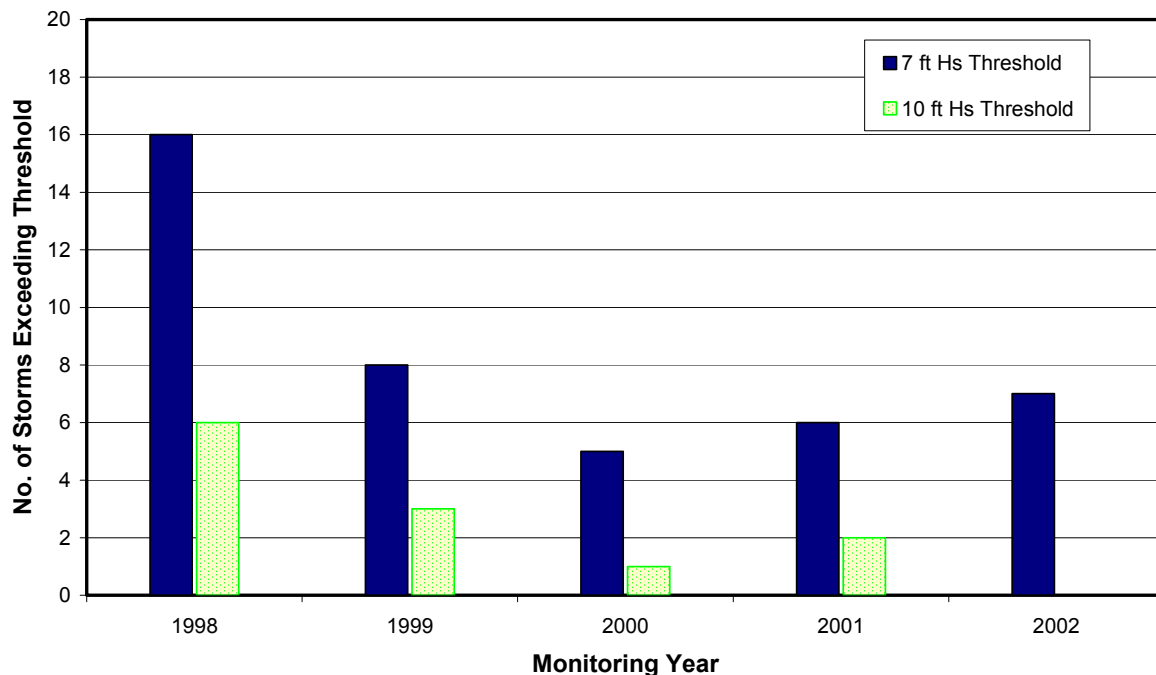


Figure 9. Storm Events per Year with Significant Wave Heights Exceeding 7 ft and 10 ft, 1998-2002

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.

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 (d_{50}) 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; in the Silver Strand Cell, 120,000 cy were placed at Imperial Beach.

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 these depended on “sand of opportunity” that was derived from activities

Table 1. RBSP Beach Fills

Littoral Cell	Receiver Beach	Fill Characteristics				Construction Period
		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⁾ d₅₀ represents median grain size of fill material.

Source: Noble Consultants, 2001

whose primary motive was not 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 2002 are summarized below by littoral cell. Two periods are considered: (1) the seven-year period from November 1993 through October 2000, and (2) the RBSP Monitoring Period (November 2000 through October 2002). 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) for the littoral cell. With the exception of the RBSP, no sand replenishment projects were undertaken during the 2001 or 2002 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
<i>Average Annual Nourishment Rate in the Silver Strand Cell = 73,000 cy/yr</i>				

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

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 Mission Beach Cell received no additional nourishment material during the 2001 and 2002 Monitoring Years.

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 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
<i>Average Annual Nourishment Rate in the Oceanside Cell (Nov 93 – Oct 00) = 393,000 cy/yr</i>				

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

Table 4 lists the two small non-RBSP nourishment projects undertaken in the Oceanside Cell during the RBSP Monitoring Period. Both projects 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.

**Table 4. Non-RBSP Beach Nourishment in the Oceanside Littoral Cell,
November 2000 through October 2002**

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
<i>Average Annual Nourishment Rate in the Oceanside Cell (Nov 00 – Oct 02) = 1,000 cy/yr</i>				

Source: Frenken, 2002; Keeley, 2003

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 have been modified relative to those presented in the 2001 Annual Report (Coastal Frontiers, 2002) to reflect more accurate information provided recently 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. The average rate at Batiquitos was far lower, at 2,000 cy/yr.

The sediment quantities bypassed at each site during the RBSP Monitoring Period (November 2000-October 2002) are presented in Table 6. Bypass operations were conducted at all three locations during the 2001 Monitoring Year, but only at Oceanside Harbor during the 2002 Monitoring Year. The bypass rates during the RBSP Monitoring Period were substantially higher than those that preceded the RBSP at Batiquitos (more than ten times higher) and Agua Hedionda (50% higher), but comparable at Oceanside Harbor.

**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
	<i>Average Annual Bypass Rate at Batiquitos Lagoon = 2,000 cy/yr</i>		
Agua Hedionda Lagoon	1994	Carlsbad	159,000
	1996	Carlsbad	443,000
	1997	Carlsbad	197,000
	1999	Carlsbad	203,000
	<i>Average Annual Bypass Rate at Agua Hedionda Lagoon = 143,000 cy/yr</i>		
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
	<i>Average Annual Bypass Rate at Oceanside Harbor = 252,000 cy/yr</i>		

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

**Table 6. Sand Bypassing in the Oceanside Littoral Cell
November 2000 through October 2002**

Bypass Project	Date	Placement Location	Bypass Quantity (cy)
Batiquitos Lagoon	2001	South of Entrance	45,000
	<i>Average Annual Bypass Rate at Batiquitos Lagoon = 23,000 cy/yr</i>		
Agua Hedionda Lagoon	2001	Carlsbad	429,000
	<i>Average Annual Bypass Rate at Agua Hedionda Lagoon = 215,000 cy/yr</i>		
Oceanside Harbor	2001	Oceanside	80,000
	2002	Oceanside	400,000
	<i>Average Annual Bypass Rate at Oceanside Harbor = 240,000 cy/yr</i>		

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

The unusually high bypass rates at Agua Hedionda and Batiquitos were not caused by the RBSP, because the bypass work was conducted prior to or concurrent with the April 2001 start of the nourishment activities

2.3. The Year in Perspective

Table 7 compares the environmental conditions that prevailed during the RBSP Monitoring Period with those in the recent past. Both precipitation and streamflow were well below average, while the wave conditions were relatively mild. The implications of these circumstances 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.

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	5.3	49%
Streamflow ⁽³⁾ (cfs)			
<i>San Luis Rey River</i>	49.3	13.9	28%
<i>San Diego River</i>	43.4	13.9	32%
Wave Climate ⁽⁴⁾			
<i>Energy Index</i>	125	94	75%
<i>Storms w/ $H_s > 7$ ft</i>	9.7	6.5	77%
<i>Storms w/ $H_s > 10$ ft</i>	3.3	1.0	30%

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 (2001-2002).

⁽⁶⁾ % of Hist. Average represents RBSP Average divided by Historical Average.

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 8. Beach Nourishment: 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	60,000	(73,000)	(13,000)
Mission Beach	2,000	0	76,000	(2,000)	+74,000
Oceanside	393,000	1,000	917,000	(392,000)	+524,000
Total	468,000	1,000	1,053,000	(467,000)	+585,000

Notes: ⁽¹⁾ Historical Average based on the period 1993-2000.

⁽²⁾ RBSP Average based on the RBSP Monitoring Period (2001-2002).

⁽³⁾ Difference represents RBSP Average minus Historical Average.

As indicated above, the only non-RBSP nourishment provided during the 2001 and 2002 Monitoring Years was 2,000 cy (1,000 cy/yr) at Moonlight Beach. As a result, 934,000 cy of the RBSP fill material (about 44%) served to compensate for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 1,170,000 cy, represented incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 1,048,000 cy (equivalent to 524,000 cy/yr over the two-year RBSP Monitoring Period). The Mission Beach Cell received an additional 148,000 cy (74,000 cy/yr), while the Silver Strand Cell incurred a deficit of 26,000 cy (13,000 cy/yr) due to the lack of nourishment activities other than the RBSP.

The sand bypass rates at Batiquitos, Agua Hedionda, and Oceanside Harbor during the RBSP Monitoring Period are compared with the average values from the seven prior monitoring years in Table 9. The rates at Batiquitos and Agua Hedionda were substantially higher than the prior values, while the rate at Oceanside Harbor was comparable to the prior value. The high rates at the two lagoon entrances were not caused by the RBSP, because the bypass work was conducted prior to or concurrent with the April 2001 start of the nourishment activities.

The implications of the bypass data in Table 9 are as follows:

- The beaches adjacent to the Batiquitos and Agua Hedionda Lagoon entrances benefited from the increased bypass rates at these sites.
- The beaches at Oceanside and North Carlsbad were neutrally impacted by the provision of near-typical bypass rates at Oceanside Harbor.

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	23,000	21,000
Agua Hedionda	143,000	215,000	72,000
Oceanside Harbor	252,000	240,000	(-12,000)

Notes: ⁽¹⁾ Historical Average based on the period 1993-2000.
⁽²⁾ RBSP Average based on the RBSP Monitoring Period (2001-2002).
⁽³⁾ Difference represents RBSP Average minus Historical Average

3. MONITORING METHODS

As indicated in Section 1, the general objective of the 2002 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 prior to 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.

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. Beach Profile Surveys

Beach profile data were obtained in the Spring and Fall of 2002, corresponding to the transitions between the winter and summer wave seasons. As indicated above, four sites were added to the program in 2002, while one was removed. Two of the additions, Transects SD-0595 and SD-0610, were established by the City of Solana Beach in May 2002 at the inauguration of the city's beach monitoring program. The transects were included in both the Spring and Fall 2002 surveys.

The other two transects added to the SANDAG Monitoring Program, DM-0560 and SS-0005, represented historical beach profile sites that were reoccupied in Fall 2002 for the first time since the 1980's. Transect DM-0560 was added to provide improved coverage in the Del Mar area. Transect SS-0005 was substituted for SS-0007, which was abandoned after the Spring 2002 survey because the site is influenced more by the migration of the Tijuana River mouth than by coastal processes (Coastal Frontiers, 2002).

As a result of the foregoing changes, the Spring 2002 survey encompassed 60 transects while the Fall survey encompassed 61. The locations of the 62 transects that were included in one or both surveys are listed in Table 10, and illustrated in Figures 10a and 10b.

The Spring 2002 beach profiling activities were conducted over a two-week period that began on May 17 and ended on May 31. The transects in the Silver Strand Cell were surveyed on May 17, after which field activities were suspended due to heavy surf. Following the acquisition of profile data in the Mission Beach Cell on May 22 and 23, adverse sea conditions forced a second interruption in the field work. The conditions improved several days later, allowing the Oceanside Cell beach profiling to occur between May 29 and 31. Despite the interruptions caused by 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 2002 profile work was conducted between October 25 and November 6, during which period the field operations again were hindered by episodes of large waves. Profile data were acquired in the Silver Strand Cell on October 25 and the Mission Beach Cell on October 28, in both cases under favorable wind and wave conditions. The sea conditions then turned marginal, however, forcing a six-day postponement in the data acquisition activities. When work resumed in the Oceanside Cell on November 4, the winds were light and the seas seldom exceeded 3 ft.

The data acquisition and processing methods used for the 2002 profile surveys are described below. Although several improvements were made in the data acquisition techniques, 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 monument to an

Table 10. Beach Profile Transect Locations

	TRANSECT ⁽⁶⁾	LOCATION	SPONSOR	TRANSECT ⁽⁶⁾	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-0007 ⁽⁵⁾	Tijuana Estuary	SANDAG	SS-0077	Silver Strand	SANDAG
	SS-0015 ⁽³⁾	Imperial Beach	SANDAG	SS-0090	Silver Strand	SANDAG
	SS-0020 ^(1,2,3)	Imperial Beach	SANDAG	SS-0160	Coronado	SANDAG
	SS-0025 ^(1,2,3)	Imperial Beach	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⁾ New 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 removed from monitoring program in 2002.
⁽⁶⁾ Transect locations shown in Figures 10a and 10b.

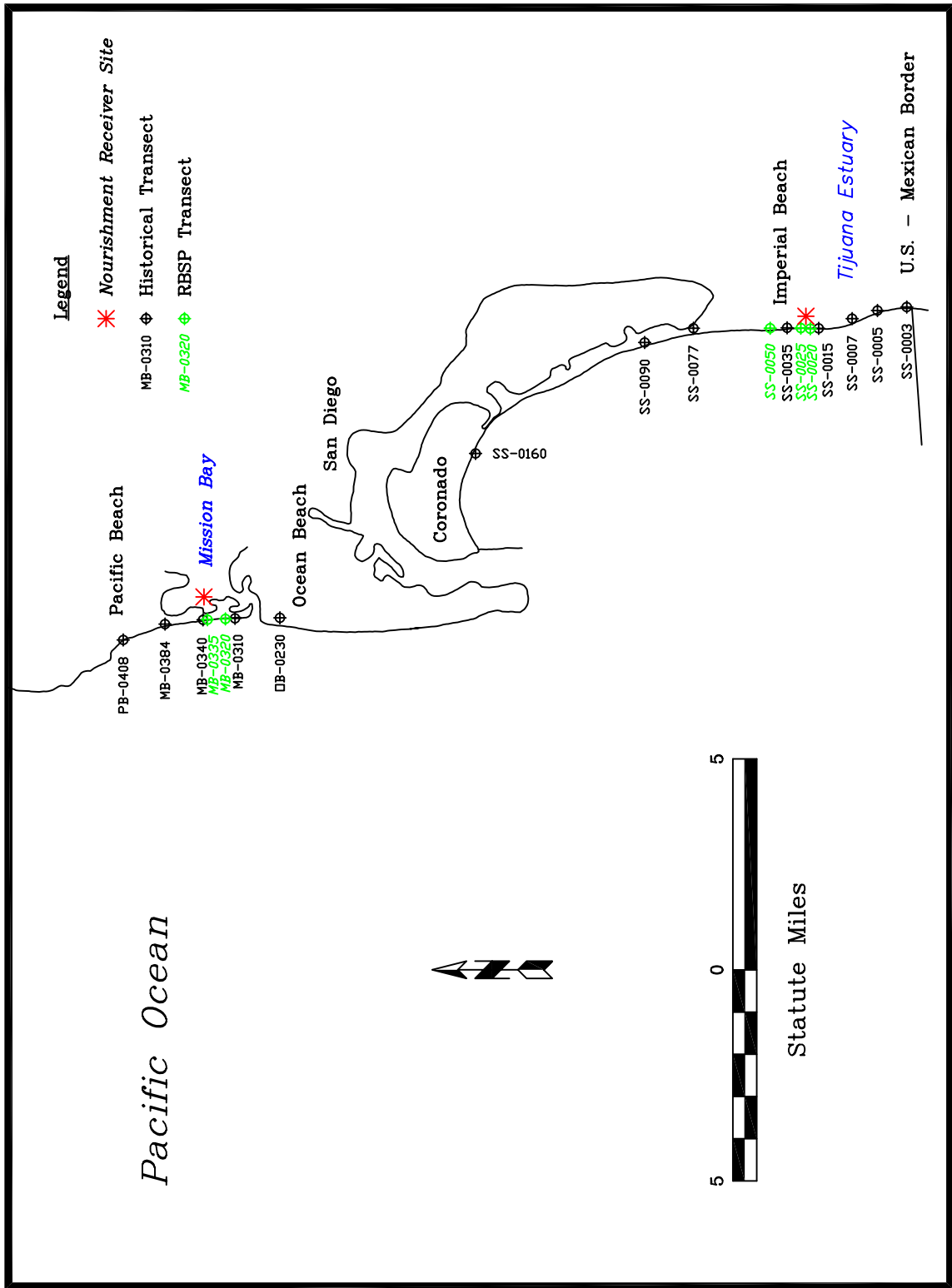


Figure 10a. Beach Profile Transects in the Silver Strand and Mission Beach Littoral Cells

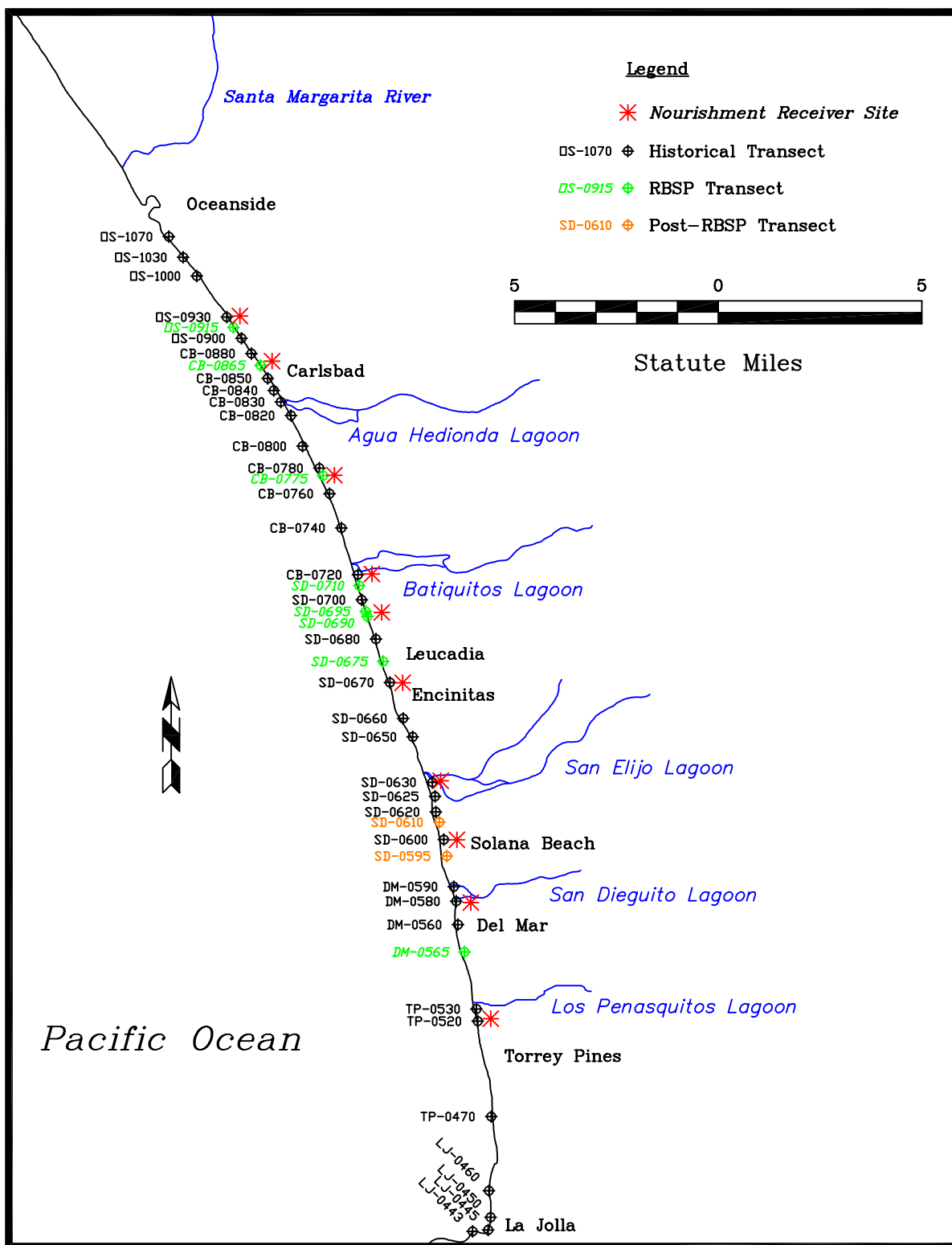


Figure 10b. Beach Profile Transects and Lagoons Entrances in the Oceanside Littoral Cell

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 monument 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. The vessel’s position was determined by a GPS unit receiving real-time corrections (DGPS) broadcast from the U.S. Coast Guard Station on Point Loma. Although the data acquisition procedure was similar to that employed in the past, the following two changes were implemented in 2002 to improve the quality of the results:

1. Dynamic Motion Sensor: A dynamic motion sensor was used aboard the survey vessel during the Spring and Fall surveys to provide real-time corrections to the echo sounder data for wave-induced vessel heave.
2. On-Board Data Acquisition Computer: A ruggedized field computer was used aboard the survey vessel during the Fall survey to log digital sounding and position data.

The net impact of these changes was to improve the vertical resolution of the bathymetric sonar system, particularly in areas of localized vertical relief.

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). During the Spring survey, when the echo sounder and DGPS system were operated independently, the soundings were correlated with vessel position fixes at 10-second intervals, or approximately every 60 ft. During the Fall survey, when the echo sounder and DGPS system were interfaced to the on-board computer, 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 during the Fall survey to measure the speed of sound in sea water.

Data Processing

The data from the wading portion of the survey were processed using software developed by Spectra Precision. 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 echo sounder record from the bathymetric portion of the survey was examined to confirm that the motion compensator had properly filtered wave contamination from the soundings. In a limited number of 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. In the case of the Spring survey, the soundings were digitized at each vessel fix and merged with the corresponding DGPS horizontal position data. As indicated previously, the sounding and position data obtained in Fall 2002 were merged in real time by the Hypack software.

A correction was computed and applied to the measured depths based on the results of the bar check and CTD calibration procedures. The corrected soundings then were adjusted to MLLW datum using the water levels recorded at the National Ocean Service tide gauge on Scripps Pier in La Jolla.

The Fall bathymetric data were thinned to a nominal interval of 10 ft to produce a manageable file size suitable for developing beach profile plots. The Spring sounding data were acquired at 60-ft intervals and therefore did not require thinning. For each survey, the resulting x, y, z triplets (northing, easting, and elevation) were inserted into the CAD drawing containing the corresponding wading data. The soundings were examined in the region of overlap 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. 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 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 wading data are inherently more accurate than the bathymetric data. The electronic total

station used to conduct the survey is capable of measuring ranges to within ± 0.5 ft and elevation differences to within ± 0.1 ft. However, because the swimmer was required to negotiate 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 seaward end of the wading data.

3.1.2. Aerial Photography

To augment the beach profile data, oblique aerial photographs of the twelve RBSP receiver sites were obtained 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 May 9. The Fall photo mission, flown on November 4, followed the completion of the first RBSP fill at Torrey Pines by 18 months, and the completion of the last fill at Oceanside by 13.5 months.

3.1.3. 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 specified that data were to be obtained monthly, at a time when the predicted tide height was 1 to 3 ft above MLLW. The beach width was 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 was to be measured just above the still water level and recorded along with the date and time of the observation.

