COASTAL

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San Dieguito Lagoon, October 2005

2005 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

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SANDAG
2005 REGIONAL BEACH MONITORING PROGRAM

ANNUAL REPORT

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SANDAG

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EXECUTIVE SUMMARY

This report presents the findings of the SANDAG 2005 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 2005 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on 61 shore-perpendicular transects and semi-annual oblique aerial photography of the twelve RBSP receiver sites. The lagoon entrance component addressed five sites in the Oceanside Littoral Cell: the jetty-stabilized entrances at Agua Hedionda and Batiquitos Lagoons, and the unstabilized entrances at San Elijo, San Dieguito, and Los Peñasquitos Lagoons (Figure 1). 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. Topographic data were acquired at each location at the time of the Spring 2005 Survey, after which this component of the program was discontinued.

To provide continuity with SANDAG's previous monitoring work, November 2004 through October 2005 was defined as the 2005 Monitoring Year, the prior four one-year periods as the 2004, 2003, 2002 and 2001 Monitoring Years, and the five-year period from November 2000 through October 2005 as the RBSP Monitoring Period. In the case of the five lagoon entrances, post-RBSP conditions were evaluated during the four-year period encompassing the 2002 through 2005 Monitoring Years to reflect the conclusion that the fills did not impact the lagoons prior to this period.

The principal study findings are as follows:

1. Although the precipitation and streamflow recorded in 2005 greatly exceeded the pre-RBSP averages, the wave energy and storm frequency were below average. When the five-year RBSP Monitoring Period is considered, only the streamflow in the San Luis Rey River exceeds the pre-RBSP average. The implications are threefold: (1) the mild

wave conditions helped to prolong the life of the beach fills; (2) the scant precipitation and low streamflows were inadequate to deliver significant quantities of beach-quality sediment to the coast until the last year of the RBSP Monitoring Period; and (3) the low streamflows were inadequate to flush coastal sediment from the lagoon entrances in the Oceanside Cell until the last year of the RBSP Monitoring Period.

2. The only non-RBSP nourishment provided during the RBSP Monitoring Period was 2,000 cy (less than 1,000 cy/yr) at Moonlight Beach, and 301,000 cy (60,000 cy/yr) at Imperial Beach. As a result, approximately 97% of the RBSP fill material (2,040,000 cy) may be regarded as compensating for the average annual nourishment of 408,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, consisting of only 64,000 cy, represents incremental nourishment. The Mission Beach Cell has been the greatest beneficiary of incremental nourishment, having received 140,000 cy. The Silver Strand Cell has received an incremental 55,000 cy, but the Oceanside Cell has incurred a deficit of 130,000 cy. (It should be noted that, due to rounding, the sum of the incremental nourishment volumes shown above equates to 65,000 cy, rather than the reported value of 64,000 cy.)

   It is noteworthy that the Oceanside Cell incurred a nourishment deficit in 2005 for the first time since placement of the RBSP fill material. This circumstance, which has resulted from the virtual cessation of nourishment activities since 2001, increases the potential for reversing the improvements that resulted from the RBSP. Conversely, the incremental nourishment provided to the Mission Beach and Silver Strand Cells suggests that these beaches will be able to sustain the benefits derived from the RBSP over a longer period of time.

3. The average annual sand bypassing rates at Oceanside Harbor, Agua Hedionda and San Elijo Lagoon during the RBSP Monitoring Period (283,000, 228,000 and 25,000 cy/yr) exceeded the average annual rates in prior years by 31,000, 85,000, and 11,000 cy/yr, respectively. The increased bypassing rates constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor, north and south of Agua Hedionda, and south of the San Elijo Lagoon entrance. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the historical and RBSP Monitoring Period bypassing rate is not meaningful.

4. During the 2005 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, with volume gains and losses nearly balanced among the survey transects. In contrast, shoreline retreat predominated during the one-

year period. The apparent paradox created by a stable shorezone volume and a retreating shoreline may be explained by the fact that sediment continued to move from the subaerial portion of the profile to the submerged portion, but remained within the shorezone. The predominance of shoreline retreat appears to be attributable to the offshore dispersal of the RBSP fill material coupled with a lack of beach nourishment activities (other than the material placed offshore in the Silver Strand Cell in 2005). Despite above-average precipitation and high streamflows during the 2005 Monitoring Year, the profile data suggest that sediment input from rivers and streams was relatively modest. The stability of the shorezone sediment volume implies that the limited nourishment, lack of substantial riverine sediment input, and relatively mild wave conditions neither added or removed significant quantities of material from the coast.

5. After three consecutive years of shoreline retreat (2003, 2004, and 2005), the beach widths at most locations in the Silver Strand and Oceanside Cells had diminished to such an extent that they were less than the pre-RBSP values for the first time since placement of the nourishment material. In the Mission Beach Cell, the changes in beach width over the RBSP Monitoring Period were balanced between losses and gains. Notwithstanding the prevalence of shoreline retreat relative to the pre-RBSP condition in two of the three littoral cells, sediment volumes tended to increase over the five-year RBSP Monitoring Period. The greatest shorezone volume gains occurred in the Oceanside Cell. The primary causes of these gains appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period.

6. The performance of the individual RBSP fills varied considerably. In the majority of cases, however, the receiver beaches experienced an increase in both shoreline position and shorezone volume. In many cases, dispersal of the fill material was accompanied by shorezone volume gains on the downdrift beaches. The positive impact of the RBSP was most evident in the Oceanside-North Carlsbad area, where the monitoring data suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally to benefit more than two miles of shoreline. A similar situation was observed in the Encinitas area involving the Batiquitos and Leucadia fills.

7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth following the RBSP (Fall 2001 to Fall 2005). Of the three unstabilized entrances, San Elijo closed on four occasions, San Dieguito on five, and Los Peñasquitos on seven. It is noteworthy that no closures occurred during the 2005 Monitoring Year. This pronounced variation in closure frequency resulted in the San Elijo entrance channel

remaining open to tidal exchange for a greater percentage of time than the pre-RBSP average (93% vs. 43% historically), the San Dieguito channel remaining open for a lesser percentage of time (63% vs. 77% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (90% vs. 93% historically).

8. At San Elijo Lagoon, the dredge rate following the RBSP (25,000 cy/yr) exceeded the historical average (15,000 cy/yr) by 67%. However, the higher rate is attributable, at least in part, to an increased level of maintenance made possible by additional funding. The post-RBSP dredge rate at Agua Hedionda (178,000 cy/yr) was within 3% of the pre-RBSP rate (182,000 cy/yr). At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the two dredge rates is not meaningful.

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SANDAG
2005 REGIONAL BEACH
MONITORING PROGRAM

ANNUAL REPORT

1. INTRODUCTION

This report presents the findings of the SANDAG 2005 Regional Beach Monitoring Program. As in the case of nine prior annual monitoring programs conducted between 1996 and 2004 (Coastal Frontiers, 1997 through 2005), the 2005 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 2005 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 (cy) of sand to the receiver beaches between April 6 and September 23, 2001.

The 2005 Monitoring Program consisted of a beach component and a lagoon entrance component. The beach component included semi-annual profiling on 61 shore-perpendicular transects and semi-annual oblique aerial photography of the twelve RBSP receiver sites. The lagoon entrance component addressed five sites in the Oceanside Littoral Cell: the jetty-stabilized entrances at Agua Hedionda and Batiquitos Lagoons, and the unstabilized entrances at San Elijo, San Dieguito, and Los Peñasquitos Lagoons (Figure 1). 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. Topographic data were acquired at each location at the time of the Spring 2005 Survey.

In deference to budgetary constrains, the beach and lagoon monitoring components of 2005 program were reduced by eliminating those elements deemed to be of marginal utility. Specifically, the monthly beach width measurements were discontinued and the lagoon entrance topographic surveys were terminated following the Spring survey.