After the end of the 2001 and 2002 Monitoring Years, the data for that year were transmitted to Coastal Frontiers for processing. 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 that elevation produce inaccurate estimates of the MSL beach width.

3.2. Lagoon Entrance Monitoring

The 2002 lagoon monitoring effort was virtually identical to the 2001 effort, 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. 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 8, 9, and 10, while the Fall work was performed between October 30 and November 6.

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 wading depth in the lagoon. Particular emphasis was placed on areas perceived either to control 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. 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 9 and

November 4). 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 +0.9 to +2.0 ft (MLLW) during the Spring overflight, and -0.5 to +0.3 ft during the Fall overflight.

3.2.3. Monthly Inspections

Monthly inspections 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. The inspections continued throughout the 2002 Monitoring Year. In addition to photographs from repeatable locations, these site visits included notes on whether the channels were open to tidal exchange.

4. MONITORING DATA

This section presents the results of the 2002 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 2002 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.

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	61

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 2002 data, the plots display the profiles from 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).

When reviewing Appendices C and D, it is important to recognize that the pronounced vertical relief evident in the Fall 2002 profiles resulted from 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 profile is the presence of exposed rock reefs (which were not identifiable until the on-board dynamic motion sensor and data acquisition computer were added for the Fall survey). Although the profile data obtained in such areas may vary slightly in the future due to differences in the vessel track and the wave conditions, the improved resolution afforded by the new technology should prove beneficial in identifying potential hard-bottom habitat.

It should be noted that the vertical control points used for the wading portion of the survey on Transects SD-0620 and SD-0625 were found to be in error by approximately 0.5 feet. The error occurred in Fall 2000 during transect establishment, but was not discovered until after the Fall 2002 survey. An elevation adjustment was applied to the wading data at these transects for the five surveys commencing with Fall 2000. All data products contained in this report have been adjusted to reflect this correction, including those pertaining to prior years as well as the 2002 Monitoring Year.

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 the post-nourishment profiles (Fall 2001, Spring 2002, and Fall 2002) indicates that a material change in beach condition may have resulted from the RBSP nourishment activities.

Tables and plots of shoreline position and beach width derived from the profile data are provided in **Appendix E**. Data from the following 17 surveys were utilized to the extent that they were available:

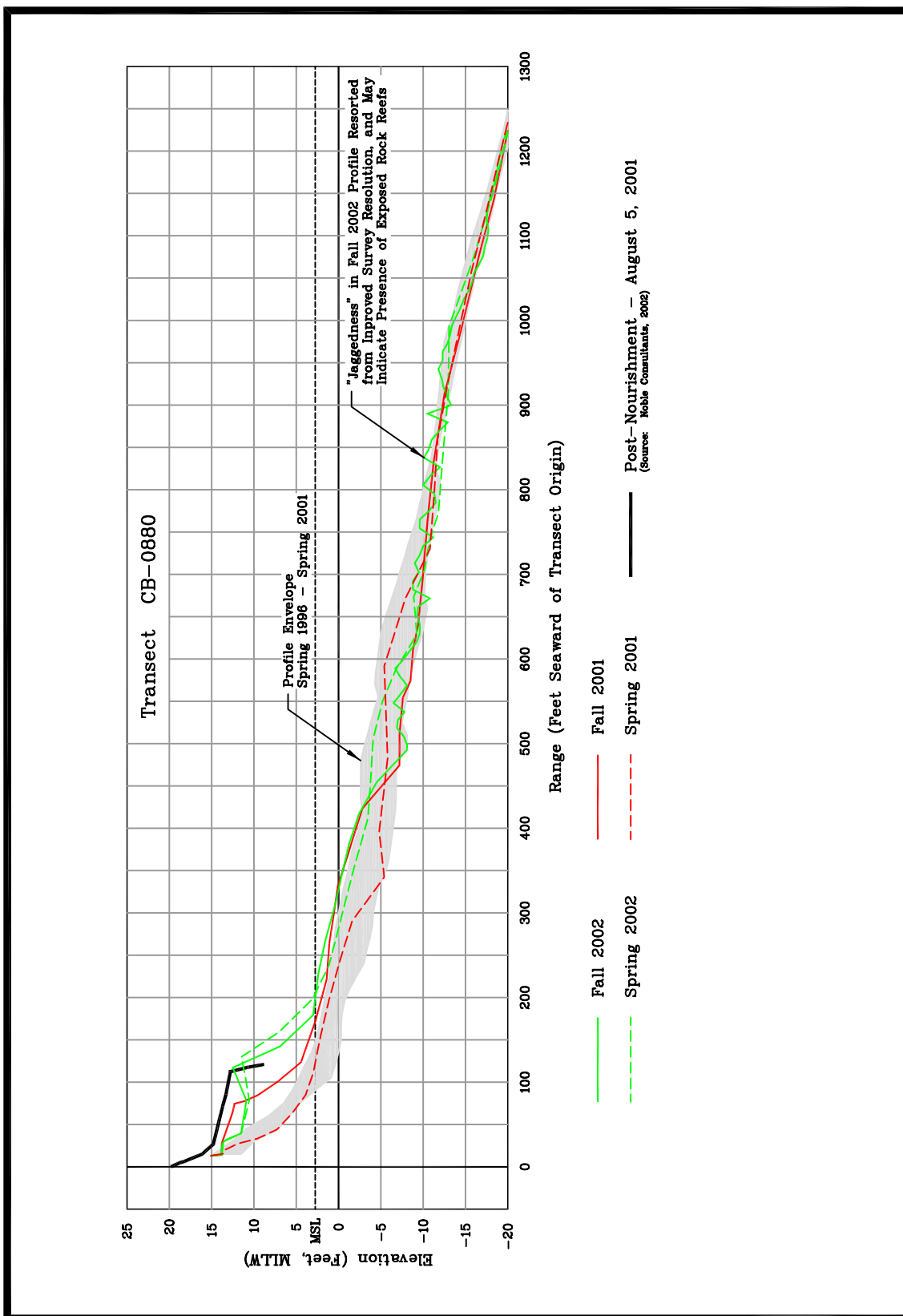


Figure 11. Transect CB-0880 in Carlsbad

Pre-1984:	Date Varies	1998:	Spring and Fall
1984:	Fall	1999:	Spring and Fall
1989:	Fall	2000:	Spring and Fall
1996:	Spring and Fall	2001:	Spring and Fall
1997:	Spring and Fall	2002:	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 seven most recent summers (1996 through 2002), and six most recent winters (1996-97, 1997-98, 1998-99, 1999-2000, 2000-2001, 2001-2002). 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 2002.

- MSL Beach Widths: Beach width provides an indication of both recreational area and 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. Beach width data derived from surveys conducted prior to the inception of the SANDAG Monitoring Program in 1996 should be considered approximate.

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 prior annual monitoring reports, 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 modification, including those pertaining to prior years as well as to the 2002 Monitoring Year.

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 of σ 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 utilized, 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 survey, Spring 2002, was included in an attempt to define a control volume that would encompass the seaward dispersion of the RBSP fill material. For those transects that lacked profile data encompassing the relatively severe El Niño winter of 1997-98, the range of closure was estimated from the adjoining transect or 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 to facilitate a direct comparison of annual volume changes in the shorezone. Unless extraordinary events cause substantial profile changes outside the computed ranges of 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 new transects (such as SS-0005 and DM-0560), the range of closure will be 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 16 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

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

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	tbd	tbd
	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	tbd	tbd
	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	1031	-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.

⁽⁵⁾ Range of closure on new transect to be determined ("tbd") when more data become available.

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

Long-Term:

Fall 1997 to Fall 2000 (Pre-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 16 periods as changes in shorezone volume above the depth of closure.

4.1.2. Aerial Photographs (Section 5)

Oblique aerial photographs obtained at the twelve RBSP receiver sites in 2001 and 2002 are provided in Section 5.

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 and 2002 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 inspections and photographs at the unstabilized entrances to San Elijo, San Dieguito, and Los Peñasquitos.

4.2.1. Topographic Data (Appendix H)

The 2002 lagoon entrance monitoring data are presented in graphical form in **Appendix H**. For Agua Hedionda and Batiquitos, the channel cross-sections obtained in Spring 2002 and Fall 2002 were plotted with those from Fall 2001 to illustrate the changes in channel 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 2001;
- A contour map depicting the topographic data obtained in Spring 2002;
- A contour map depicting the topographic data obtained in Fall 2002;
- A contour map illustrating the elevation changes that occurred between Fall 2001 and Spring 2002, as well as the net change in volume within the survey area;
- A contour map illustrating the elevation changes that occurred between Spring 2002 and Fall 2002, as well as the net change in volume within the survey area;
- A contour map illustrating the elevation changes that occurred between Fall 2001 and Fall 2002, as well as the net change in volume within the survey area.

4.2.2. Aerial Photographs (Section 6)

Oblique aerial photographs obtained at the five lagoon entrances in 2001 and 2002 are provided in Section 6.

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 RBSP Monitoring Period (November 2000 through October 2002). Section 5.1 provides a regional overview, while Section 5.2 describes the performance of each of the twelve RBSP beach fills. Except where indicated otherwise, statistical comparisons between the 2001 and 2002 Monitoring Years are derived from the 44 transects with measurements dating back to Fall 2000.

5.1. Regional Overview

The combination of beach fills and mild wave conditions during the RBSP Monitoring Period proved to be extremely beneficial for the San Diego County coast. Beach width and sediment volume tended to increase during this two-year period, producing a significant improvement in the state of the coast. Although shoreline retreat and shorezone volume losses predominated at the RBSP fill sites during the most recent monitoring year (2002), shoreline advance and shorezone volume gains occurred at many of the adjacent beaches as the nourishment material was dispersed along the coast.

5.1.1. Shoreline and Subaerial Volume Changes

As indicated in Figure 12, the percentage of transects exhibiting shoreline advance decreased from 59% in the 2001 Monitoring Year to 41% in the 2002 Monitoring Year. This decline is attributable to the absence of significant nourishment activities in 2002, as well as shoreline retreat at the RBSP fill sites occasioned by flattening of the nourished profiles. When the entire RBSP Monitoring Period is taken into consideration, 59% of the transects experienced shoreline advance (despite the aforementioned profile adjustments at the receiver sites). The breakdown of shoreline changes during this two-year period is as follows:

- 26 transects (59%) exhibited shoreline advance in excess of 10 ft;
- 15 transects (34%) exhibited essentially no shoreline change (10 ft or less);
- 3 transects (7%) exhibited shoreline retreat in excess of 10 ft.

The percentage of transects experiencing shoreline advance during the RBSP Monitoring Period was highest in the Oceanside Cell, at 70% (23 of 33 transects). In contrast, shoreline advance occurred at 40% of the transects in the Mission Beach Cell (two

of five transects) and 17% in the Silver Strand Cell (one of six transects). This disparity is consistent with the fact that more than 85% of the RBSP nourishment material was placed in the Oceanside Cell.

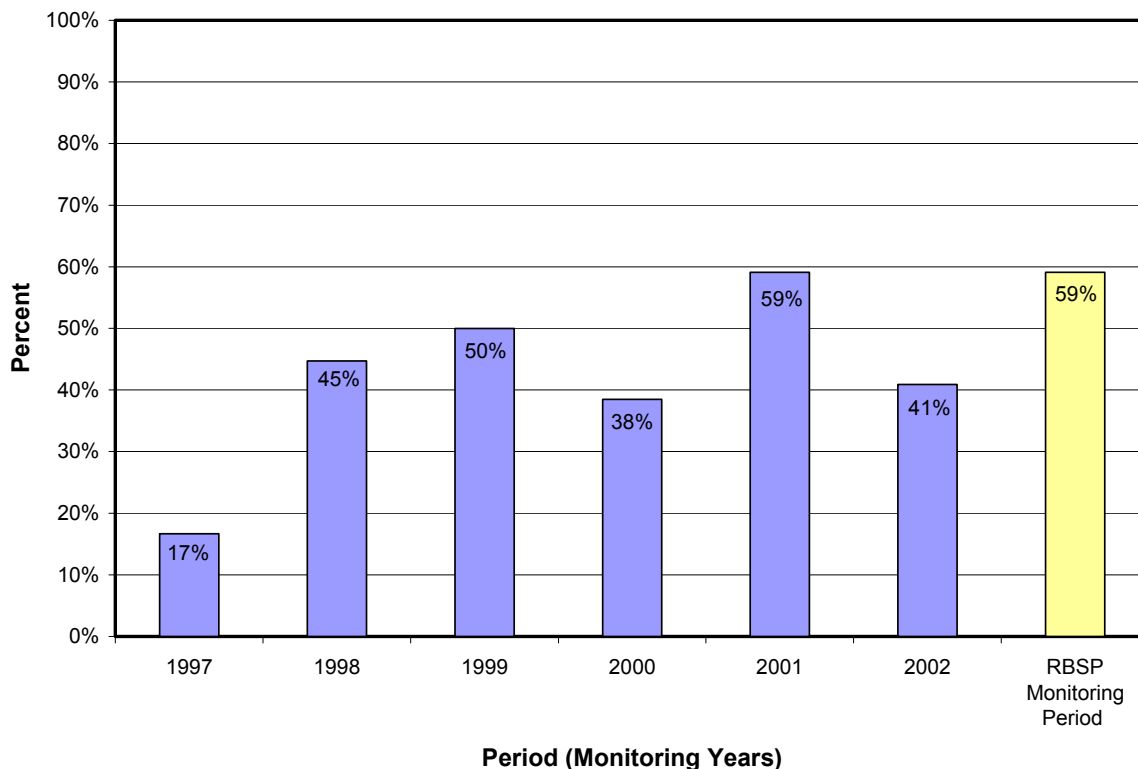


Figure 12. Percentage of Transects Exhibiting MSL Shoreline Advance

Detailed shoreline position data are provided in Appendix E. Changes in MSL shoreline position that occurred during the 2002 Monitoring Year and the entire RBSP Monitoring Period are presented graphically in Figures 13a and b. The plots illustrate the aforementioned predominance of shoreline advance during the entire RBSP Monitoring Period, as well as the more balanced nature of advance and retreat that occurred in 2002 (when the shoreline advanced at 18 transects, retreated at 15 transects and changed 10 ft or less at eleven transects).

The dispersion of fill material that took place during the 2001 and 2002 Monitoring Years is illustrated in Figure 14, which compares the subaerial volume changes (above MSL) at the receiver site transects with those at transects located updrift and downdrift of the receiver sites. It should be noted that Figure 14 was developed from all transects for which data were available, rather than just those with measurements dating back to Fall 2000.

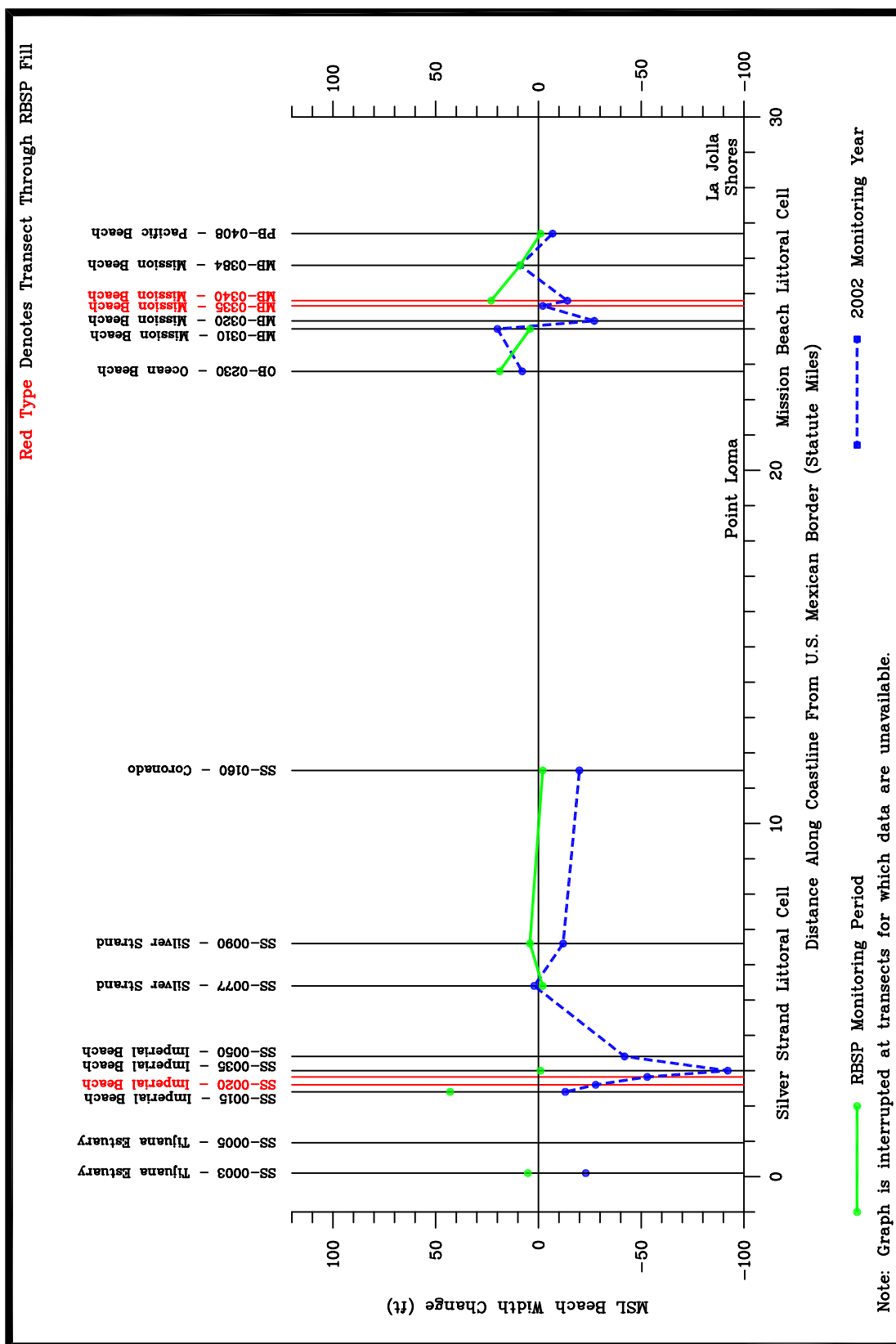


Figure 13a. MSL Shoreline Changes in the Silver Strand and Mission Beach Littoral Cells

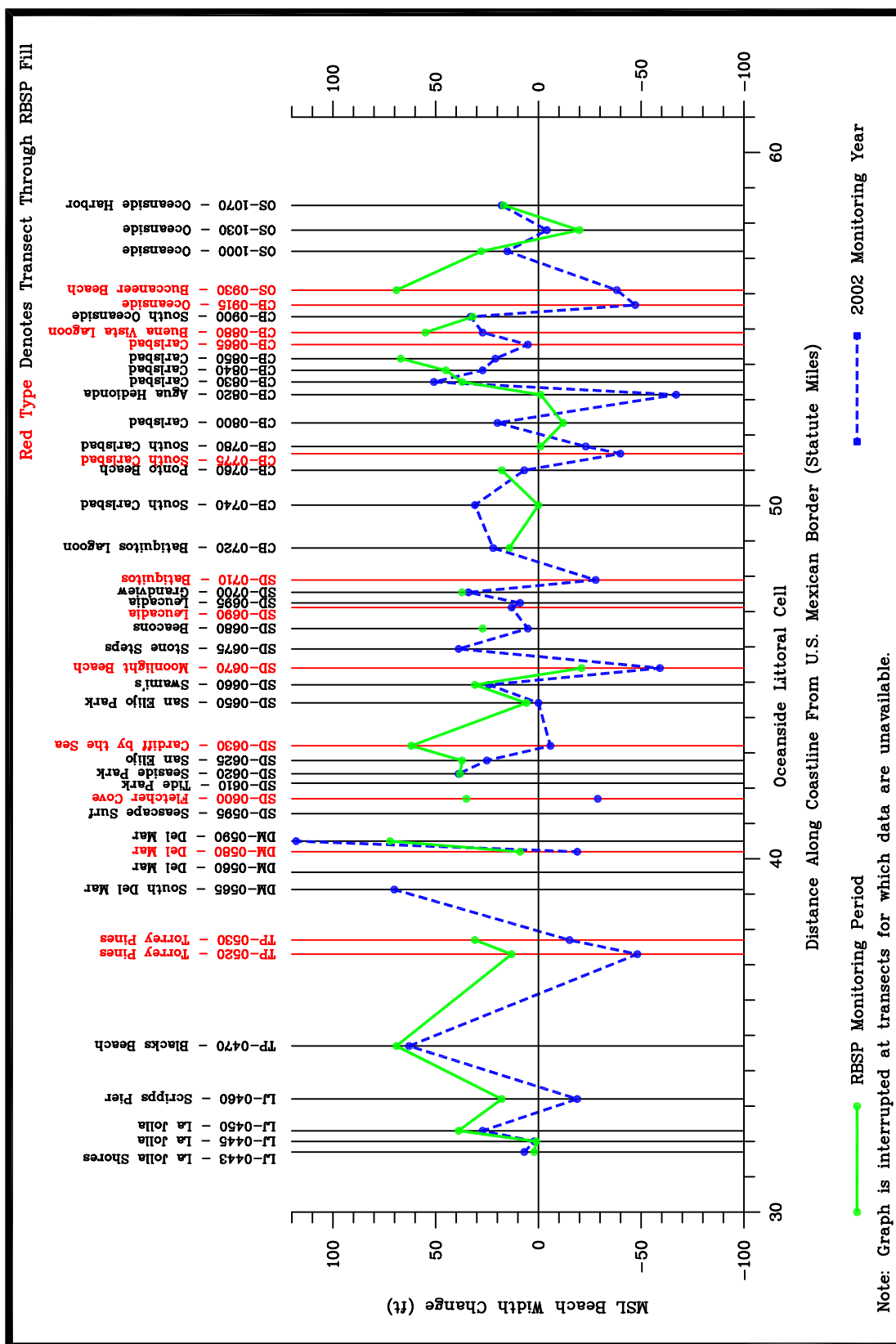


Figure 13b. MSL Shoreline Changes in the Oceanside Littoral Cell

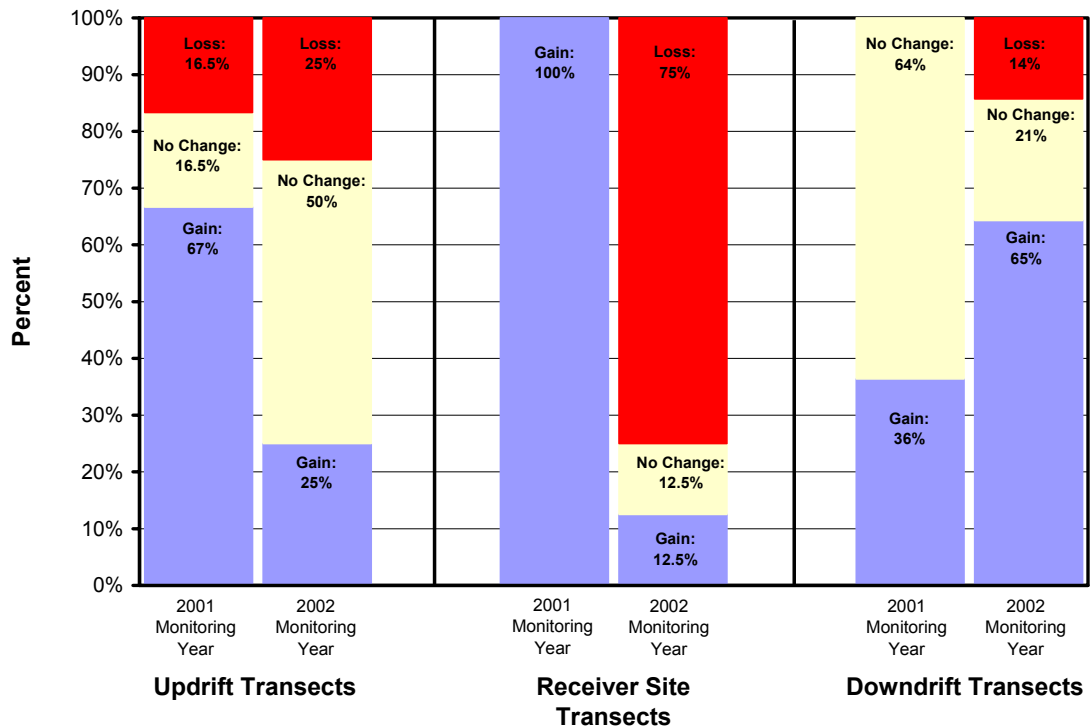


Figure 14. Subaerial Volume Changes during RBSP Monitoring Period

The downdrift direction was assumed to be southerly in the Oceanside and Mission Beach Cells, and northerly in the Silver Strand Cell (DBW, 1994). Based on beach profile data obtained in conjunction with the 1984 release of 180,000 cy of sediment at San Onofre Nuclear Generating Station, Inman (1987) estimated that sand accretion waves propagate downdrift at rates which initially range from 2,000 to 3,600 ft/yr. Using the upper end of this range with an average period of 16 months between RBSP fill placement and the Fall 2002 survey, a distance of approximately 5,000 ft was computed for the downdrift propagation of the nourishment material. Accordingly, “downdrift” transects were defined as those within 5,000 ft of the downdrift fill boundary. “Updrift” transects were defined as those within 2,500 ft of the updrift fill boundary, in recognition of the likelihood that sediment moves updrift more slowly than downdrift.