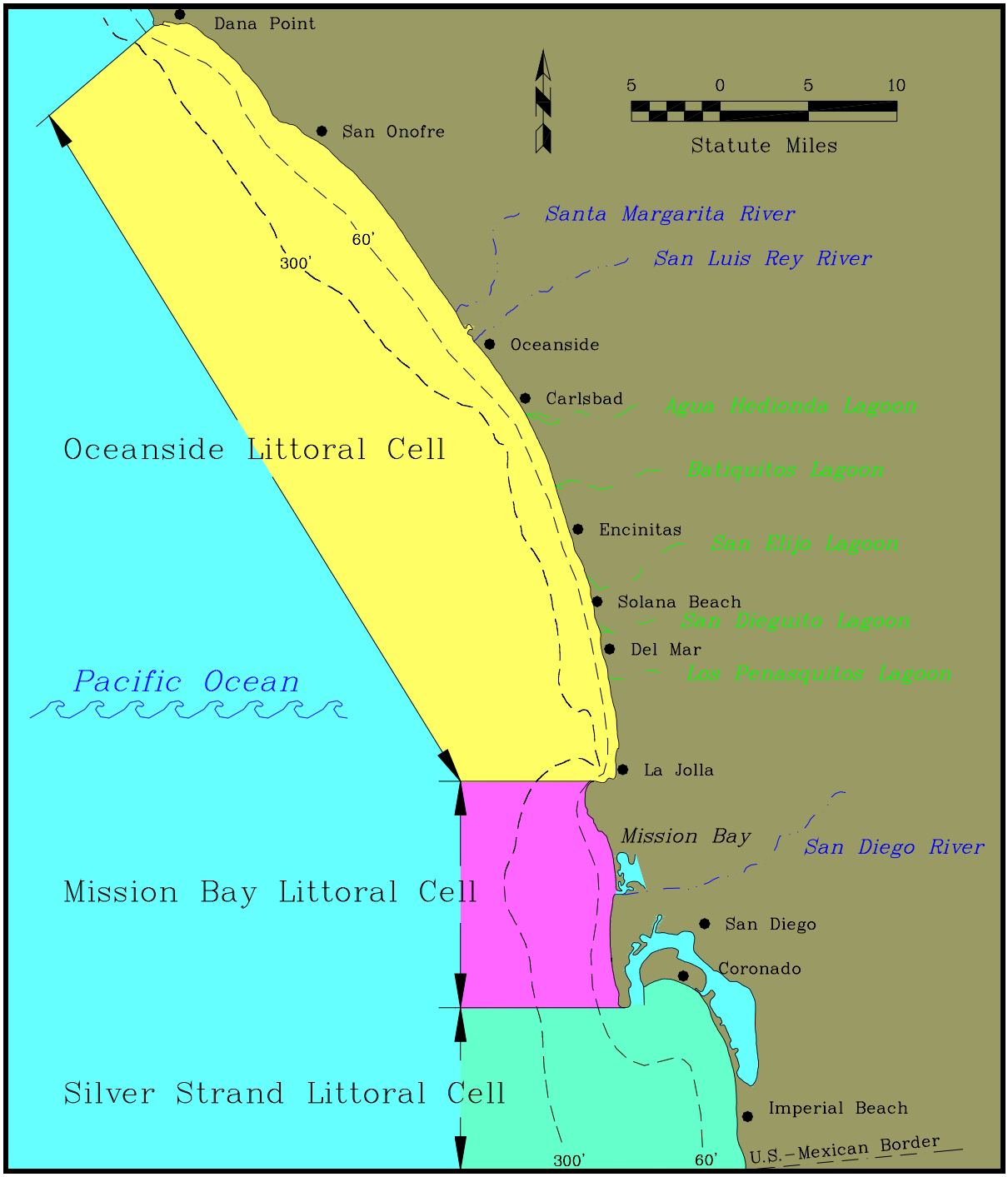


Figure 1. The Coast of San Diego County

Although most of the 2005 Monitoring Program was sponsored by SANDAG, beach profile data for selected transects were provided by the Cities of Carlsbad, Encinitas, and Solana Beach. Their contributions are gratefully acknowledged by SANDAG.

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

2001 Monitoring Year:	November 2000 through October 2001;
2002 Monitoring Year:	November 2001 through October 2002;
2003 Monitoring Year:	November 2002 through October 2003;
2004 Monitoring Year	November 2003 through October 2004;
2005 Monitoring Year	November 2004 through October 2005;
RBSP Monitoring Period:	November 2000 through October 2005 (5 years).

Although the primary focus of this report is the 2005 Monitoring Year, emphasis also is placed on the evolution of the County's beaches during the entire five-year RBSP Monitoring Period.

The remainder of this report provides a detailed account of the 2005 Regional Beach Monitoring Program. Pertinent background information is provided in Section 2, which discusses the environmental conditions and human intervention that occurred during the RBSP Monitoring Period. Monitoring methods are described in Section 3, while Section 4 presents the results. The condition of San Diego County's beaches is analyzed in Section 5, while 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 digitally in Appendices A through H. All elevations are referenced to Mean Lower Low Water (MLLW), which lies 2.73 ft below Mean Sea Level (MSL).

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

the 2003 Regional Beach Monitoring Program Annual Report (Coastal Frontiers, 2004), and should be regarded as superceding the previously-reported values.

2. BACKGROUND INFORMATION

This section presents background information on the natural and human factors that exert a significant influence on the state of the San Diego County coast. It is intended not only to provide a general context for the monitoring data, but also to aid in evaluating the performance of the twelve RBSP beach fills and their impact on coastal lagoons. Environmental conditions are discussed in Section 2.1, followed by sediment management activities (including the RBSP) in Section 2.2. In Section 2.3, the conditions that have prevailed during the five-year RBSP Monitoring Period are compared with those in the recent past. All data are presented in terms of "monitoring years" that commence on November 1 and end on October 31. The 2005 Monitoring Year, for example, extends from November 1, 2004 through October 31, 2005.

2.1. Environmental Conditions

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

2.1.1. Precipitation

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

Figure 2 shows the annual precipitation measured at Lindberg Field from 1915 through 2005 (Western Regional Climate Center, 2006). The average value prior to 2001 was 10.3 inches, with a maximum of 26.4 inches in 1941 and a minimum of 3.6 inches in 1961. During the SANDAG monitoring period that preceded the RBSP (1996-2000), above-average precipitation was recorded only in 1998 (corresponding to the El Niño winter of 1997-98). During the 2001 Monitoring Year, when the RBSP was implemented, the

precipitation measured 7.3 inches, or about 30% below average. The precipitation during the 2002 Monitoring Year was even lower, at 3.3 inches - the lowest value recorded during the entire period of record. In 2003 and 2004, the total precipitation (10.3 and 10.2 inches, respectively) approximated the long-term average. (It should be noted that the Western Regional Climate Center revised the reported precipitation for October 2004 from 6.4 inches to 5.0 inches, thereby reducing the total precipitation for the 2004 Monitoring Year as reported in the 2004 Annual Report from 11.6 inches to 10.2 inches.)