As a result of the RBSP nourishment operations conducted in Summer 2001, all of the receiver site transects exhibited subaerial volume gains during the 2001 Monitoring Year. Subaerial volume gains also occurred at 67% of the updrift transects during this period, suggesting that some of the nourishment material was transported updrift during the summer wave season. In contrast, volume gains were recorded at only 36% of the downdrift transects.

The foregoing trends were reversed during the 2002 Monitoring Year, when 75% of the receiver site transects experienced subaerial volume losses, 25% of the updrift transects experienced gains, and 65% of the downdrift transects experienced gains. These results indicate that, as expected, the RBSP nourishment material is being preferentially dispersed toward the downdrift beaches.

5.1.2. Beach Widths

In Figures 15a and b, the MSL beach widths measured in Spring 2002 and Fall 2002 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 16 of the 38 transects (42%) with measurements dating back to 1997, the beach width in Fall 2002 was greater than that noted in any of the pre-RBSP years. Furthermore, in no instance was the beach width measured in Spring 2002 or Fall 2002 found to be less than the lower limit of the pre-RBSP envelope. The largest increase relative to this envelope, 69 ft, occurred at Blacks Beach on Transect TP-0470.

5.1.3. Shorezone Volume Changes

Figures 16a and b present the volume changes that occurred in the shorezone (inside the range of closure) during the 2002 Monitoring Year and the entire RBSP Monitoring Period. The supporting data are provided in Appendix F.

In 2002, gains and losses in shorezone volume were nearly balanced in the Silver Strand and Mission Beach Cells. Gains predominated in the Oceanside Cell, however, by a ratio of more than 3:2. In keeping with the shoreline and subaerial volume data discussed above, the shorezone volume losses were concentrated at the receiver sites whereas the gains tended to occur at the adjacent beaches.

Over the two-year RBSP Monitoring Period, shorezone volume gains predominated by a wide margin. The breakdown is as follows:

- 26 transects (59%) exhibited gains in excess of 10 cy/ft;
- 13 transects (30%) exhibited no significant change (10 cy/ft or less);
- 5 transects (11%) exhibited losses in excess of 10 cy/ft.

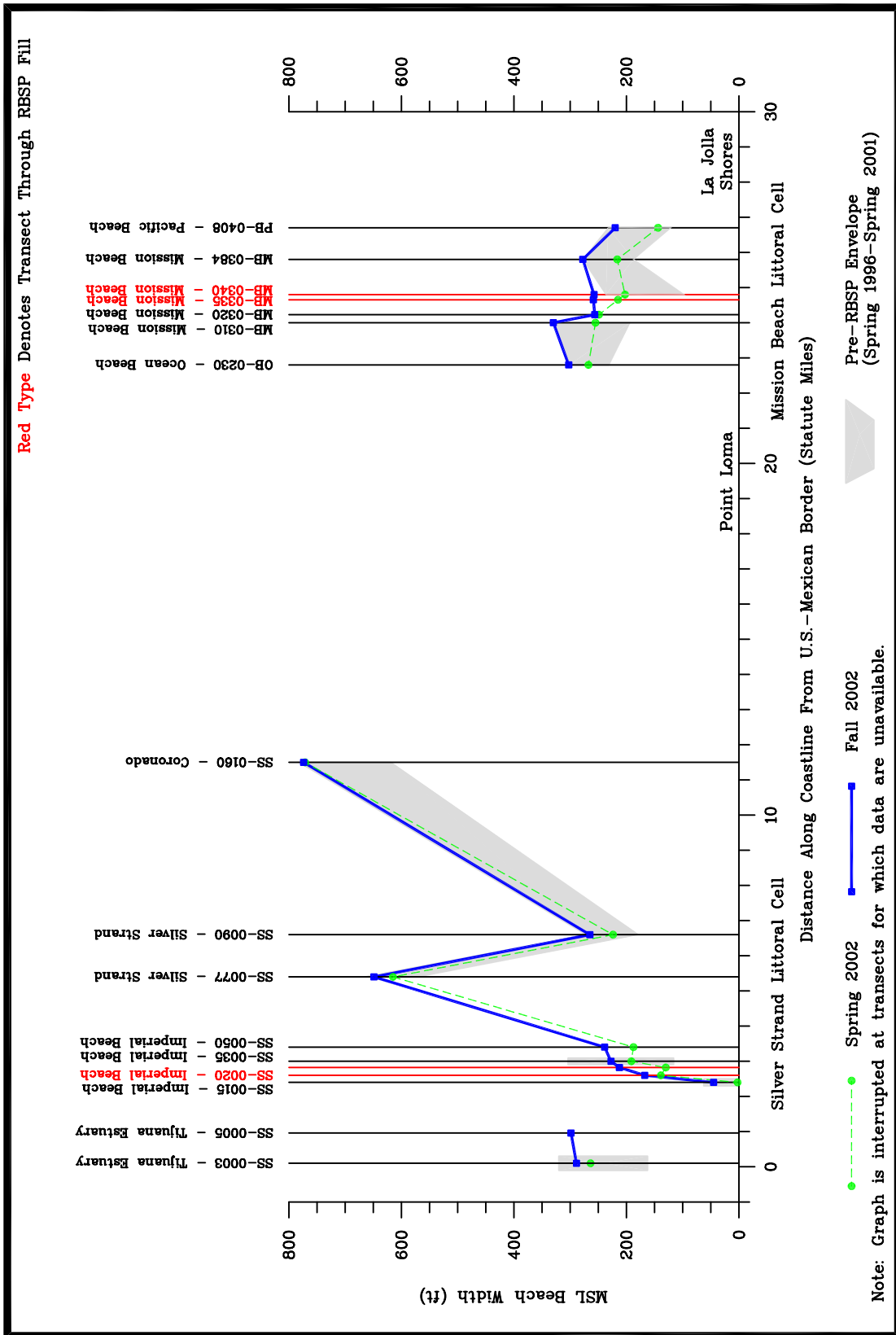


Figure 15a. Comparison of 2002 MSL Beach Widths with Pre-RBSP Envelope in the Silver Strand and Mission Beach Littoral Cells

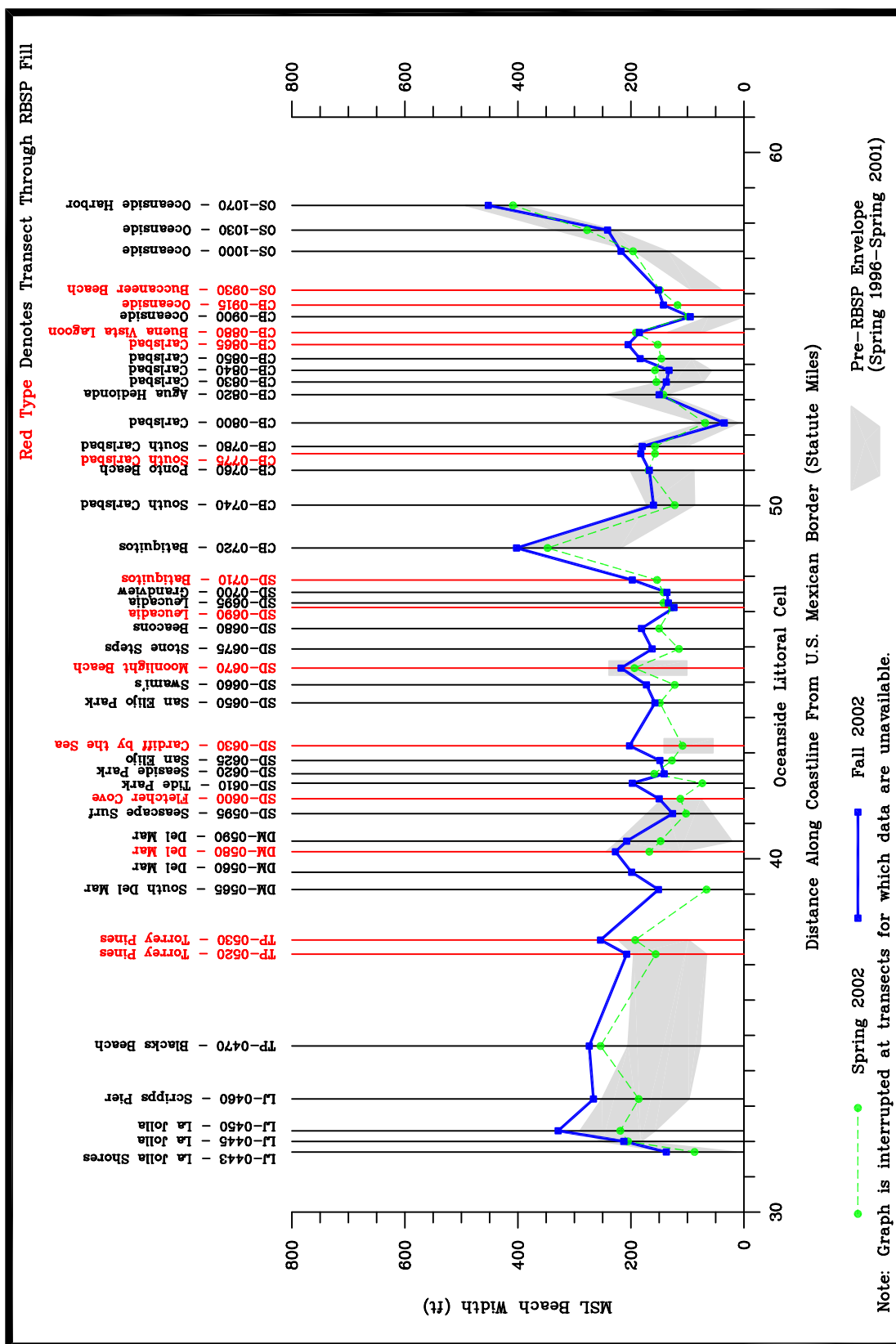


Figure 15b. Comparison of 2002 MSL Beach Widths with Pre-RBSP Envelope in the Oceanside Littoral Cell

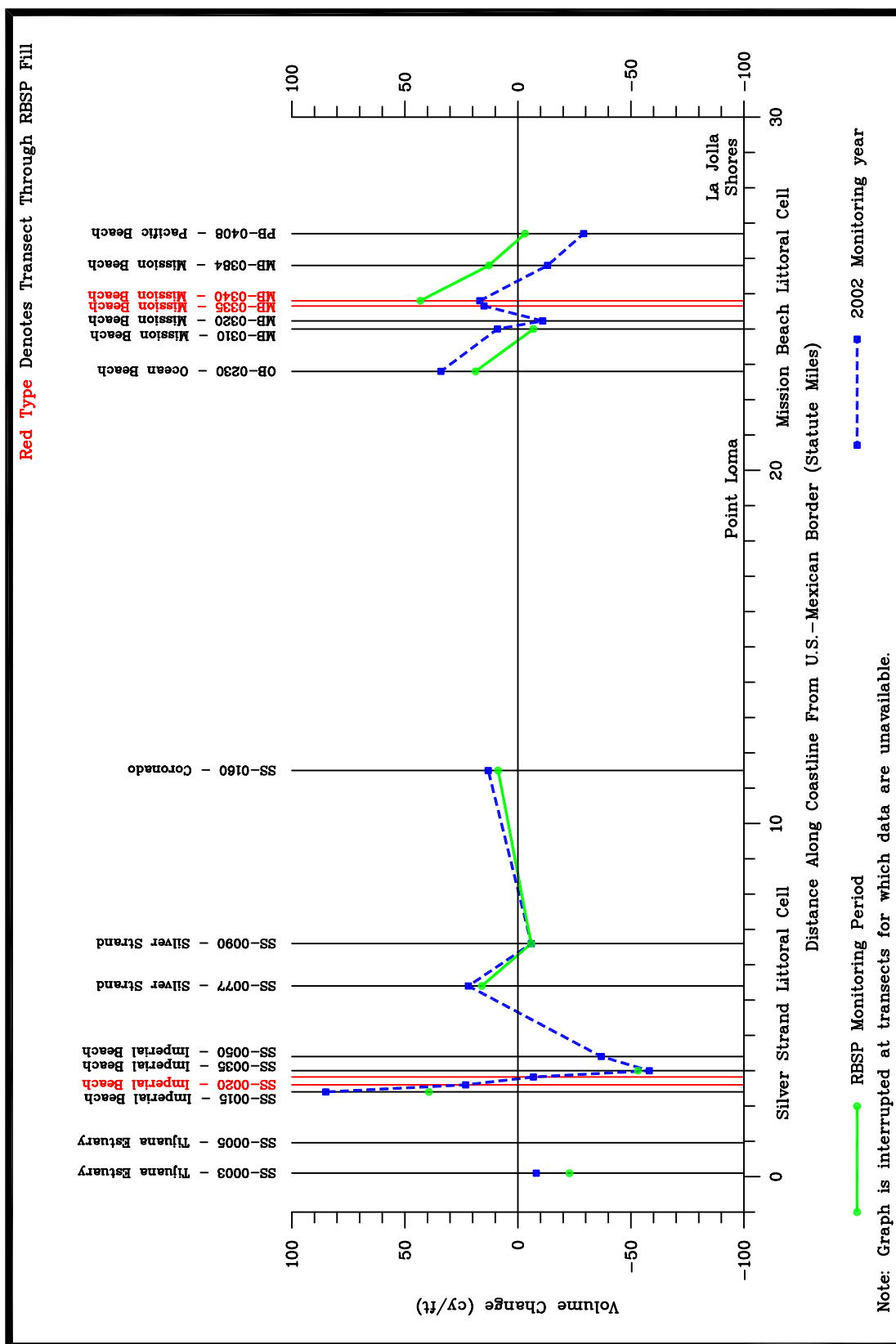


Figure 16a. Shorezone Volume Changes in the Silver Strand and Mission Beach Littoral Cells

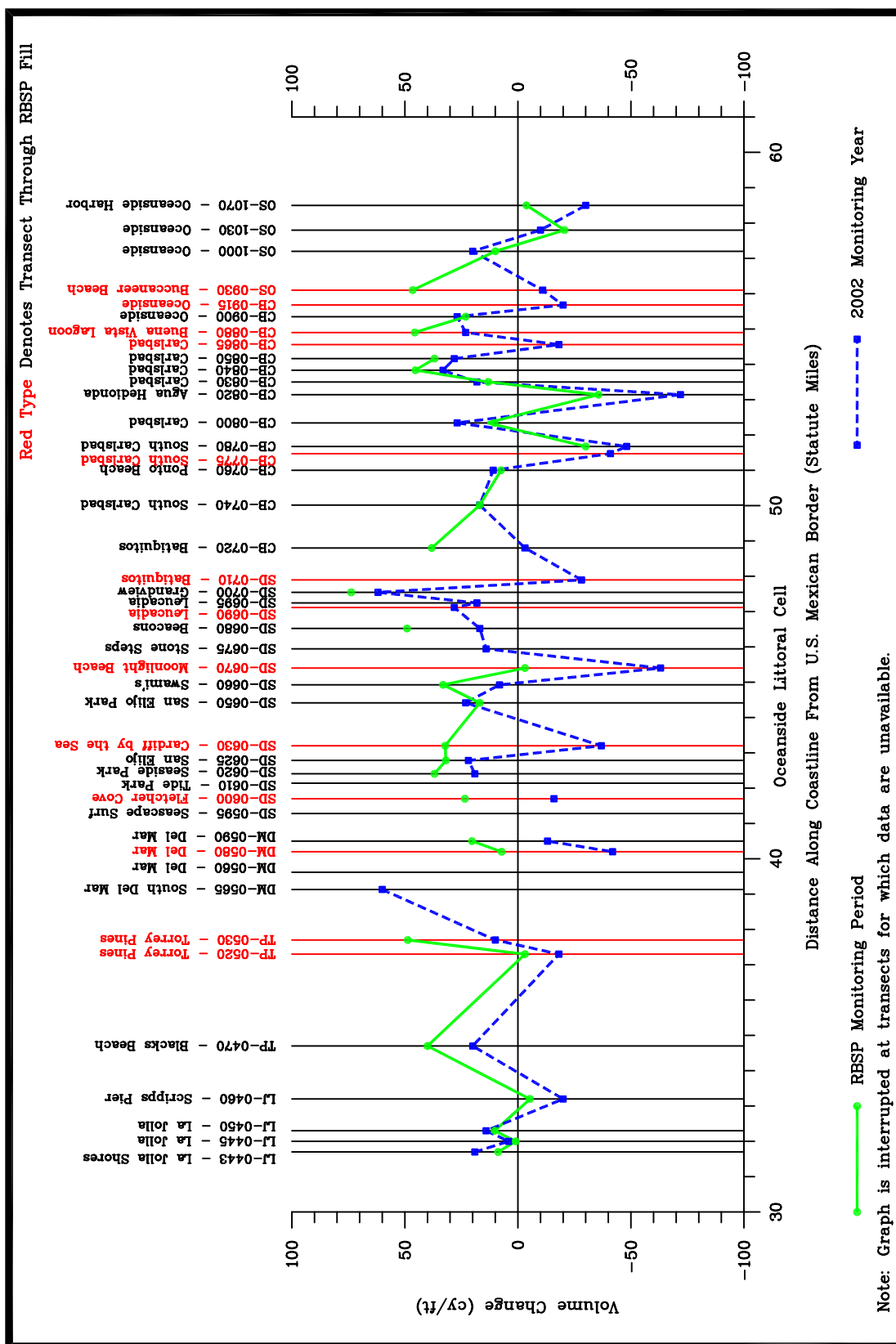


Figure 16b. Shorezone Volume Changes in the Oceanside Littoral Cell

As indicated in Figure 17, the percentage of transects experiencing shorezone volume gains was higher in each of the two years comprising RBSP Monitoring Period than in any of the four prior monitoring years: 53% in 2001 and 50% in 2002 versus prior values ranging from 18 to 46%. Moreover, the percentage of transects experiencing volume gains over the entire RBSP Monitoring Period was even higher, at 59%.

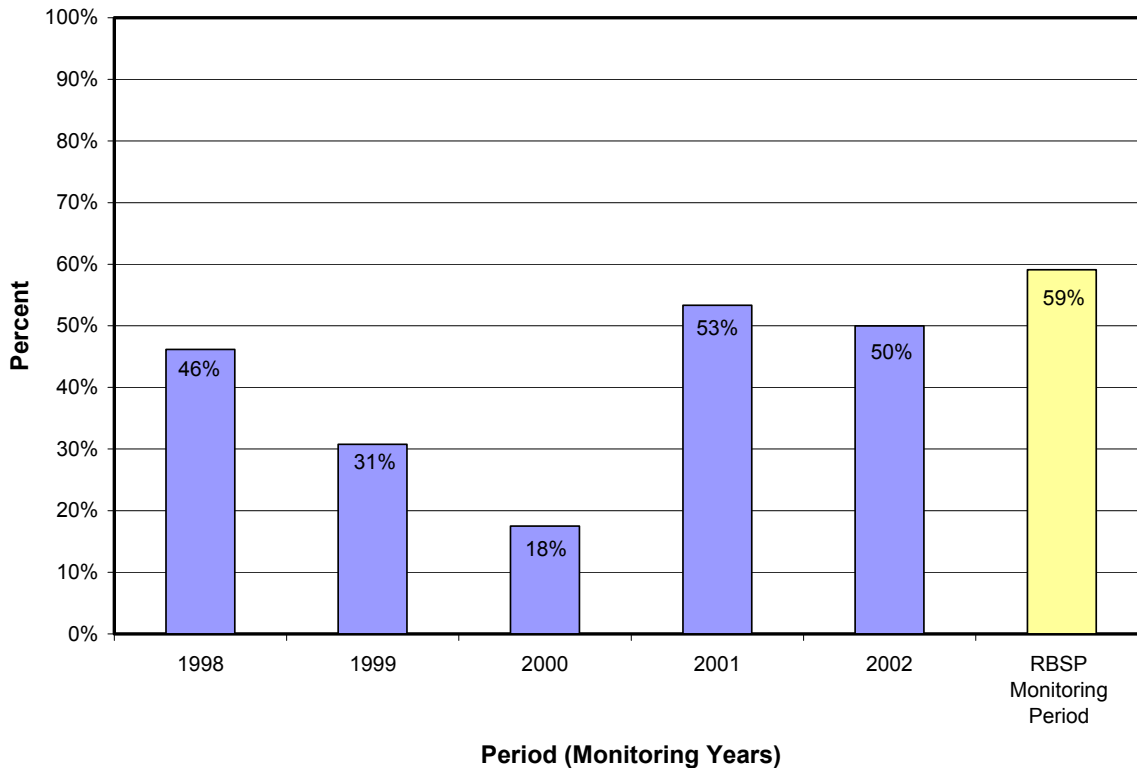


Figure 17. Percentage of Transects Exhibiting Shorezone Volume Gains

In the absence of other nourishment programs and of significant riverine sediment input, the volume gains recorded during the RBSP Monitoring Period may be attributed primarily to the RBSP beach fills. The dispersal of the fill material that occurred during the 2002 Monitoring Year, while reducing the shorezone volumes at the receiver sites, produced significant gains at many of the adjacent beaches (particularly in the Oceanside Cell, as illustrated in Figure 16b).

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 18 through 23.

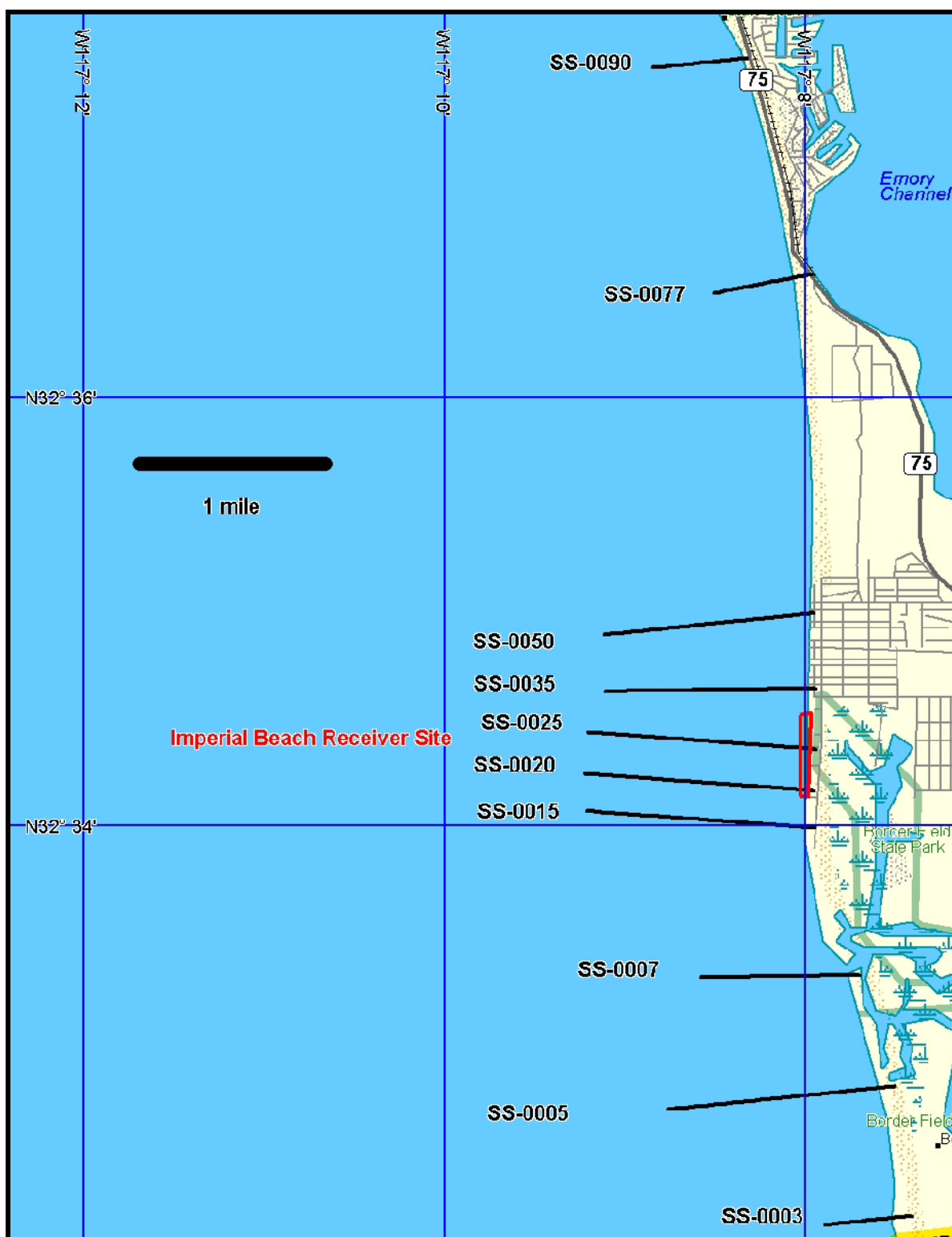


Figure 18. Location Map for Imperial Beach Receiver Site



Figure 19. Location Map for Mission Beach Receiver Site

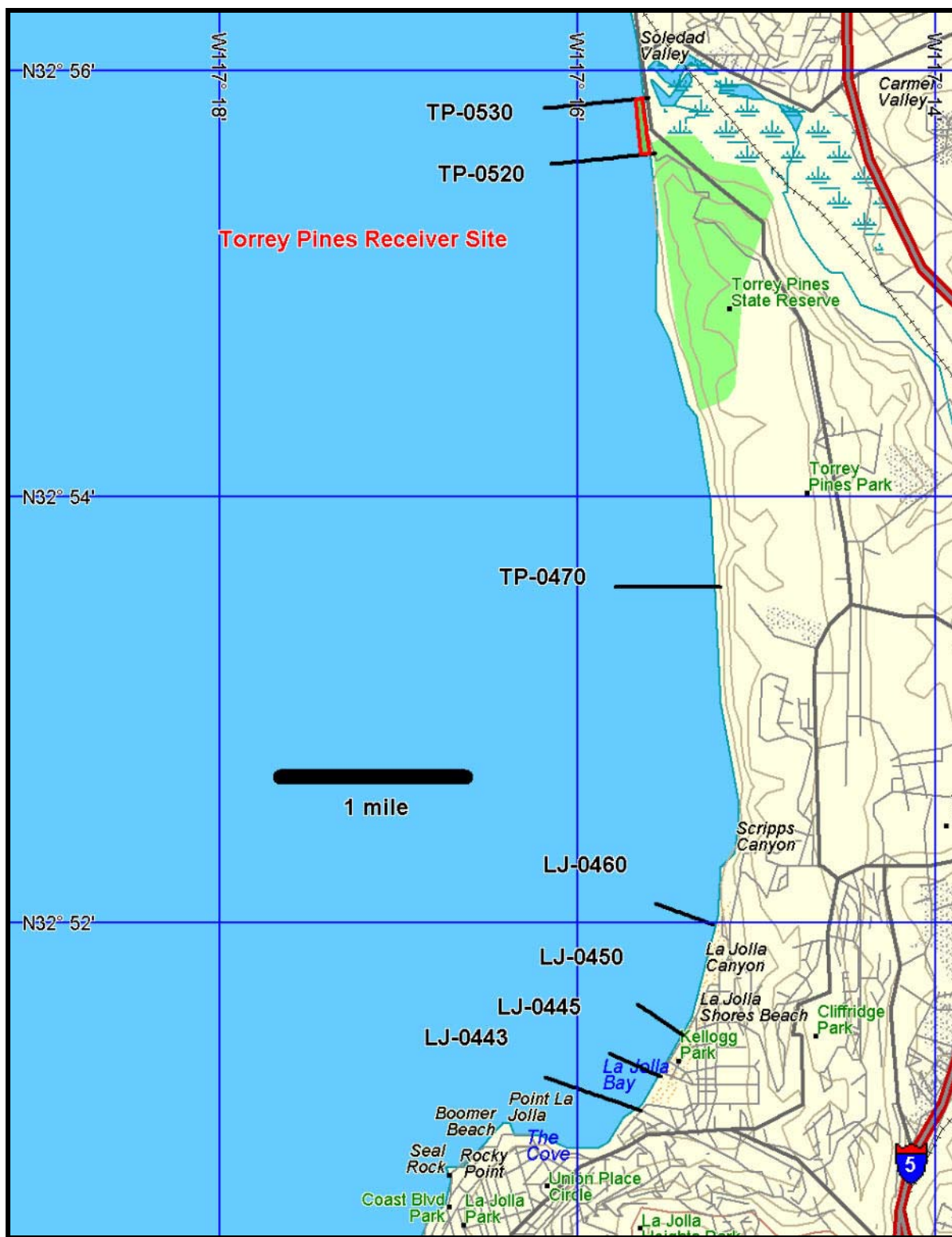


Figure 20. Location Map for Torrey Pines Receiver Site

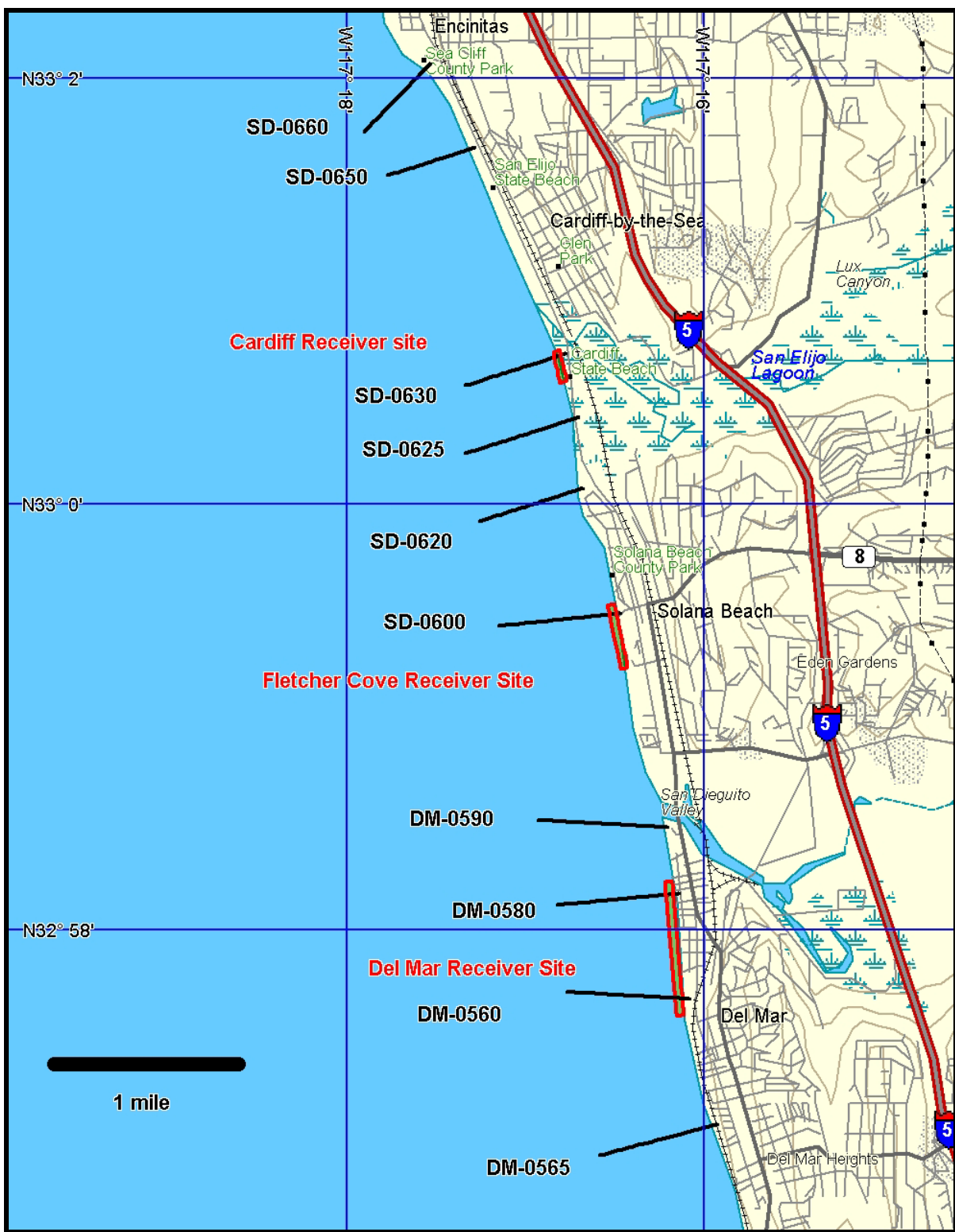


Figure 21. Location Map for Del Mar, Fletcher Cove, and Cardiff Receiver Sites

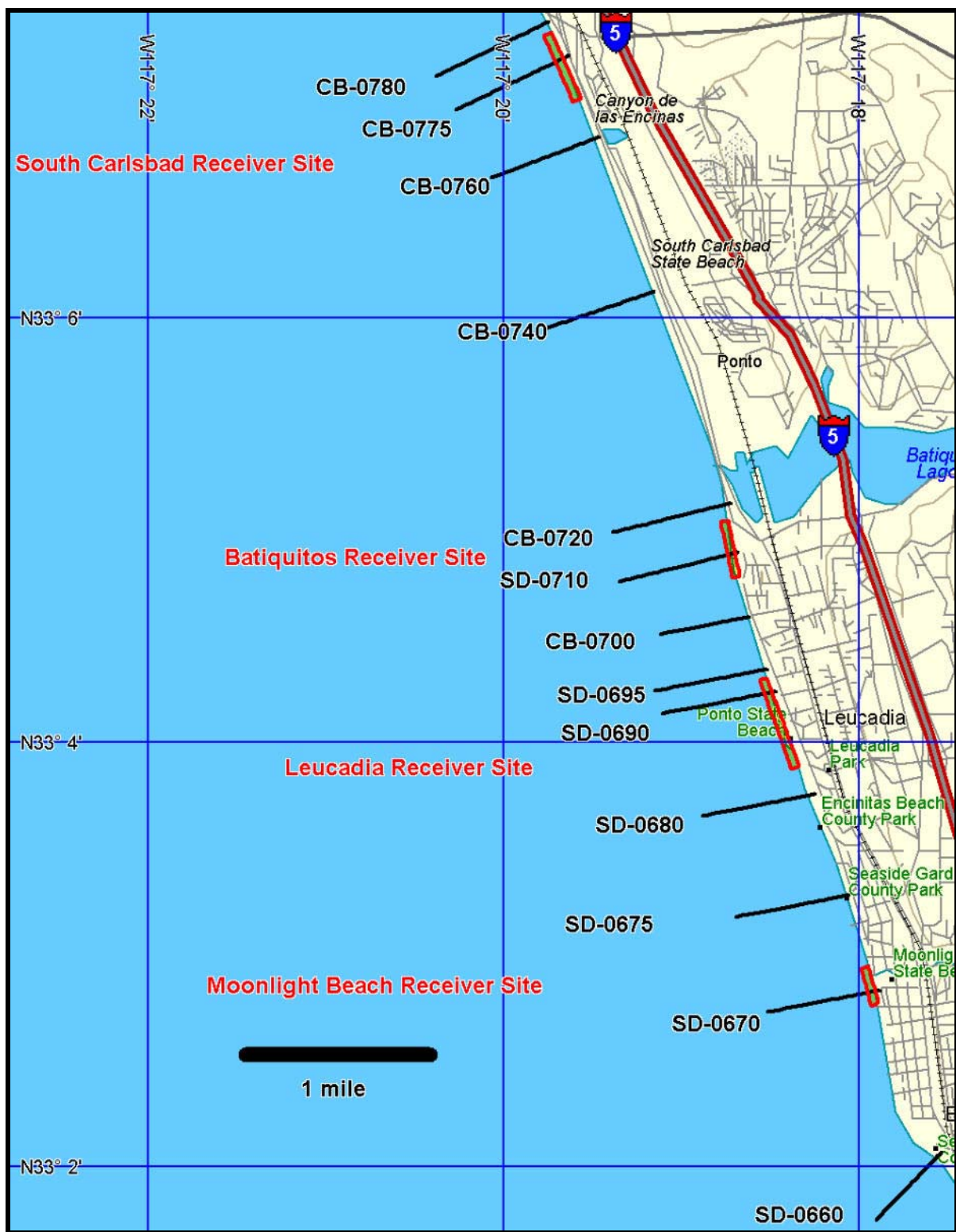


Figure 22. Location Map for Moonlight Beach, Leucadia, Batiquitos, and South Carlsbad Receiver Sites



Figure 23. Location Map for North Carlsbad and Oceanside Receiver Sites

Table 13 provides the MSL shoreline change and shorezone volume change that occurred between Spring 2001 and Fall 2002 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 for each parameter.

Table 13. RBSP Beach Fill Performance

Receiver Beach	Indicator Transect	MSL Shoreline Change, Spring 01–Fall 02 (ft)	Shorezone Volume Change, Spring 01–Fall 02 (cy/ft)
Imperial Beach	SS-0025	140	27
Mission Beach	MB-0340	96	24
Torrey Pines	TP-0520	103	6
Del Mar	DM-0580	115	4
Fletcher Cove	SD-0600	55	16
Cardiff	SD-0630	111	28
Moonlight Beach	SD-0670	85	-33
Leucadia	SD-0690	43	42
Batiquitos	SD-0710	49	-31
S. Carlsbad	CB-0775	63	27
N. Carlsbad	CB-0865	116	36
Oceanside	OS-0930	88	54
<i>Average</i>		<i>89</i>	<i>17</i>
<i>Maximum</i>		<i>140</i>	<i>54</i>
<i>Minimum</i>		<i>43</i>	<i>-33</i>

It should be noted that the MSL shoreline changes in Table 13 reflect not only the effects of the nourishment program, but also a seasonal bias introduced by comparing shoreline positions from Spring (2001) and Fall (2002). 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 was 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.

5.2.1. Imperial Beach (Figure 18)

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.



April 2001 (Pre-RBSP)



November 2001 (5.5 months after nourishment)



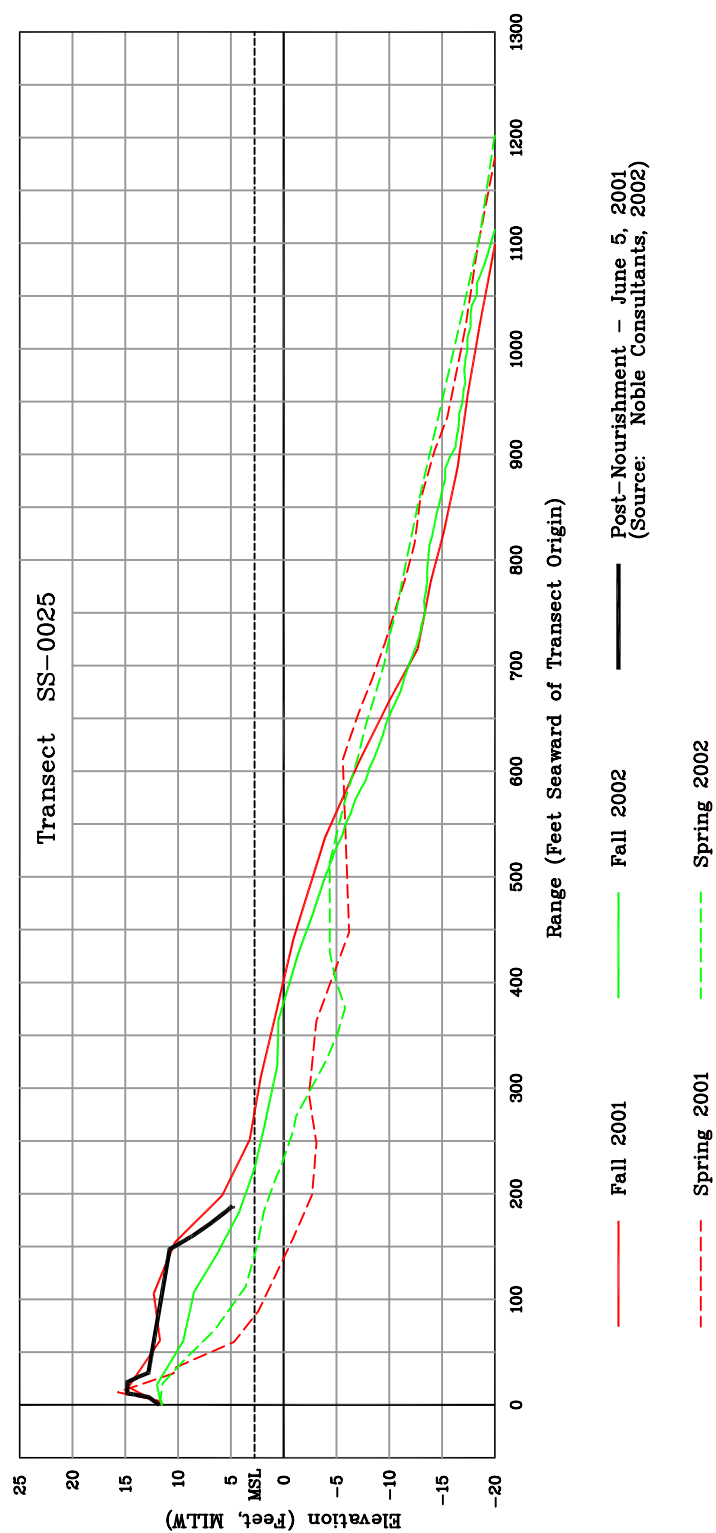
May 2002 (11.5 months after nourishment)



November 2002 (17.5 months after nourishment)

Plate 1. Imperial Beach Receiver Site, April 2001 through November 2002

Figure 24 displays the Spring 2001 (pre-project) and Post-Nourishment profiles on Transect SS-0025, along with subsequent profiles obtained in Fall 2001, Spring 2002, and Fall 2002. The data indicate that considerable accretion occurred above the waterline in Summer 2001, following fill placement. This trend was reversed during the ensuing Winter



Note: 120,000 cy of nourishment ($d_{50} = 0.24-0.52$ mm) was provided from May 22 to June 6, 2001.

Figure 24. Transect SS-0025 at Imperial Beach Receiver Site

(Fall 2001 to Spring 2002), when sediment moved offshore in response to the more energetic wave conditions. It also appears that some of the nourishment material was transported to the south, based on substantial accretion that occurred on the below-water portion of Transect SS-0015 (Appendix D). Although seasonal onshore transport returned sediment to the above-water portion of Transect SS-0020 between Spring 2002 and Fall 2002, accretion was still evident on the below-water portion of SS-0015 at the time of the Fall survey. Hence, in keeping with the pattern identified in Section 5.1, the RBSP nourishment material served to benefit not only the receiver site but also the adjacent beach.

The net result of these profile changes was a shoreline advance of 140 ft and a shorezone volume increase of 27 cy/ft between Spring 2001 and Fall 2002. 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 17 cy/ft.