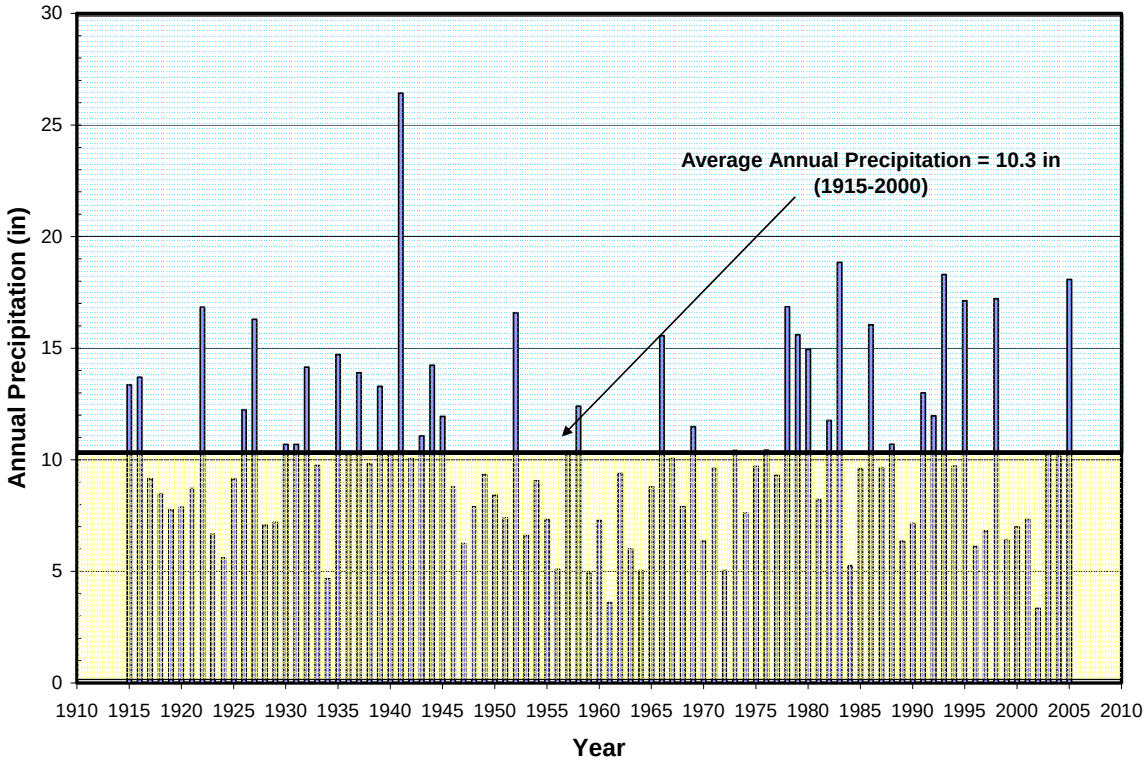


Figure 2. Annual Precipitation at Lindberg Field, 1915-2005

The precipitation during the 2005 Monitoring Year (18.1 inches) represented the fourth highest annual total on record. Over 90% of the rainfall (16.5 inches) occurred between December 2005 and March 2006. The precipitation totals during these four months exceeded the respective long-term monthly averages, but did not surpass the previously recorded monthly maxima. It also should be noted that the record-breaking precipitation in October 2004 (5.0 inches) occurred following the completion of the Fall 2004 Survey. As a result, the influence of this event on the beach and lagoon entrance conditions was first reflected in the Spring 2005 Survey.

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.

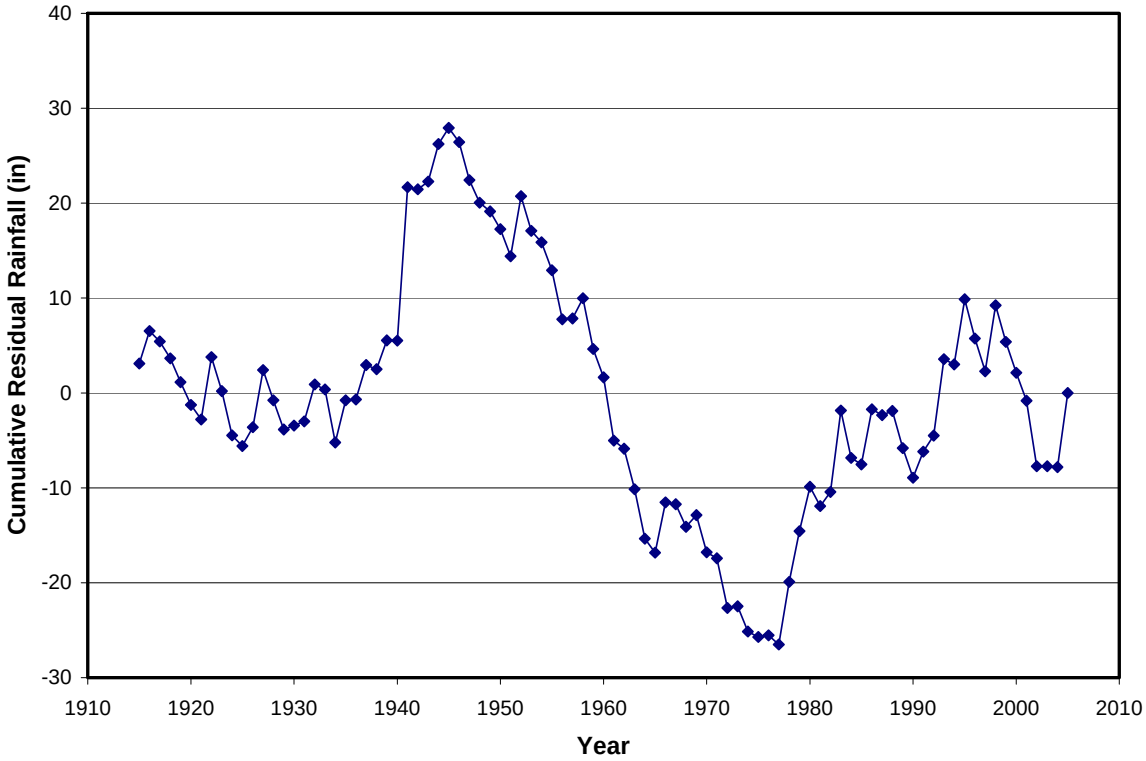


Figure 3. Cumulative Residual Rainfall at Lindberg Field, 1915-2005

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, six consecutive years of below- or near-average rainfall followed the 1997-98 El Niño event (1999 to 2004). The abnormally high precipitation in 2005 may signify the end of this dry period, or simply represent a short-term anomaly similar to those noted above.

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, 2006). The mouth of the San Luis Rey

River is located approximately 0.5 miles southeast of Oceanside Harbor, while that of the San Diego River adjoins the entrance to Mission Bay (Figure 1). These rivers were selected for analysis because they are among the largest in the study area, and because streamflow data are available for an extended period of record that includes the RBSP Period.

Figure 4 presents the annual mean streamflow measured in each river between 1983 and 2005. As in the case of precipitation (Section 2.1.1), the flow in both rivers remained below average for six consecutive years following the 1997-1998 El Niño event. During the 2005 Monitoring Year, however, the streamflow in the San Luis Rey River was the highest recorded during the 23-year period of record (1983 to 2005). While the streamflow in the San Diego River exceeded both the long-term and RBSP averages, it ranked as only the forth highest during the period of record. 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 were characterized by high streamflow 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.

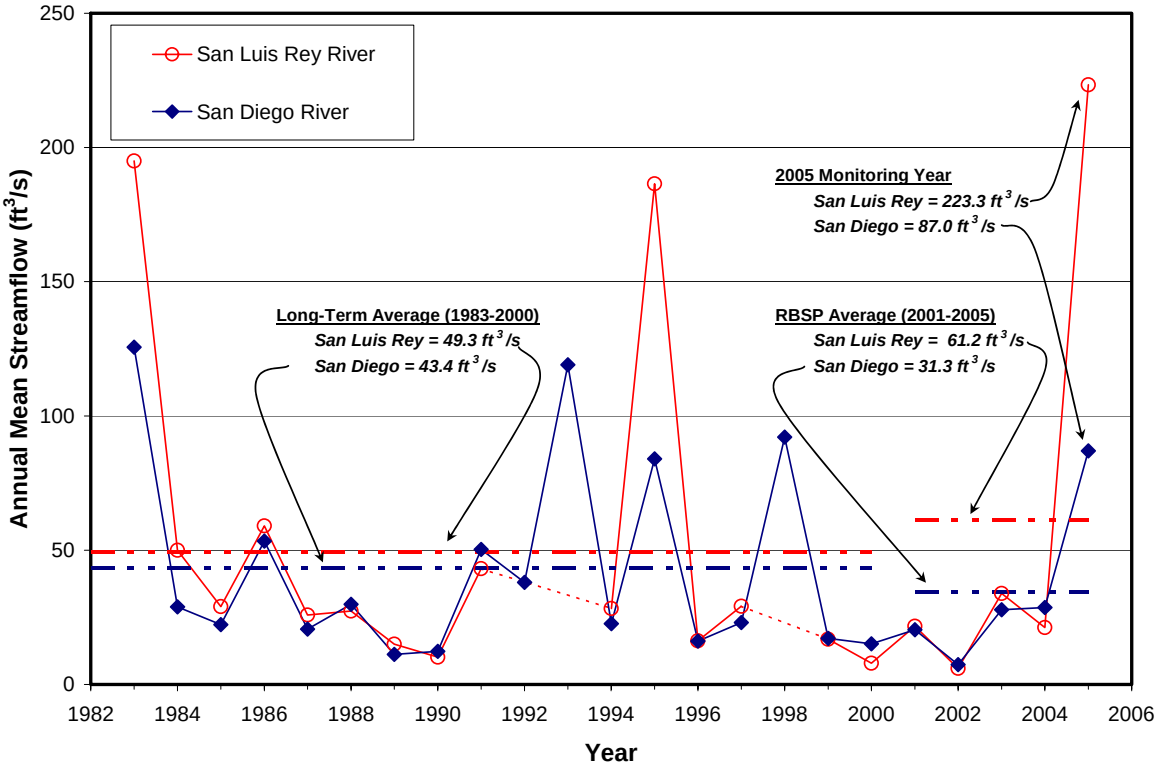


Figure 4. Annual Mean Streamflow in the San Luis Rey and San Diego Rivers, 1983-2005

Figures 5 and 6 compare the monthly mean streamflow in each river for each year of the RBSP Monitoring Period with the long-term monthly mean values for the 18-yr period between 1983 and 2000. As in the case of the annual data presented in Figure 4, the