5.2.2. Mission Beach (Figure 19)

The Mission Beach fill consisted of 151,000 cy of coarse sand placed from May 10 to May 21, 2001. The five profiles obtained on Transect MB-0340 from Spring 2001 through Fall 2002 are plotted in Figure 25 (four semi-annual profiles plus the Post-Nourishment profile). Pre-and post nourishment photographs are shown in Plate 2.

The profile data indicate that although the beach face became flatter following the nourishment program, the above-water profiles in Spring 2002 and Fall 2002 remained above the pre-RBSP envelope. The prominent berm evident in these two profiles resulted not from natural processes, but rather from mechanical grading undertaken to eliminate ponding in the backbeach 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 2002, the MSL shoreline advanced 96 ft and the shorezone volume increased by 24 cy/ft on Transect MB-0340. Both of these values exceeded the respective averages for the RBSP receiver sites. In contrast, changes in beach width and shorezone volume tended to be modest on the transects flanking the Mission Beach receiver site during the 2002 Monitoring Year. This finding suggests that alongshore dispersal of the fill material had been minimal.

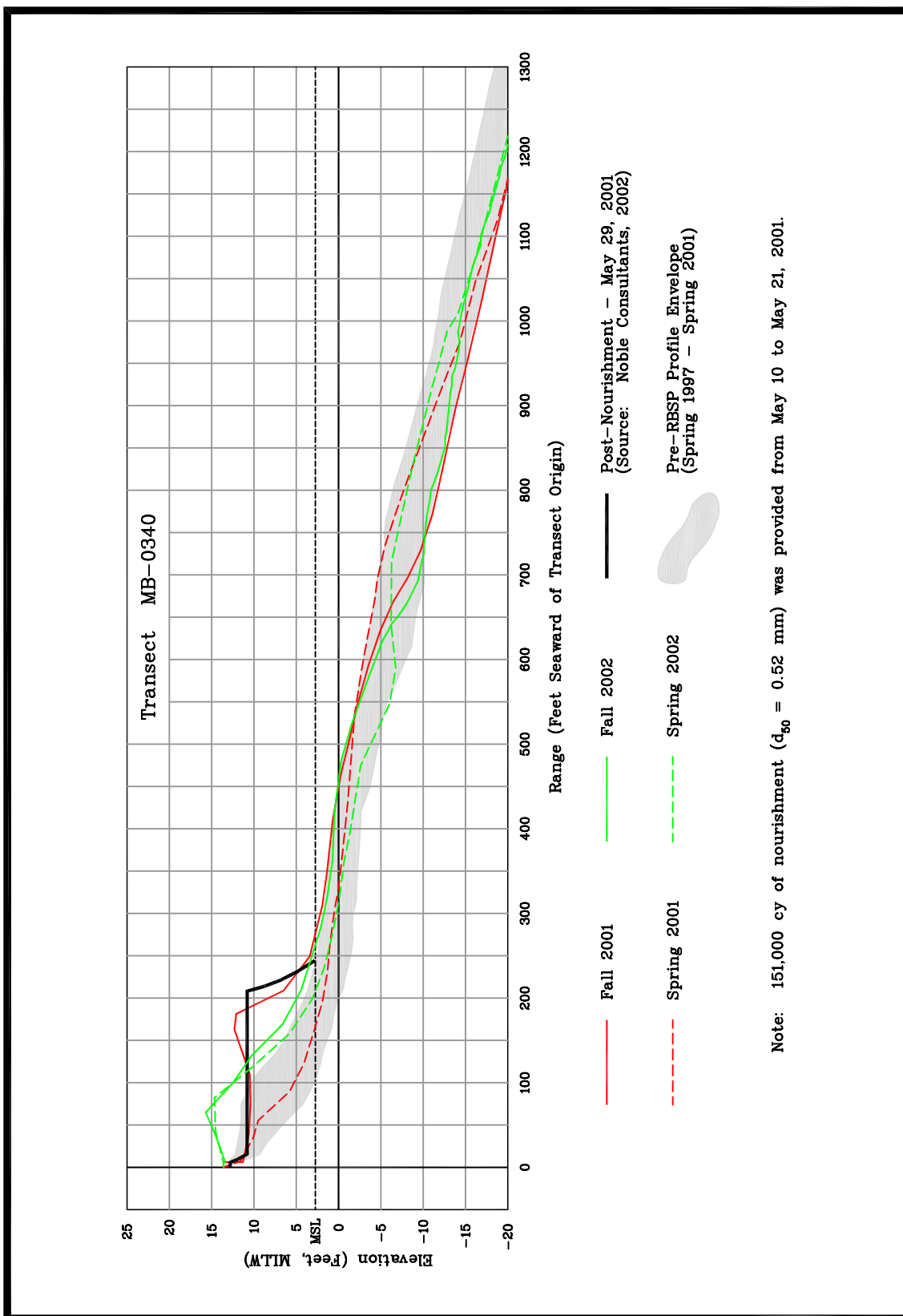


Figure 25. Transect MB-0340 at Mission Beach Receiver Site



April 2001 (Pre-RBSP)



November 2001 (6 months after nourishment)



May 2002 (12 months after nourishment)



November 2002 (18 months after nourishment)

Plate 2. Mission Beach Receiver Site, April 2001 through November 2002

5.2.3. Torrey Pines (Figure 20)

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 26, while pre- and post-nourishment photographs are provided in Plate 3.

Noteworthy aspects of the profile data on Transect TP-0520 include initial flattening of the beach fill during the Summer of 2001, significant erosion of the above-water beach accompanied by accretion below -5 ft during the following Winter, and partial recovery of the above-water beach during the Summer of 2002. When integrated over the 18-month period between Spring 2001 and Fall 2002, these changes produced a sizeable shoreline advance of 103 ft with a near-negligible shorezone volume gain of 6 cy/ft. The situation is illustrated graphically in Figure 26, which shows the Fall 2002 profile at the upper edge

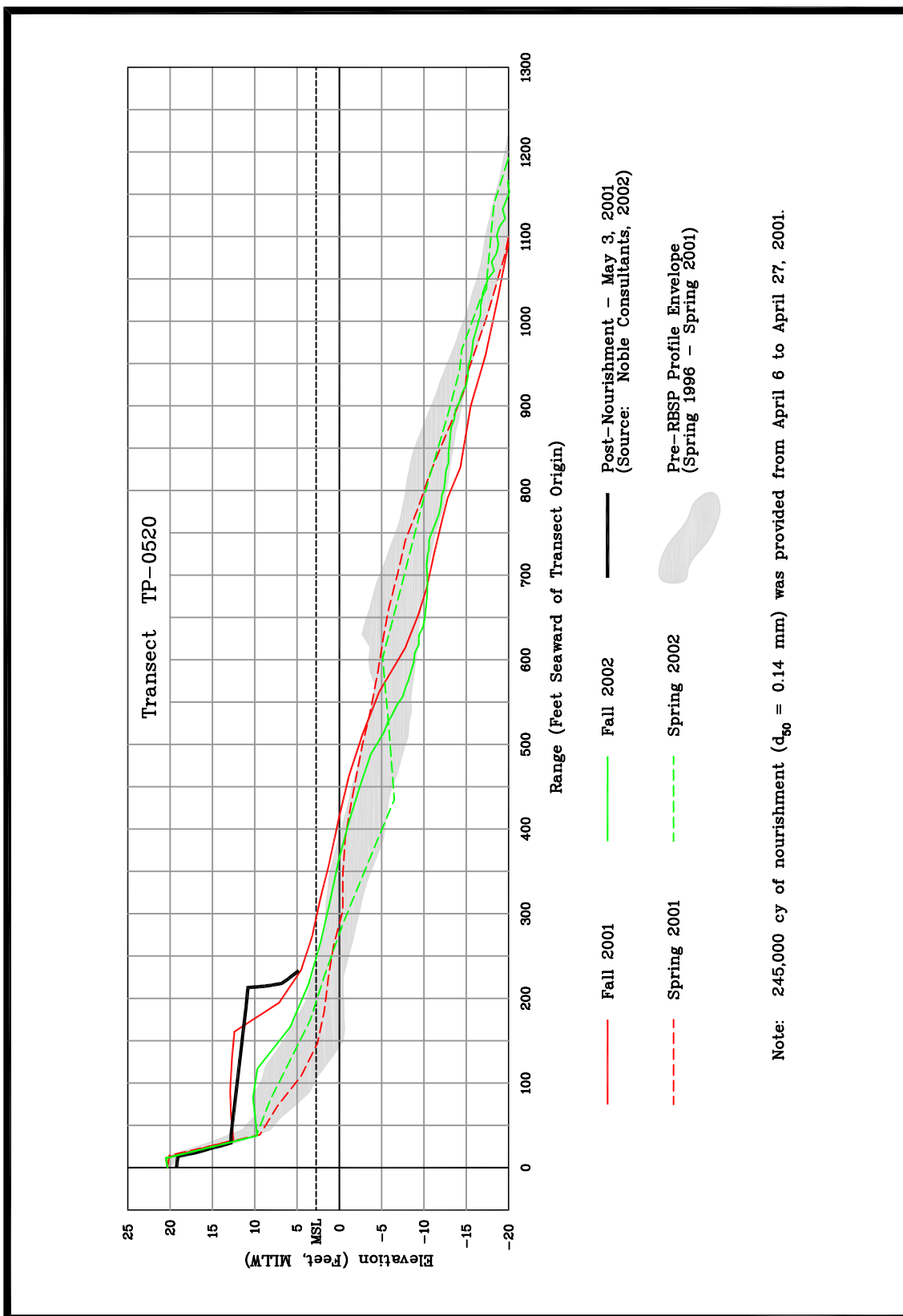


Figure 26. Transect TP-0520 at Torrey Pines Receiver Site



April 2001 (Pre-RBSP)



November 2001 (6.5 months after nourishment)



May 2002 (12.5 months after nourishment)



November 2002 (18.5 months after nourishment)

Plate 3. Torrey Pines Receiver Site, April 2001 through November 2002

of the pre-RBSP envelope on the above-water beach, but at the lower edge of the envelope seaward of -8 ft.

The initial sequence of events was somewhat different at Transect TP-0530 (Appendix D), which crosses the north end of the Torrey Pines fill. Here, the subaerial beach accreted after placement of the nourishment, suggesting northerly transport of the fill during the Summer 2001 wave season. As in the case of Transect TP-0520, material moved offshore during the Winter of 2001-2002 and partially returned to the above-water beach in Summer 2002. Because the beach gained rather than lost sediment immediately after fill placement, the net outcome was more positive than at TP-0520: a shoreline advance of 155 ft and a shorezone volume gain of 50 cy/ft between Spring 2001 and Fall 2002.

Additional information regarding the performance of the Torrey Pines fill can be obtained from the Southern California Beach Processes Study. The study findings, which

include detailed wave data and bi-weekly surveys, 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 21)

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 27, the fill material on the above-water beach was largely depleted during the Winter of 2001-2002. Much of the sand returned in Summer 2002, resulting in a net shoreline advance of 115 ft between Spring 2001 and Fall 2002.

As in the case of Transect TP-0520, a significant portion of the below-water profile approached the lower limit of the pre-RBSP envelope in Fall 2002. This paucity of sediment on the below-water slope offset the gain on the above-water slope, producing a shorezone volume increase of only 4 cy/ft.

Approximately 3,400 ft south of the receiver site, at Transect DM-0565, significant gains in beach width and shorezone volume occurred between Fall 2001 and Fall 2002: 70 ft and 60 cy/ft, respectively (Appendix E). The probable explanation is downcoast transport of the Del Mar fill material during the 18-month period following placement.

5.2.5. Fletcher Cove (Figure 21)

The Fletcher Cove fill, placed from June 15 to 24, 2001, consisted of 146,000 cy of fine sand. Figure 28 displays the Spring 2001 and Post-Nourishment profiles on Transect SD-0600, along with the profiles acquired from Fall 2001 through Fall 2002. Pre- and post nourishment photographs are provided in Plate 5.

The profile data indicate that about half of the nourishment material was lost from the above-water beach during the Summer of 2001. Subaerial erosion continued during the Winter months, resulting in substantial depletion of the fill by the time of the Spring 2002 Survey. Partial recovery occurred in Summer 2002, causing the Fall 2002 profile to lie above the pre-RBSP envelope in the waterline area between +4 ft and -4 ft. The net result was a shoreline advance of 55 ft and a shorezone volume increase of 17 cy/ft between Spring 2001 and Fall 2002. The shorezone volume gain is of particular interest because it suggests a residual benefit from the nourishment program despite the relatively rapid dispersal of the fill from the above-water placement site.

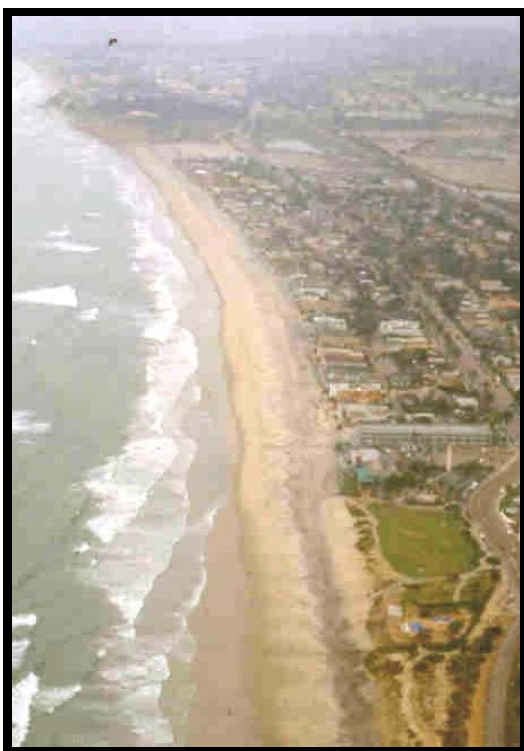
Unfortunately, the extent to which the Fletcher Cove fill has nourished the adjacent beaches cannot be quantified. This situation arises from the fact that Transects SD-0595



April 2001 (Pre-RBSP)



November 2001 (6 months after nourishment)



May 2002 (12 months after nourishment)



November 2002 (18 months after nourishment)

Plate 4. Del Mar Receiver Site, April 2001 through November 2002

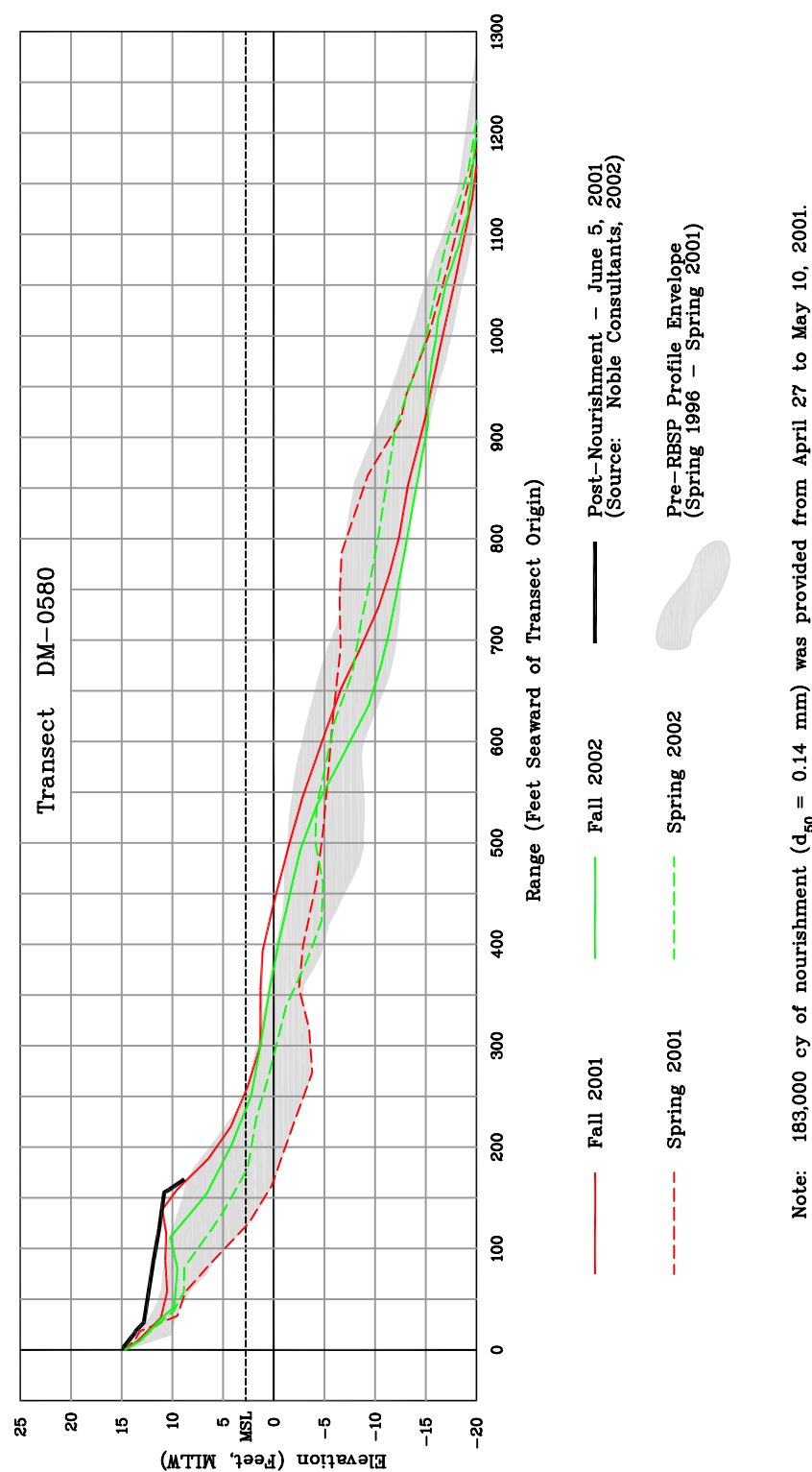


Figure 27. Transect DM-0580 at Del Mar Receiver Site

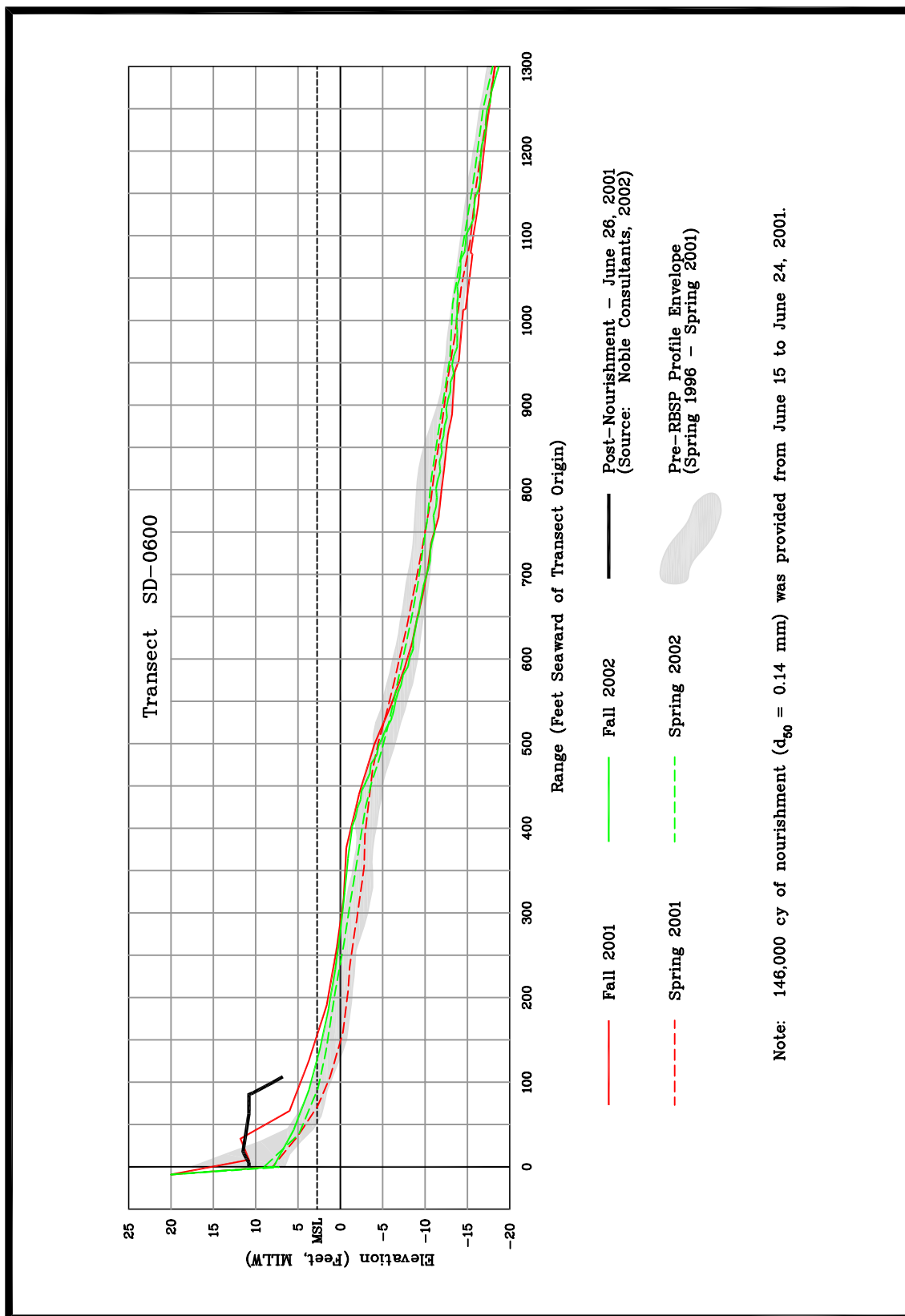


Figure 28. Transect SD-0600 at Fletcher Cove Receiver Site



April 2001 (Pre-RBSP)



November 2001 (4.5 months after nourishment)



May 2002 (9 months after nourishment)



November 2002 (15 months after nourishment)

Plate 5. Fletcher Cove Receiver Site, April 2001 through November 2002

and SD-0610, which flank the receiver site, were established and surveyed for the first time in Spring 2002.

5.2.6. Cardiff (Figure 21)

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 29, while pre- and post-nourishment photographs are provided in Plate 6.