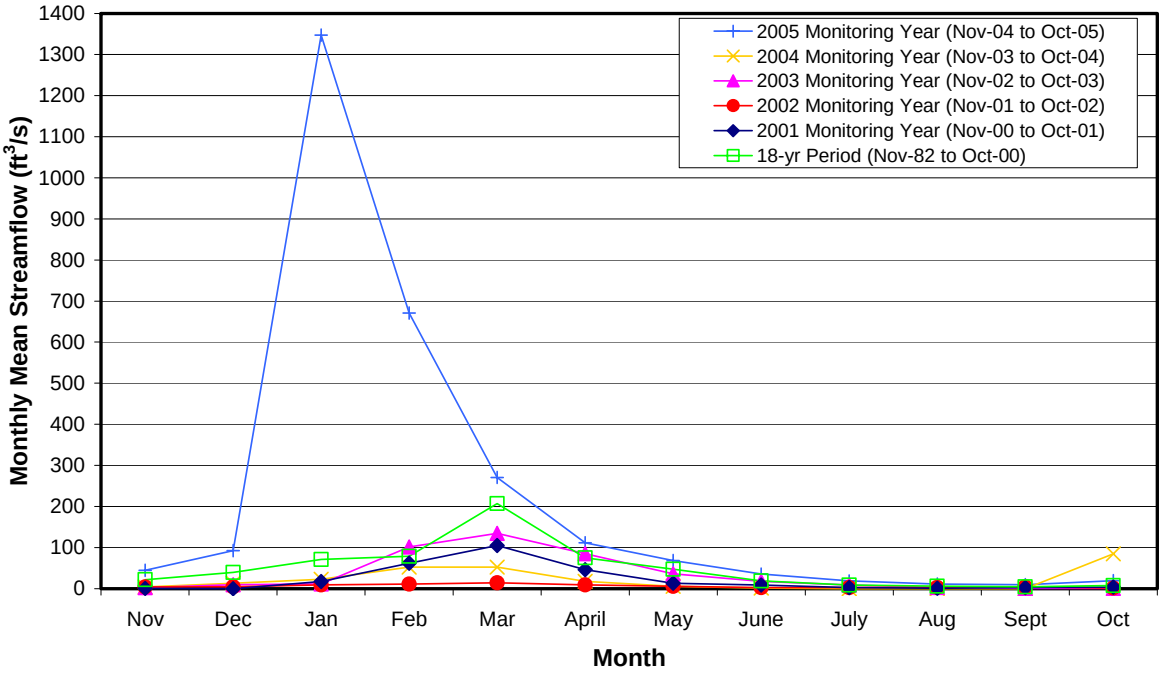


Figure 5. Monthly Mean Streamflow in the San Luis Rey River

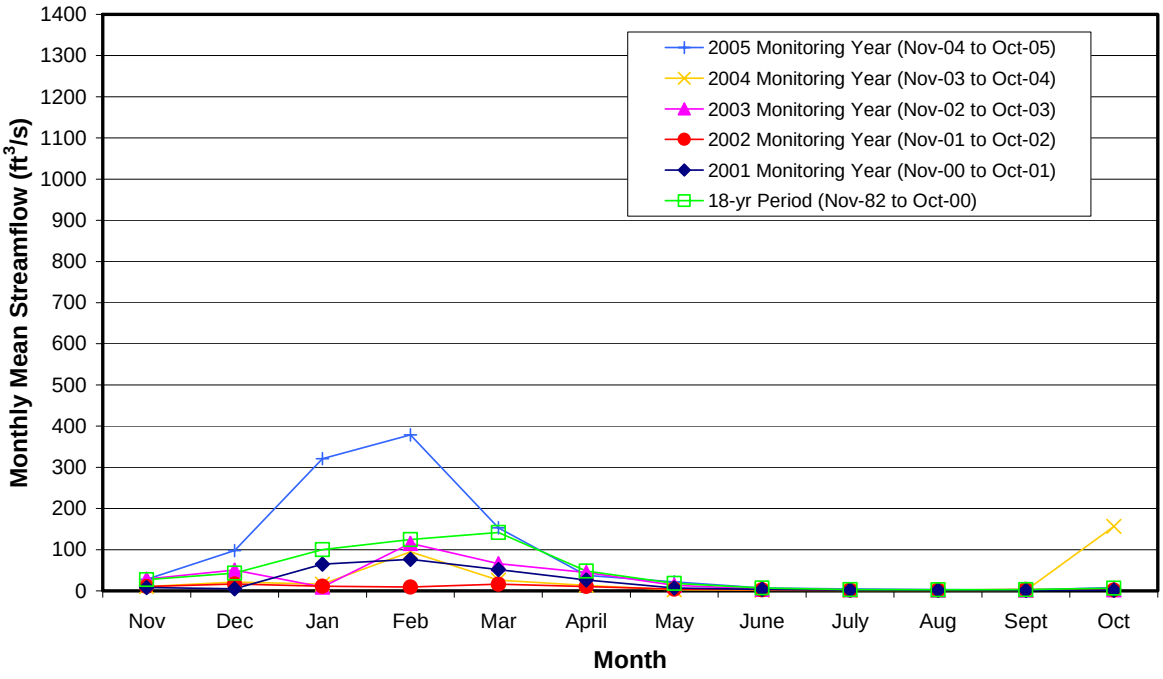


Figure 6. Monthly Mean Streamflow in the San Diego River

monthly data indicate that the first four years of the RBSP Monitoring Period (2001 to 2004) were characterized by below-average streamflow rates. The most notable exception occurred in October 2004. In contrast, the monthly streamflow rates exceeded the long-term average values for nearly every month during the 2005 Monitoring Year. The highest streamflows occurred in January and February. It should be noted, however, that the long-term monthly values for the San Luis Rey would be higher than those shown in Figure 5 were it not for the two data gaps identified above.

2.1.3. Wave Climate

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

The analysis was undertaken with wave measurements acquired under the auspices of the Coastal Data Information Program (CDIP), which is operated by Scripps Institution of Oceanography (2006). 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 2005 Monitoring Year are presented as time series in Figure 7. Northerly swell characteristic of the winter months predominated in December and January, while southerly swell characteristic of the summer months predominated from April through September. The remaining months, February and March in the spring and October and November in the fall, served as transitional periods with a mixture of northerly and southerly swell. The three most severe storms occurred in December, January, and April.