Figure 29 indicates that modest reshaping of the Cardiff fill material occurred between the Post-Nourishment and Fall 2001 surveys, with sediment eroding from the oversteepened beach face and accumulating between the waterline and -10 ft. In a manner analogous to the Fletcher Cove receiver site, the remaining nourishment material was largely

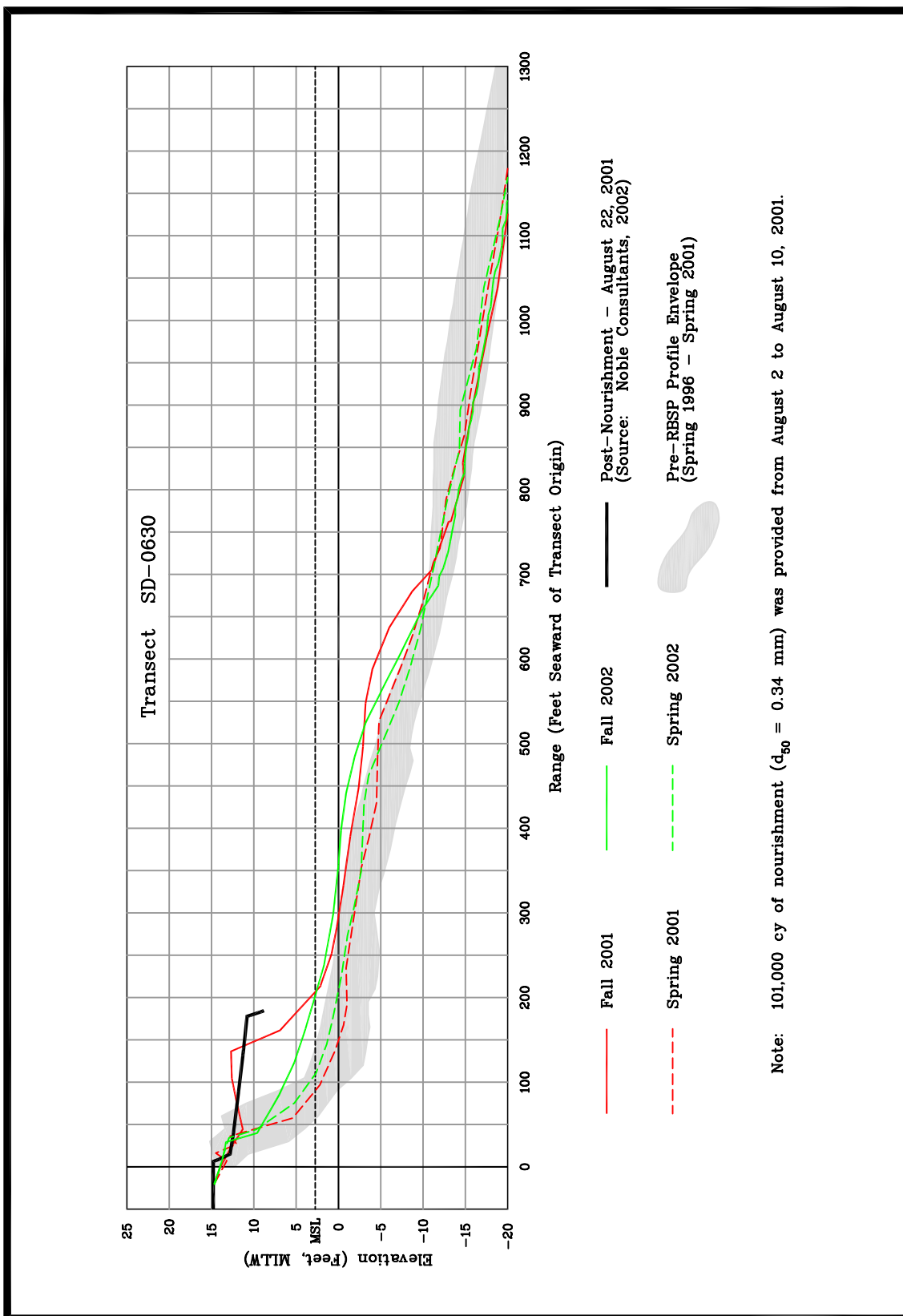


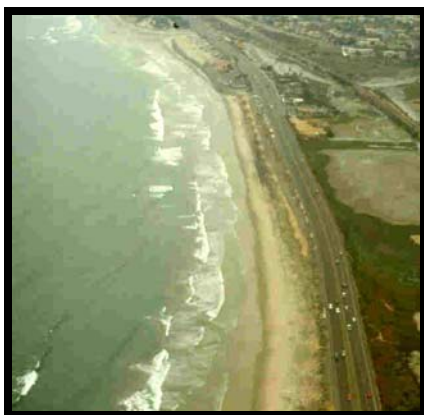
Figure 29. Transect SD-0630 at Cardiff Receiver Site



April 2001 (Pre-RBSP)



November 2001 (3 months after nourishment)



May 2002 (9 months after nourishment)



November 2002 (15 months after nourishment)

Plate 6. Cardiff Receiver Site, April 2001 through November 2002

removed from the above-water beach during the winter of 2001-2002, and partially restored during the following summer. At the time of the Fall 2002 Survey, the profile exceeded the pre-RBSP envelope from -8 ft to +7 ft. This accumulation resulted in a shoreline advance of 111 ft and a shorezone volume increase of 28 cy/ft relative to the pre-nourishment condition that prevailed in Spring 2001. The fact that both of these values exceed the respective RBSP averages is particularly impressive when the small size of the fill is taken into consideration.

Southerly dispersal of the Cardiff fill material is suggested by the survey data obtained on Transects SD-0625 and SD-0620 (Appendix D). In both cases, the profiles obtained in Spring 2002 and Fall 2002 reflect accretion in the waterline area relative to the corresponding profiles obtained a year earlier.

5.2.7. Moonlight Beach (Figure 22)

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 30.



April 2001 (Pre-RBSP)



November 2001 (3 months after nourishment)



May 2002 (9 months after nourishment)



November 2002 (15 months after nourishment)

Plate 7. Moonlight Beach Receiver Site, April 2001 through November 2002

As occurred at most of the other RBSP sites, the Moonlight Beach fill experienced progressive flattening and erosion during the interval between the Post-Nourishment and Spring 2002 surveys. A substantial portion of the fill material remained on the above-water beach at the time of the Spring survey, however, and additional sediment moved onshore during the 2002 Summer season. In consequence, the sand elevations exceeded the pre-RBSP envelope from +6 ft to +15 ft at the time of the Fall 2002 survey, and the shoreline registered an advance of 85 ft relative to the Spring 2001 profile.

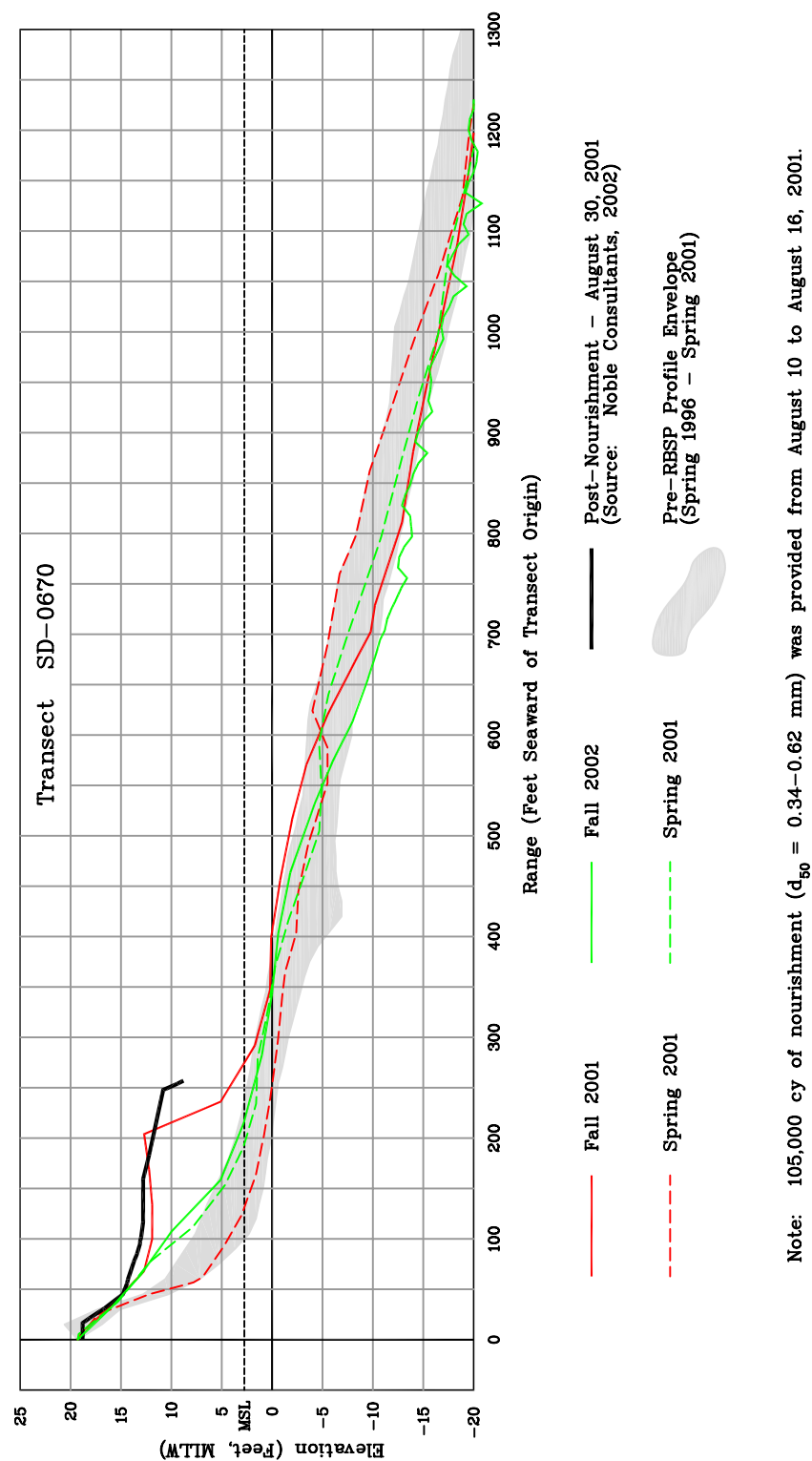


Figure 30. Transect SD-0670 at Moonlight Beach Receiver Site

Notwithstanding the shoreline and volume gains that occurred on the above-water portion of the beach, the shorezone experienced a net volume loss of 33 cy/ft between Spring 2001 and Fall 2002. As is evident in Figure 30, the loss reflects significant erosion between -5 ft and -20 ft. The sand elevations decreased by as much as 7 ft in this region, causing the Spring 2002 profile to fall below the pre-RBSP envelope in some areas.

As no survey transects exist immediately to the south of the Moonlight Beach receiver site, the extent to which the nourishment material benefited the downdrift beaches can only be speculated upon.

5.2.8. *Leucadia (Figure 22)*

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 31.

The profile data indicate that despite progressive erosion, a portion of the Leucadia fill remained on the above-water slope at the time of the Spring 2002 survey. In contrast to many of the other receiver beaches, onshore transport was negligible at Leucadia during the 2002 Summer season. As a result, the shoreline advanced only 43 ft between Spring 2001 and Fall 2002 – the smallest gain among the twelve receiver beaches. Although the shorezone volume increased by a substantial 42 cy/ft, the gain appears to have resulted more from the enhanced mapping of offshore reefs accomplished during the Fall 2002 survey (Section 4.1.1) than from actual sediment accretion (Figure 31).

As indicated in the 2001 Annual Report (Coastal Frontiers, 2002), the profile data from the adjacent transects (SD-0695 and SD-0680; Appendix D) suggest that the Leucadia fill material was dispersed laterally during the four-month period between the Post-Nourishment and Fall 2001 surveys. In the case of the downdrift transect, SD-0680, the subaerial volume continued to increase between Fall 2001 and Fall 2002 (Appendix F).

5.2.9. *Batiquitos (Figure 22)*

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 32.

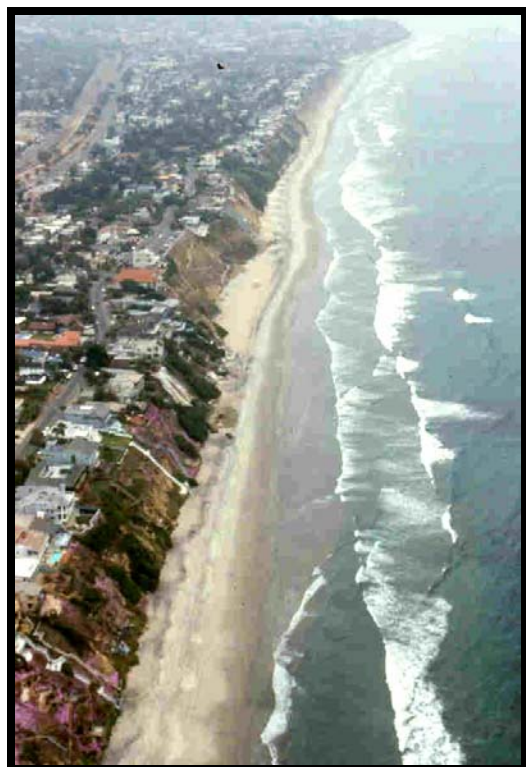
The profile data for the Batiquitos fill indicate a sequence of events similar to that which occurred at Moonlight Beach: progressive flattening and erosion of the nourishment material between the Post-Nourishment and Spring 2002 surveys, followed by modest



April 2001 (Pre-RBSP)



November 2001 (5 months after nourishment)



May 2002 (11 months after nourishment)



November 2002 (17 months after nourishment)

Plate 8. Leucadia Receiver Site, April 2001 through November 2002

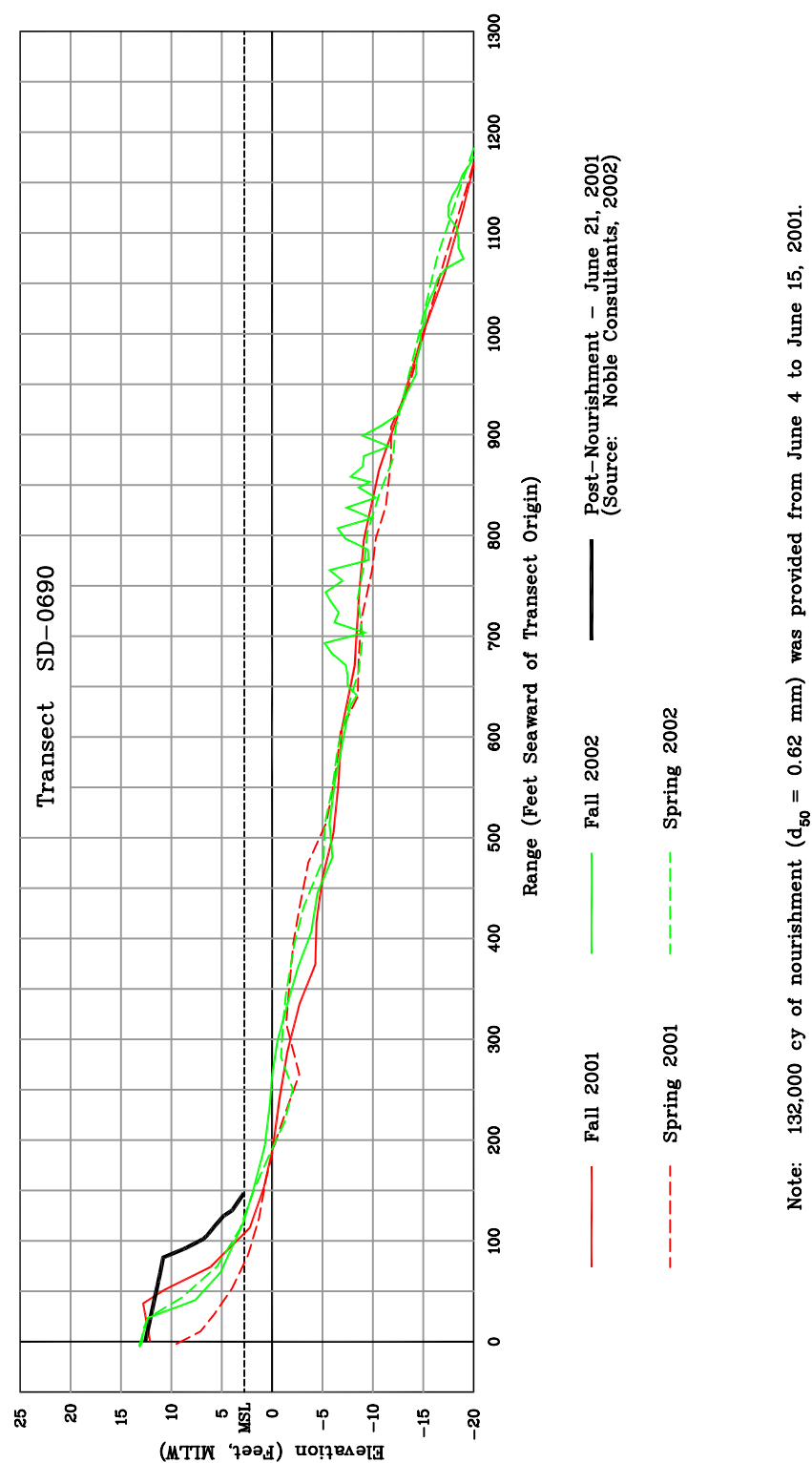


Figure 31. Transect SD-0690 at Leucadia Receiver Site



April 2001 (Pre-RBSP)



November 2001 (2.5 months after nourishment)

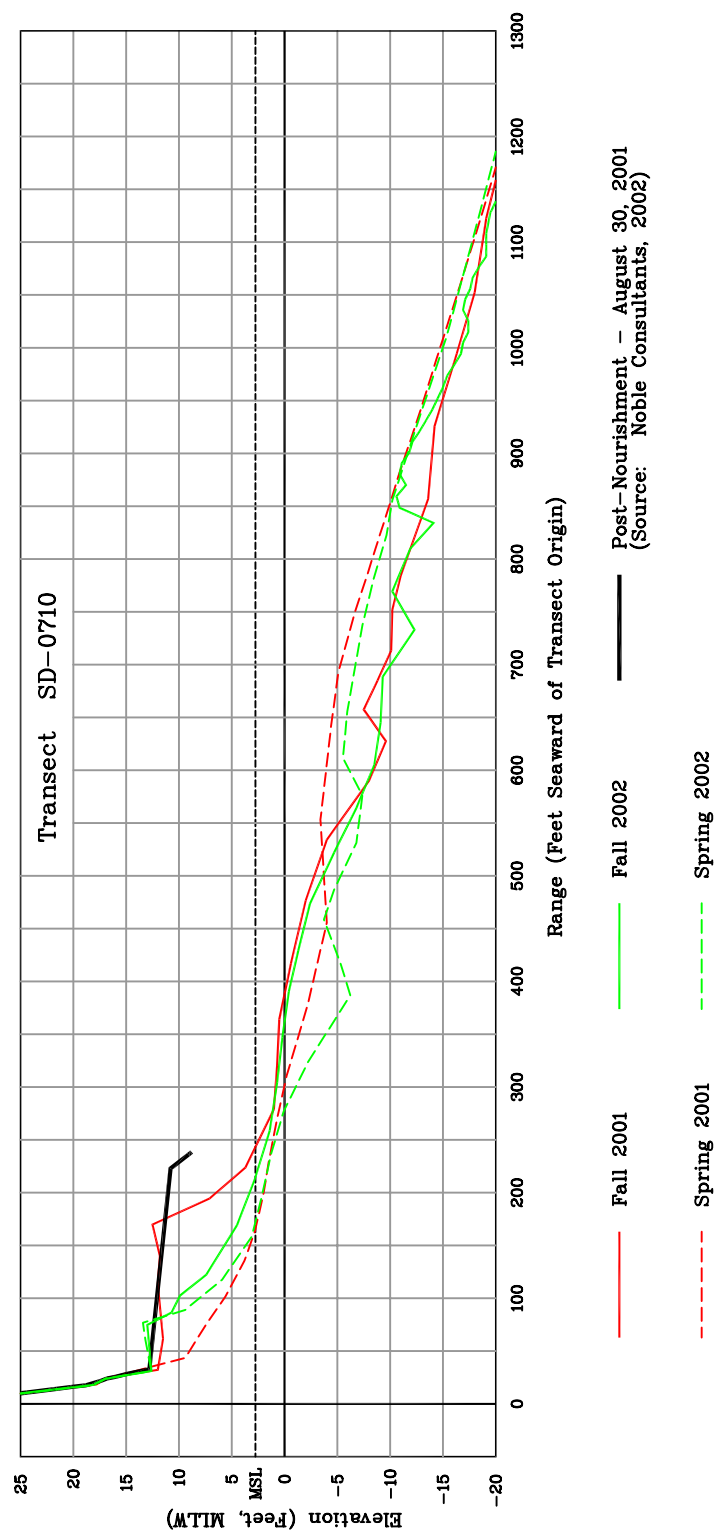


May 2002 (8.5 months after nourishment)



November 2002 (14.5 months after nourishment)

Plate 9. Batiquitos Receiver Site, April 2001 through November 2002



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

Figure 32. Transect SD-0710 at Batiquitos Receiver Site

recovery of the subaerial beach during the 2002 Summer season. The outcome also was similar, in that a shoreline advance of 49 ft between Spring 2001 and Fall 2002 was accompanied by a shorezone volume decrease of 31 cy/ft. The volume loss stemmed from pronounced erosion in water depths of -4 ft to -20 ft. It is noteworthy that among the twelve RBSP receiver sites, shorezone volume losses were recorded only at Moonlight Beach and Batiquitos.

The loss of nourishment material from the Batiquitos site appears to have resulted in gains at the adjacent beaches to the north and south. At Transect CB-0720, located approximately 500 ft to the north, the Fall 2001 profile registered accretion on the subaerial portion of the beach relative to a Post-Nourishment profile obtained several months earlier (Appendix D). This finding suggests that a portion of the nourishment material was transported to the north by the late-summer wave conditions. The benefit persisted through Fall 2002, as evidenced by essentially the same subaerial volume at that time as in Fall 2001 (Appendix F).

At Transect SD-0700, located 1,100 ft to the south of the Batiquitos receiver site, the Spring 2002 profile reflected a substantial increase in sediment volume from the back beach to MLLW relative to profiles obtained previously in Spring and Fall 2001. The probable cause of this accretion is the southerly migration of Batiquitos nourishment material under the influence of winter waves from the northwest. As in the case of Transect CB-0720, the subaerial accretion at SD-0700 was still evident at the time of the Fall 2002 survey.

5.2.10. South Carlsbad (Figure 22)

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 2002 on Transect CB-0775 are shown in Figure 33.

Like many of the other RBSP nourishment sites, the South Carlsbad fill experienced progressive erosion through Spring 2002. Although the subaerial volume remained essentially unchanged during Summer 2002, the profile data indicate that sediment accumulated from waterline to -10 ft. The net result was a shoreline advance of 63 ft and a shorezone volume gain of 27 cy/ft between Spring 2001 and Fall 2002.