The total wave energy in each Monitoring Year from 1998 through 2005 was compared using the Relative Incident Energy Index (E_r) developed by Seymour (1998). This index is based on the following proportionality between the wave power per unit crest length (P) in deep water, the significant wave height (H_s) and the peak wave period (T_p):

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

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

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

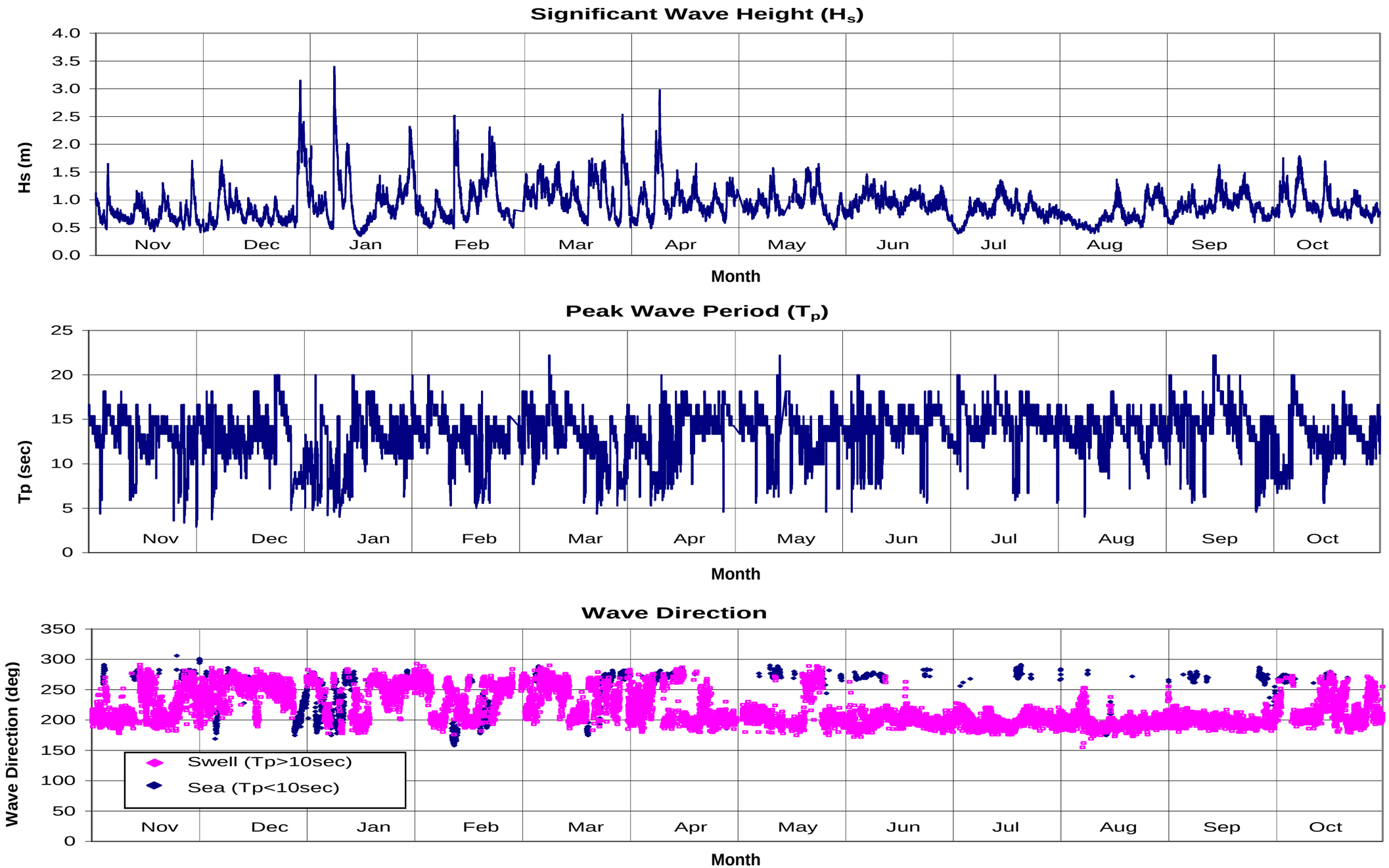


Figure 7. Wave Characteristics at the Oceanside Buoy, 2005 Monitoring Year

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:

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

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 periods lacking measurements. The highest Energy Index, with a value of 149, occurred during the 1998 El Niño year. The index then decreased during each of the next four years, attaining a minimum value of 87 in 2002 before increasing to 103 in 2003 and 100 in 2004. The index increased slightly to 105 in 2005. Although higher than the other values recorded during the RBSP Monitoring Period, it was nevertheless well below those that preceded the RBSP from 1998 through 2000.