The dispersal of the South Carlsbad nourishment material was accompanied by shoreline and volume gains at the adjacent beaches. Immediately north of the fill, at Transect CB-0780 (Appendix D), accretion of the subaerial beach was evident in the Fall 2001 profile (implying northerly transport during the 2001 Summer season). Some of



April 2001 (Pre-RBSP)



November 2001 (4.5 months after nourishment)



May 2002 (10.5 months after nourishment)



November 2002 (16.5 months after nourishment)

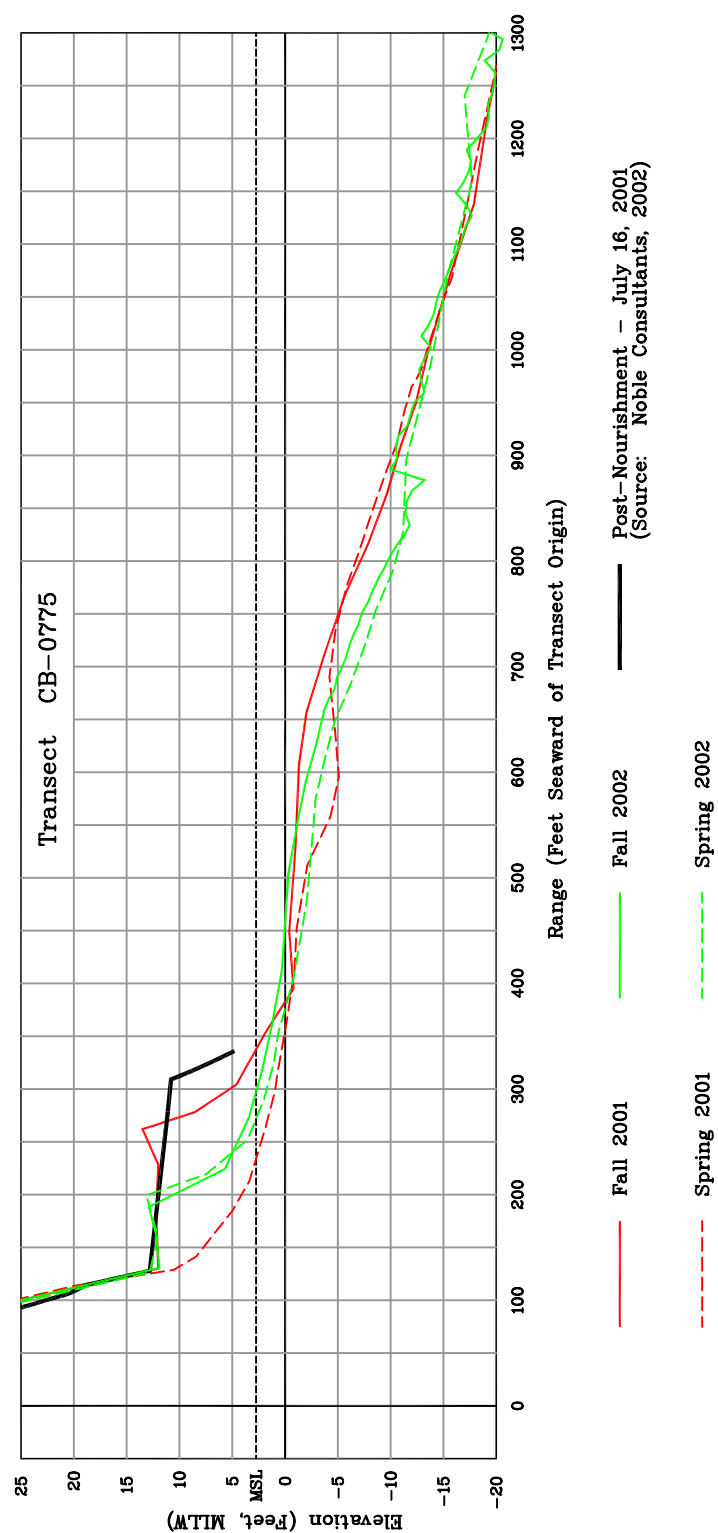
Plate 10. South Carlsbad Receiver Site, April 2001 through November 2002

this accretion was still evident at the time of the Fall 2002 survey. Eleven hundred feet south of the South Carlsbad fill, at Transect CB-0760 (Appendix D) the profiles document a progressive increase in the subaerial volume that began after placement of the nourishment material (July 2001) and continued through Fall 2002.

5.2.11. North Carlsbad (Figure 23)

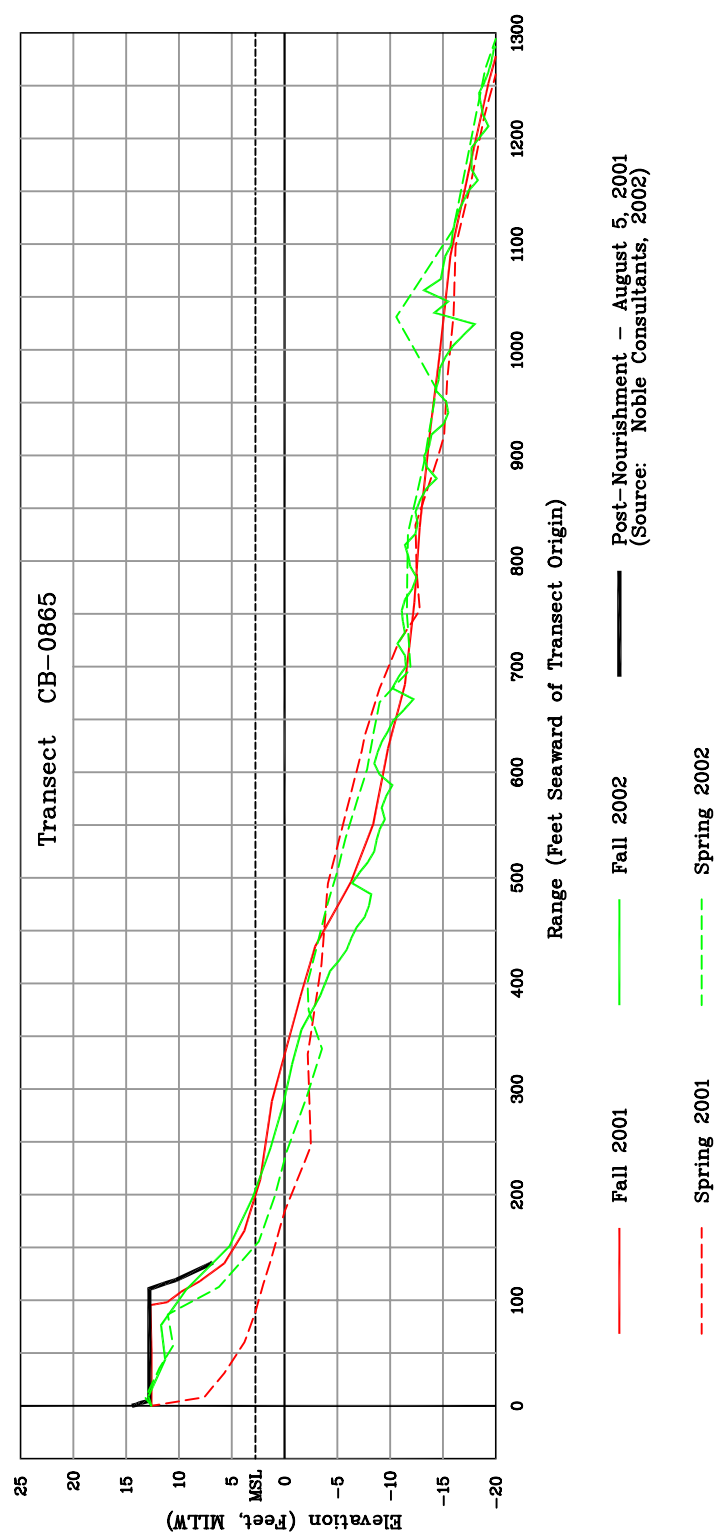
The 225,000 cy North Carlsbad fill was the third largest constructed under the RBSP. Placed from July 6 to August 2, 2001, it consisted of a mixture of coarse (21%), medium (2%) and fine (77%) sand. Beach profiles obtained on Transect CB-0865 are shown in Figure 34, while pre- and post-nourishment photographs are provided in Plate 11.

Unlike many of the other RBSP fills, the North Carlsbad fill sustained only minor erosion during the 15-month period between placement (August 2001) and the Fall 2002 Survey. In consequence, the Post-Nourishment and Fall 2002 profiles on Transect CB-0865 are quite similar. The resulting shoreline advance of 116 ft and shorezone volume increase



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

Figure 33. 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 34. Transect CB-0865 at North Carlsbad Receiver Site



April 2001 (Pre-RBSP)



November 2001 (3.5 months after nourishment)



May 2002 (9.5 months after nourishment)



November 2002 (15.5 months after nourishment)

Plate 11. North Carlsbad Receiver Site, April 2001 through November 2002

of 36 cy/ft that occurred between Spring 2001 and Fall 2002 exceed the corresponding RBSP average values by large margins.

At Transect CB-0880, located at the updrift (north) end of the North Carlsbad receiver site, about half of the fill material was eroded from the above-water beach between the time of placement and the Fall 2001 Survey (Appendix D). This erosion, which contrasts with the minimal loss at Transect CB-0865, probably resulted from accelerated sediment dispersal at the edge of the fill. Substantial accretion occurred on the above-water beach during the following Winter, however, along with an even larger increase in subaerial volume at Transect CB-0900 (located 2,000 ft to the north). The gains, which run counter to the typical seasonal pattern of subaerial losses during the winter months, suggest the arrival of nourishment material from the Oceanside receiver site (located 1,400 ft north of Transect CB-0900 and 3,400 ft north of CB-0880). In other words, it appears that southerly transport during the Winter of 2001-2002 caused the Oceanside fill to coalesce with the

North Carlsbad fill. This hypothesis also helps to explain the aforementioned paucity of fill erosion at Transect CB-0865.

Downdrift (south) of the North Carlsbad receiver beach, evidence of fill dispersal is provided by the survey data from Transects CB-0850, CB-0840, and CB-0830 (all of which lie within 5,000 ft of the nourishment site). At each of these locations, the subaerial volume increased during the Winter of 2001-2002, and the Spring 2002 profile exceeded the pre-RBSP envelope in the vicinity of the waterline. During the Summer of 2002, the subaerial beach continued to expand at Transect CB-0850 (which lies closest to the North Carlsbad fill site).

5.2.12. Oceanside (Figure 23)

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 35.

The profile data indicate that the nourished beach face became progressively flatter between Fall 2001 and Fall 2002. Some of this material appears to have moved offshore, as evidenced by volume gains from the waterline to -20 ft. The result was extremely favorable: a shoreline advance of 88 ft and a shorezone volume increase of 54 cy/ft between Spring 2001 and Fall 2002. While the increase in beach width was about average for the RBSP fills, the shorezone volume gain was the maximum recorded.

As described in the preceding section, the profile data at Transects OC-0900 and CB-0885 suggest that a portion of the Oceanside fill nourished the downdrift beaches and coalesced with the North Carlsbad fill. It is noteworthy that the substantial gains in subaerial volume that appeared on these two transects in Spring 2002 remained largely intact at the time of the Fall 2002 Survey.

Possible reasons for the exemplary performance of the Oceanside fill include the large volume of nourishment and the coarse grain size. In addition, while the sand bypassing rate at Oceanside Harbor during the RBSP Monitoring Period has approximated the pre-RBSP rate (Section 2.3), a particularly large quantity of material (400,000 cy) was discharged on the beaches north of the receiver site in January 2002 (approximately three months after completion of the RBSP fill). Hence, this material may be contributing to the longevity of the Oceanside fill as it moves downcoast.



April 2001 (Pre-RBSP)



November 2001 (1.5 months after nourishment)



May 2002 (7.5 months after nourishment)



November 2002 (13.5 months after nourishment)

Plate 12. Oceanside Receiver Site, April 2001 through November 2002

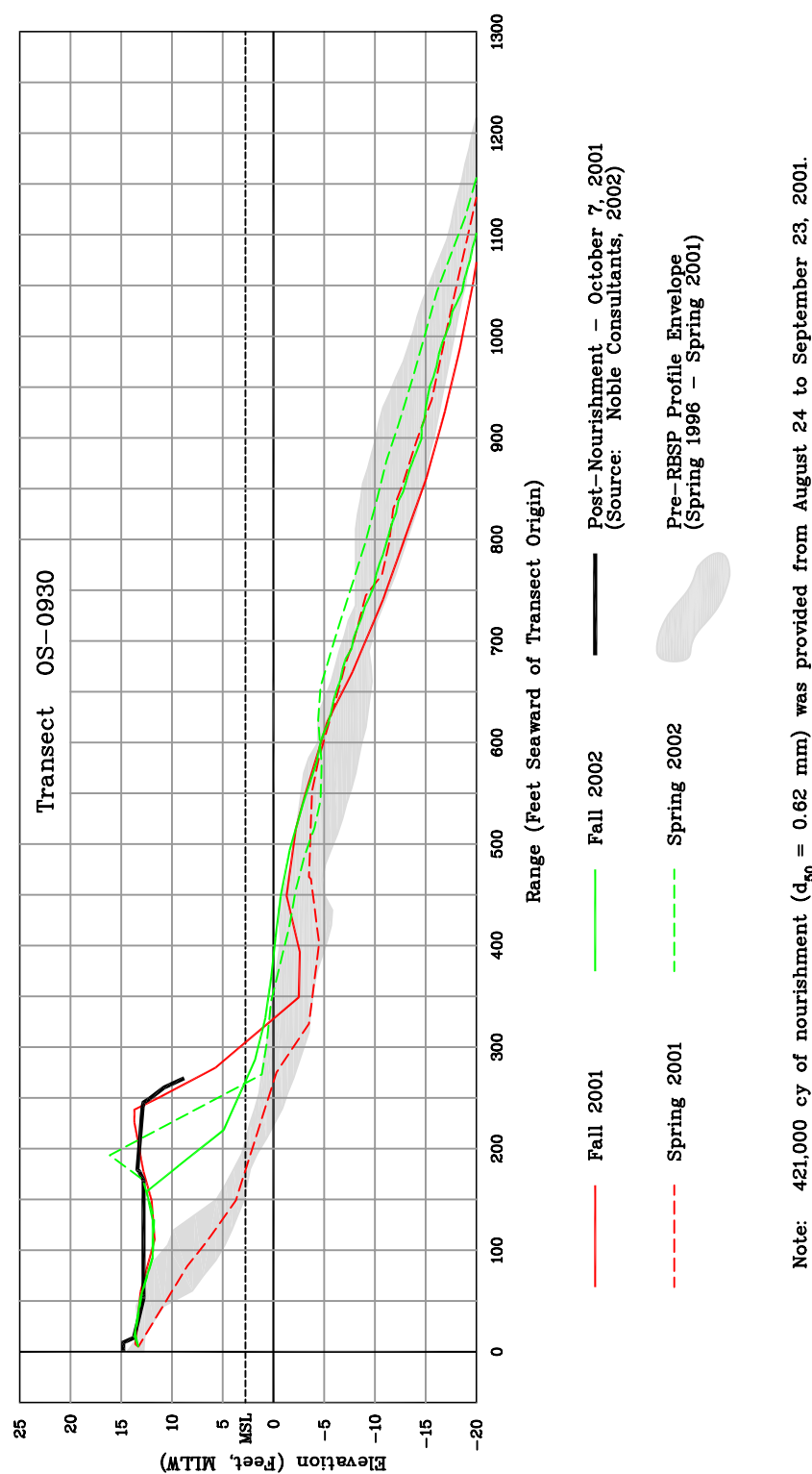


Figure 35. Transect OS-0930 at Oceanside Receiver Site

6. LAGOON ENTRANCE CONDITION

Section 6 evaluates the condition of the five lagoon entrances in the Oceanside Littoral Cell during the RBSP Monitoring Period (November 2000-October 2002). 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

The 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 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 led to human intervention, consisting primarily of inlet stabilization and mechanical excavation.

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. Illustrating the influence of climate cycles (Section 2.1.1) on lagoon condition, the study indicated that the channel would be open 66% of the time during periods of above-average precipitation and only 12% of the time during periods of below-average precipitation.

Figure 36 shows the average percentage of time that the five lagoons remained open to tidal exchange prior to the RBSP. As indicated in the figure, the period of record for each lagoon varies in accordance with the available data. 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, ranging from 39% at San Elijo to 78% at San Dieguito and 92% at Los Peñasquitos.

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. The unstabilized channels at San Dieguito and San Elijo each closed on two occasions, while the unstabilized channel at Los Peñasquitos closed on three occasions (Figure 37). Nevertheless, the closure frequencies of the unstabilized channels were less than or similar to those that preceded the RBSP. In addition, mechanical intervention to restore or enhance tidal exchange was required on fewer occasions than in the recent past.

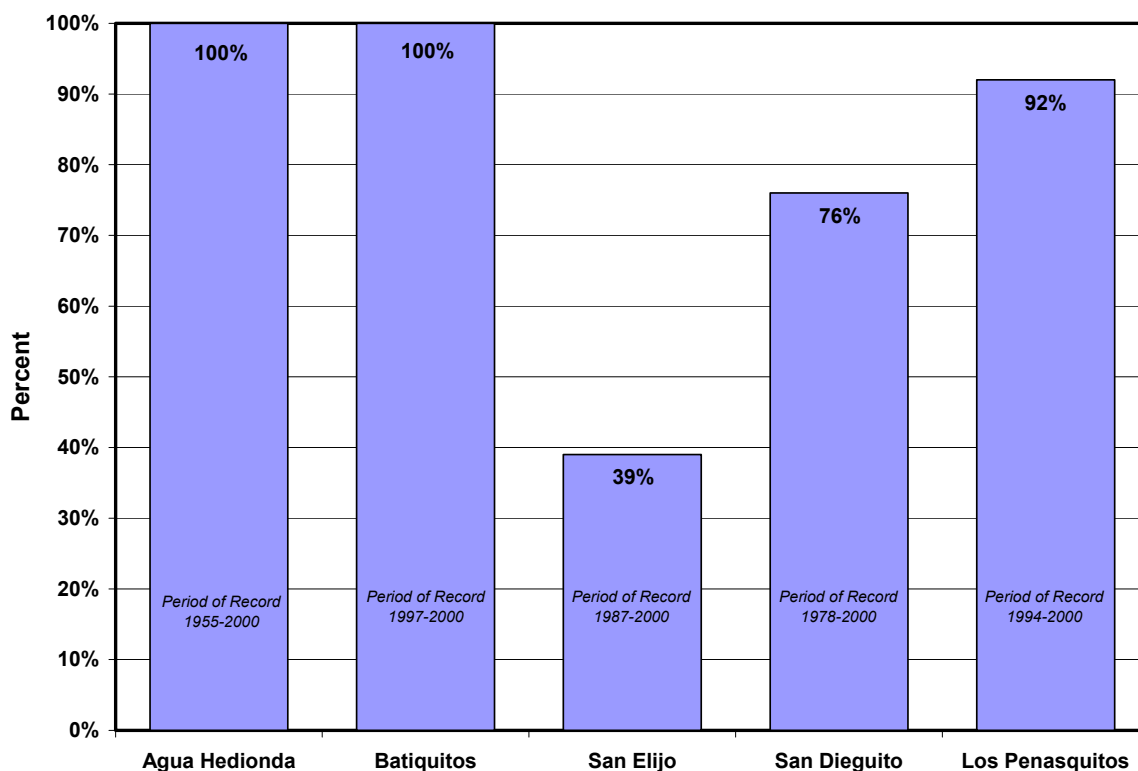
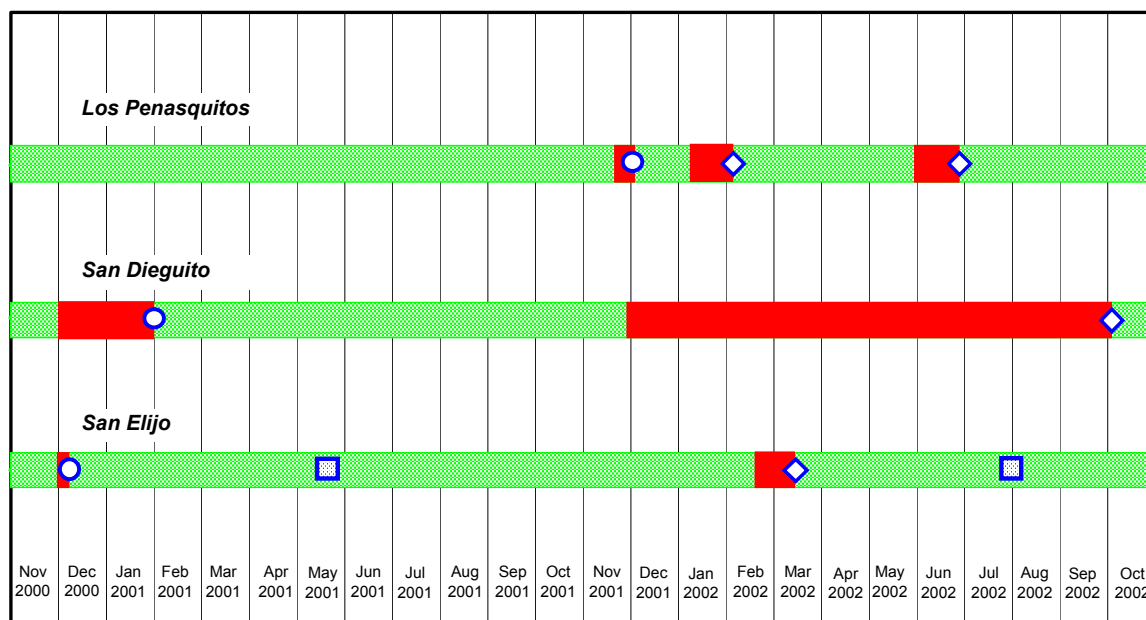


Figure 36. Percentage of Time Lagoon Entrances Open to Tidal Exchange Preceding RBSP



(Source: Gibson, 2003; Elwany, 2003; Sachs, 2003; Ward, *et al.*, 2001, 2002; West, 2003)

Channel Open Channel Closed Opened Naturally Opened Mechanically Enlarged Mechanically

Figure 37. Condition of Unstabilized Lagoon Entrances, 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.

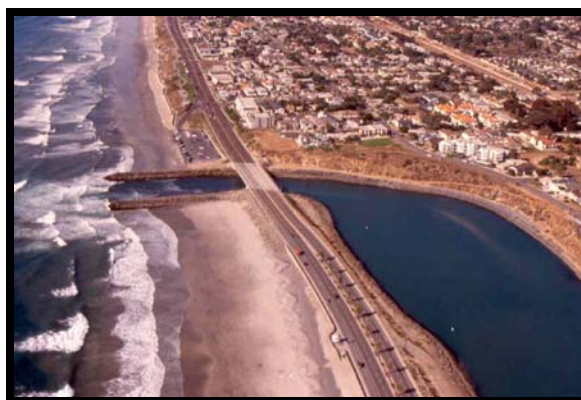
Historically, maintenance dredging has been required at intervals of one to two years, with dredge quantities ranging from 90,000 to 459,000 cy. Over the 45-yr period preceding the RBSP (1955-2000), an average of 241,000 cy/yr was removed from the lagoon and placed on adjacent beaches. As discussed in Section 2.2, the dredging operation returns sediment to the littoral system that has been trapped in the interior basin, and can be categorized as sand bypassing.

Plate 13 displays the condition of the north entrance to Agua Hedionda Lagoon on four occasions between April 2001 and November 2002. In the April 2001 photo, a dredge is evident removing a 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.

Figure 38 presents the controlling elevations that were measured in the north entrance channel on a semi-annual basis from Spring 1997 through Fall 2002. ("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 -4.0 to -5.9 ft (MLLW). Subsequent to the nourishment activities (Fall 2001 to Fall 2002), the controlling elevations were comparable: -4.9 to -5.3 ft.



April 2001



November 2001



May 2002



November 2002

Plate 13. Agua Hedionda Lagoon North Entrance, April 2001 through November 2002

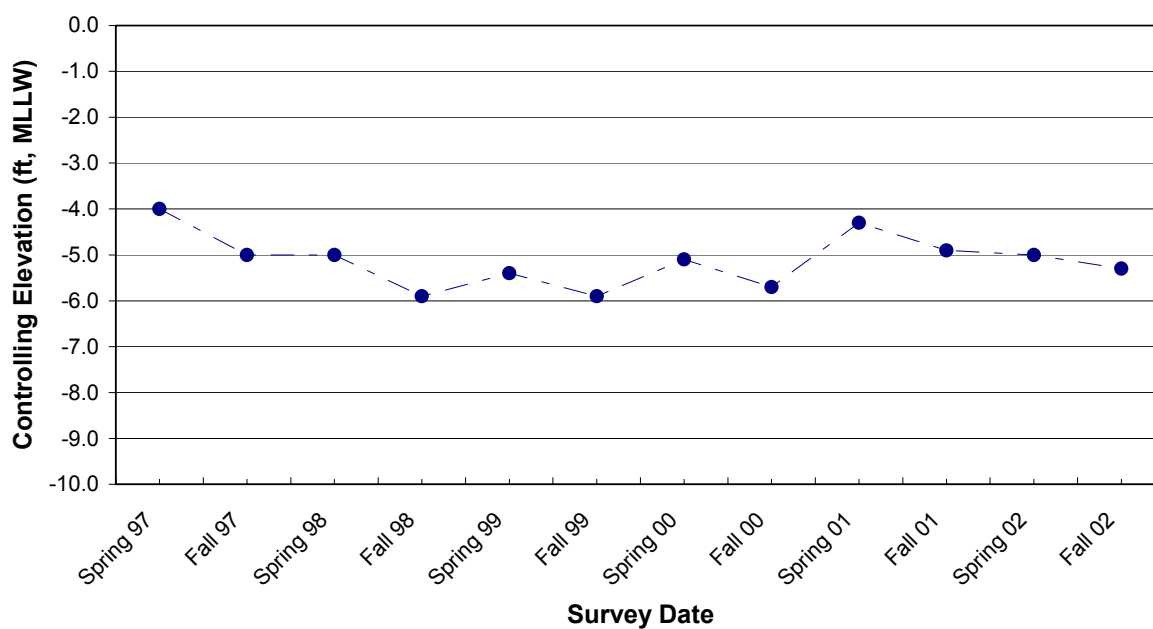


Figure 38. Controlling Elevation for Tidal Exchange in Agua Hedionda Lagoon

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 wetland restoration effort, the lagoon has remained open to tidal exchange. Periodic dredging has been required, however, to maintain tidal flow. As indicated previously in Section 2.2.3, an average of 60,000 cy was removed from the lagoon and placed on the adjacent beaches between 1999 and 2002.

The condition of the Batiquitos Lagoon entrance channel between April 2001 and November 2002 is shown in Plate 14. Substantial shoals are evident in the outer and middle basins in all four photographs, with little change evident over the 20 month period.



April 2001



November 2001



May 2002



November 2002

Plate 14. Batiquitos Lagoon Entrance, April 2001 through November 2002

Between Spring 1997 and Spring 2001, the controlling elevations in the entrance channel varied between -5.0 and -6.3 ft (Figure 39). The elevations measured after placement of the RBSP nourishment material, -5.6 to -6.0 ft, were within this narrow, pre-RBSP range.

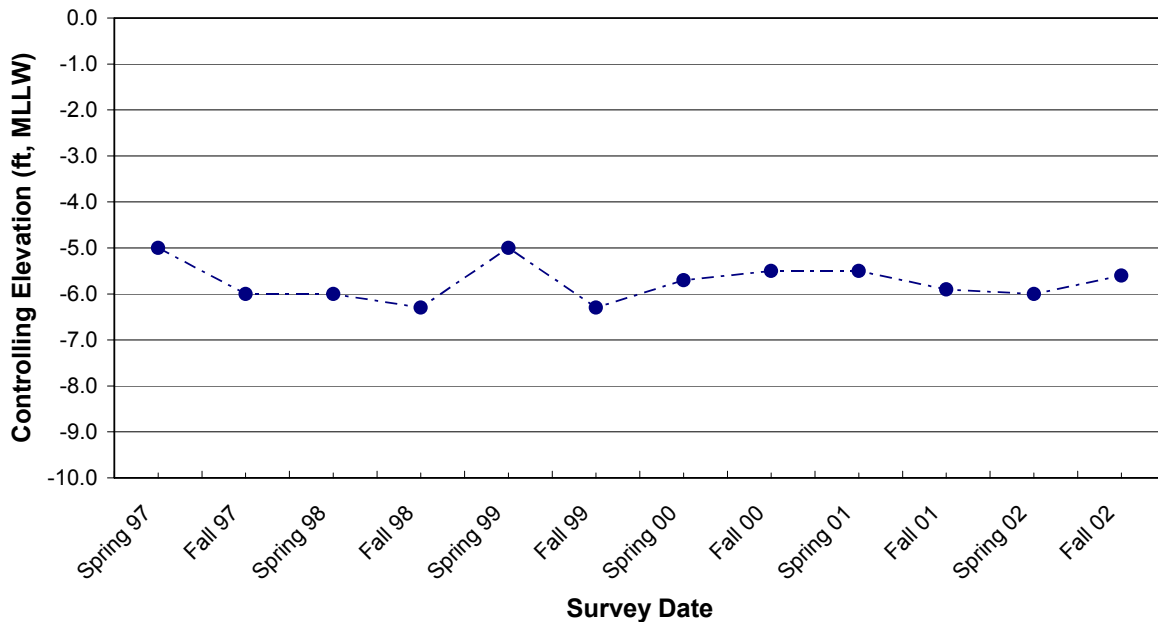


Figure 39. Controlling Elevation for Tidal Exchange in Batiquitos Lagoon

6.2.3. *San Elijo*

Based on records maintained by the San Elijo Lagoon Conservancy (Gibson, 2003), the average closure frequency prior to the RBSP was 4.6 times per 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. During 14-yr period preceding the RBSP (1987 to 2000), the lagoon was open to tidal exchange only 39% of the time.

Plate 15 shows the condition of the San Elijo entrance channel between April 2001 and November 2002. Early in the RBSP Monitoring Period (December 2000), the channel closed briefly before re-opening five days later (Figure 37). The lagoon then remained open to restricted tidal exchange for more than 14 months before closing in February 2002. Tidal exchange was restored shortly thereafter, in March 2002, by mechanical means. Mechanical enlargement of the channel was undertaken on two occasions (May 2001 and June 2002) to increase the flow.



April 2001



November 2001



May 2002



November 2002

Plate 15. San Elijo Lagoon Entrance, April 2001 through November 2002

The lagoon was open 96% of the time during the RBSP Monitoring Period, greatly exceeding the historical average of 39%. The occurrence of only two closures between Fall 2000 and Fall 2002 (1.0 closures per year) differed sharply from the channel's past history of 4.6 closures per year. The frequency of channel maintenance (mechanical openings and enlargements) during the RBSP Monitoring Period, 1.5 times per year, also was below the historical average of 3.1 times per year.

The controlling elevations noted subsequent to the RBSP nourishment activities (Fall 2001 to 2002) ranged between +1.0 and +1.4 ft, near the bottom of the range that prevailed prior to the RBSP (+0.9 to +7.0 ft; Figure 40).

Based on the elevation change data presented in Appendix H, the sediment volume in the entrance channel survey area increased by 100 cy between Fall 2001 and Spring 2002 and decreased by 1,100 cy between Spring 2002 and Fall 2002. The net change during the 2002 Monitoring Year was a modest decrease of 1,000 cy. For the two-year RBSP

Monitoring Period, the net volume decrease in the entrance channel survey area was 3,100 cy.

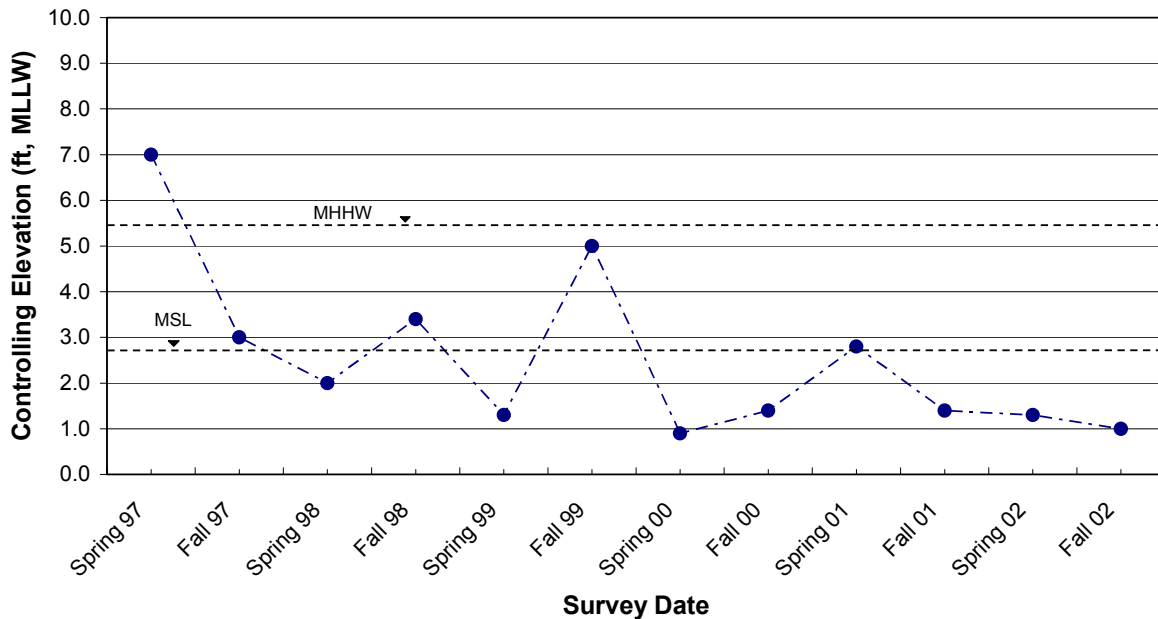


Figure 40. Controlling Elevation for Tidal Exchange in San Elijo Lagoon

6.2.4. San Dieguito

The unstabilized entrance to San Dieguito Lagoon closed repeatedly during the period preceding the RBSP. Based on data compiled by Elwany, *et al.* (1998; 2003), San Dieguito 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 two occasions during the RBSP Monitoring Period (Figure 37). 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.



April 2001



November 2001



May 2002



November 2002

Plate 16. San Dieguito Lagoon Entrance, April 2001 through November 2002

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 beach fill. 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).

The entrance to San Dieguito lagoon was open 48% of the time during the RBSP Monitoring Period, well below the historical average of 76%. This low percentage resulted primarily from the fact that the lagoon was allowed to remain closed for nearly one year (November 2001 through October 2002). Nevertheless, the frequencies of channel closure (1.0 times per year) and mechanical opening (0.5 times per year) approximated the corresponding historical averages (0.5 and 0.6 times per year, respectively). It is also noteworthy that one of the two closures occurred prior to the placement of the RBSP nourishment material (and therefore cannot be attributed to the presence of that material).

At the time of the Fall 2001 and Fall 2002 surveys, when the lagoon entrance channel was open, the controlling elevations measured +3.1 ft and +1.4 ft, respectively (Figure 41). A controlling elevation of +7.6 ft was noted in Spring 2002, clearly precluding tidal exchange. These elevations fell within the exceptionally wide range of +1.0 to +9.4 ft that prevailed prior to the RBSP.

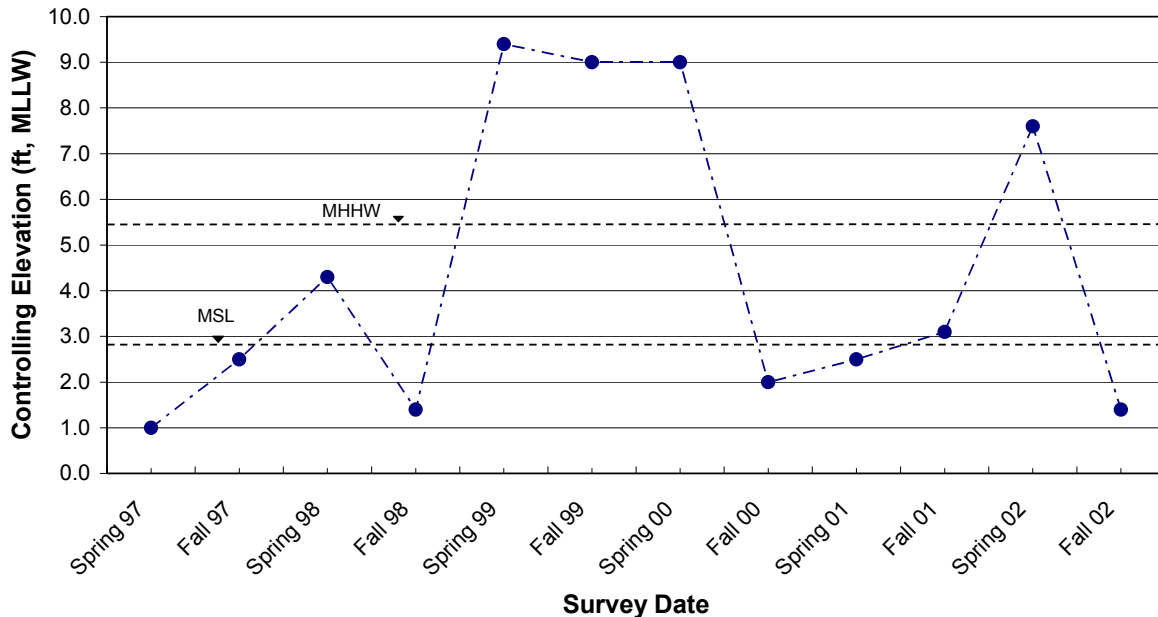


Figure 41. Controlling Elevation for Tidal Exchange in San Dieguito Lagoon

Between Fall 2001 and Spring 2002, a seasonal loss of 6,100 cy was experienced in the entrance channel survey area (Appendix H). This loss was followed by a seasonal gain of 17,300 cy between Spring and Fall, 2002, producing a net gain of 11,200 cy for the 2002 Monitoring Year. For the two-year RBSP Monitoring Period, the net volume gain in the entrance channel survey area was 2,700 cy.

6.2.5. Los Peñasquitos

Prior to the RBSP, the unstabilized entrance to Los Peñasquitos Lagoon closed several times per year on average. 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 the entrance channel 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 briefly on three occasions during the 2002 Monitoring Year (Figure 37). The channel opened naturally in December 2001, but mechanical excavation was required to re-establish tidal exchange in February and June, 2002. The channel condition at the time of the four overflights conducted between April 2001 and November 2002 is shown in Plate 17.



April 2001



November 2001



May 2002



November 2002

Plate 17. Los Peñasquitos Lagoon Entrance, April 2001 through November 2002

In Section 5.2.3, post-nourishment accretion at the waterline of Transect TP-0530 was attributed to the northerly transport of sediment from the Torrey Pines fill. As this transect is located just south of Los Peñasquitos Lagoon (Figure 20), it is likely that the RBSP fill material contributed to the channel closure that occurred in late November 2001.

The lagoon was open 89% of the time during the RBSP Monitoring Period, closely approximating the historical average of 92%. In addition, the frequencies of channel closure and mechanical opening during this period (1.5 and 1.0 times per year, respectively) were both lower than the historical averages (2.6 and 1.9 times/year).

The controlling elevations measured subsequent to the RBSP nourishment activities ranged from +3.4 to +4.1 ft. Prior to the RBSP, the values ranged from +1.8 to +7.4 ft (Figure 42). The elevation change data in Appendix H indicate that the entrance channel survey area lost 9,600 cy between Fall 2001 and Spring 2002, and gained 10,100 cy between Spring 2002 and Fall 2002. The total net gain of 500 cy for the year was concentrated in the region seaward of the coast road bridge, rather than inside the lagoon. For the two-year RBSP Monitoring Period, the entrance channel survey area gained 9,000 cy.

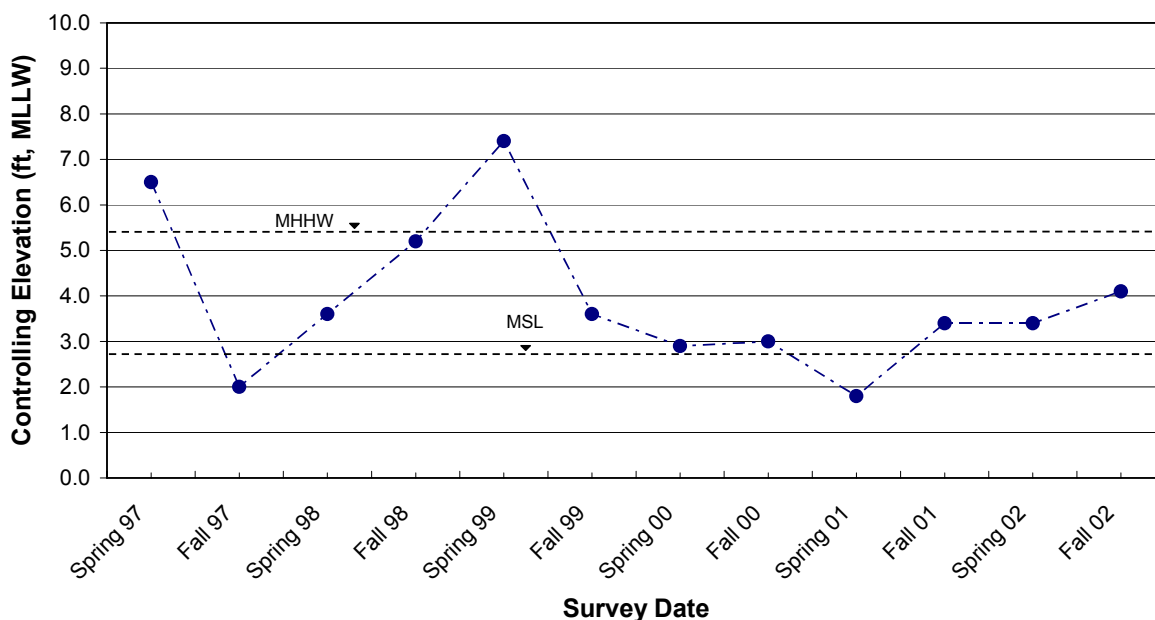


Figure 42. Controlling Elevation for Tidal Exchange in Los Peñasquitos Lagoon

7. CONCLUSIONS

Conclusions pertaining to the condition of San Diego County's beaches and the impact of the RBSP beach fills during the RBSP Monitoring Period are summarized below.

1. Precipitation and streamflow were well below average during the two-year RBSP Monitoring Period, while the wave conditions were relatively mild. 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 stream flows 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 RBSP Monitoring Period was a miniscule 2,000 cy (1,000 cy/yr) at Moonlight Beach. As a result, 934,000 cy of the RBSP fill material (about 44%) served to compensate for the average annual nourishment of 467,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, 1,170,000 cy, represented incremental nourishment. Most of this nourishment was concentrated in the Oceanside Cell, which received an additional 1,048,000 cy (equivalent to 524,000 cy/yr over the two-year RBSP Monitoring Period). The Mission Beach Cell received an additional 148,000 cy (74,000 cy/yr), while the Silver Strand Cell incurred a deficit of 26,000 cy (13,000 cy/yr) due to the lack of nourishment activities other than the RBSP.
3. The sand bypass rates at Batiquitos and Agua Hedionda Lagoons during the RBSP Monitoring Period (23,000 and 215,000 cy/yr, respectively) were substantially higher than the average annual rates in prior years (2,000 and 143,000 cy/yr). These high rates were not caused by the RBSP, because the bypass work was conducted prior to or concurrent with the April 2001 start of the nourishment activities. The sand bypass rate at Oceanside Harbor during the RBSP Monitoring Period, 240,000 cy/yr, approached the average of 252,000 cy/yr in prior years. The implications are twofold: (1) the beaches adjacent to the Batiquitos and Agua Hedionda Lagoon entrances benefited from the increased bypass rates at these sites; and (2) the beaches at Oceanside and North Carlsbad were neutrally impacted by the near-typical bypass rate at Oceanside Harbor.

4. The combination of beach fills and mild wave conditions during the RBSP Monitoring Period proved to be extremely favorable for the San Diego County coast. Although the twelve receiver sites tended to experience shoreline and volume losses subsequent to fill placement, many of the adjacent beaches benefited as the material was dispersed along the coast. As a result, wider beaches resulted in all three littoral cells: at 59% of the transects with data predating the RBSP, the beach width measured in Fall 2002 exceeded that noted in Fall 2000. The greatest increases occurred in the Oceanside Cell, where more than 85% of the RBSP nourishment material was deposited.
5. Shorezone sediment volume changes were mixed during the 2002 Monitoring Year. Over the entire RBSP Monitoring Period, however, shorezone volume gains predominated in all three littoral cells. As in the case of shoreline advance, the most substantial volume gains occurred in the Oceanside Cell. In the absence of other nourishment programs and of significant riverine input, the increase in shorezone volume may be attributed primarily to the RBSP.
6. The initial performance of the individual RBSP fills varied considerably. Based on the use of a single indicator transect, the beaches with the greatest shorezone volume gains in Fall 2002 relative to Spring 2001 consisted of Oceanside (54 cy/ft), Leucadia (42 cy/ft) and North Carlsbad (36 cy/ft).
7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange throughout the RBSP Monitoring Period. Of the three unstabilized entrance channels, San Elijo and San Dieguito closed twice while Los Peñasquitos closed three times. Nevertheless, the closure frequencies of these channels were less than or similar to the closure frequencies that preceded the RBSP. In addition, mechanical intervention to restore or enhance tidal exchange was required on fewer occasions than in the recent past.

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