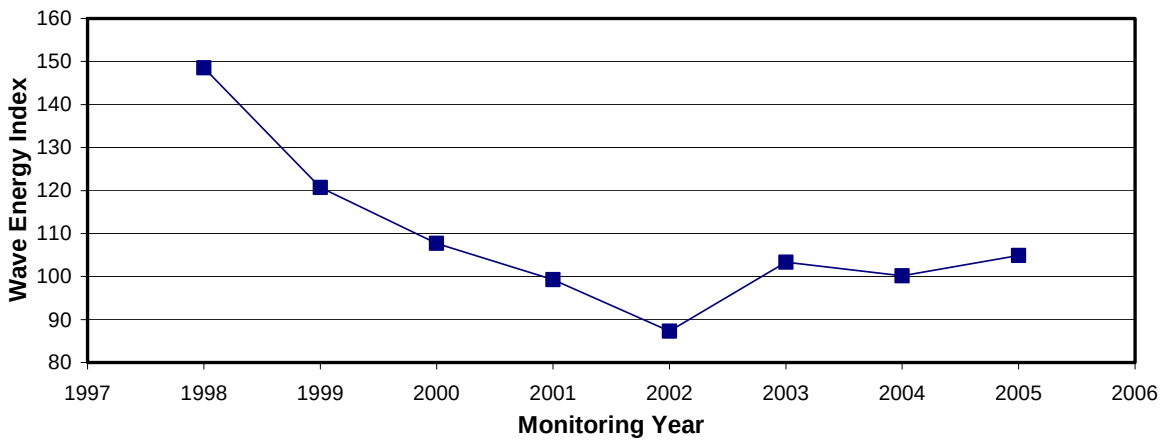


Figure 8. Relative Incident Energy Index at the CDIP Oceanside Buoy, 1998-2005

Figure 9 displays the number of storms per year with H_s exceeding threshold values of 7 ft (2.1 m) and 10 ft (3.0 m). As in the case of the Relative Incident Energy Index, the storm frequency data indicate that the most severe conditions occurred in 1998, when H_s exceeded 7 ft on sixteen occasions and 10 ft on six occasions. During the five years encompassing the RBSP Monitoring Period (2001 to 2005), H_s surpassed 7 ft between six and seven times per year, and surpassed 10 ft between zero and two times per year. During the 2005 Monitoring Year, H_s surpassed 7 ft on seven occasions, and exceeded 10 ft on two occasions. The maximum significant wave height in 2005, 11.2 ft (3.40 m), occurred on January 8 in the form of southwesterly seas with a peak period of only 7.7 seconds.

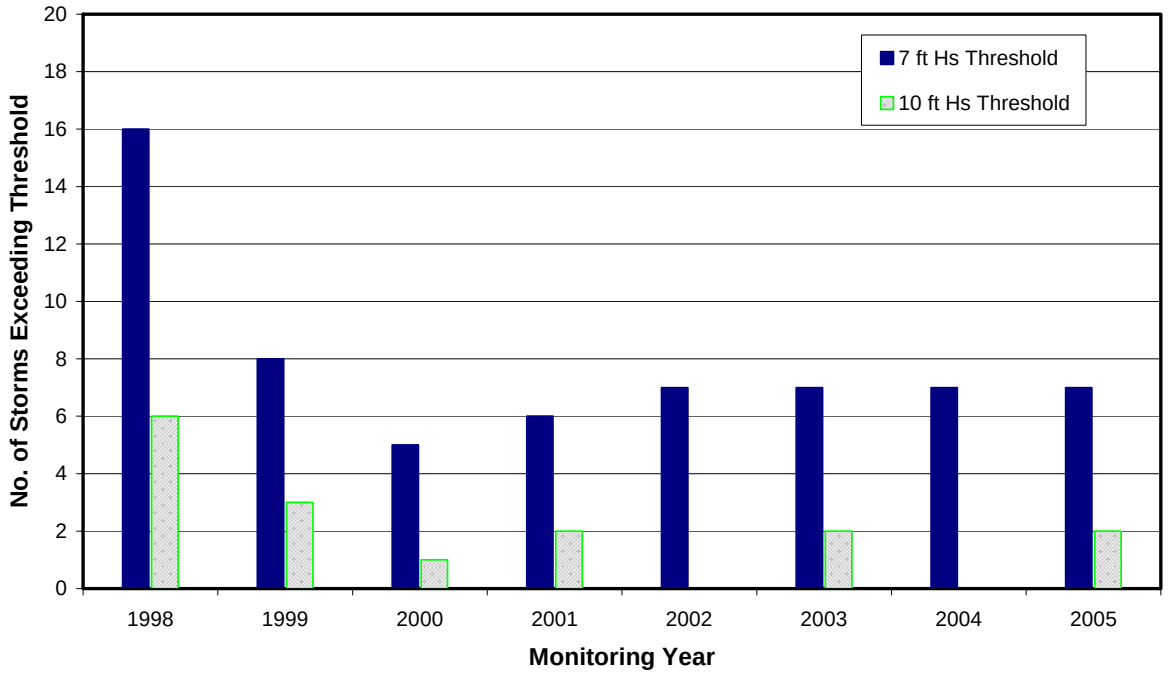


Figure 9. Storm Events per Year with Significant Wave Heights Exceeding 7 ft and 10 ft, 1998-2005

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 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 while 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 the pre-RBSP nourishment projects depended on "sand of opportunity" that was derived from activities whose primary motive was other than beach replenishment. The largest sources of opportunistic nourishment were the dredge spoils associated with lagoon restoration and harbor maintenance. The non-RBSP nourishment projects conducted between November 1993 and October 2005 are summarized below by littoral cell. Two periods are considered: (1) the seven-year span from November 1993 through October 2000, and (2) the RBSP Monitoring Period (November 2000 through October 2005). 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).

Table 1. RBSP Beach Fills

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

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

Source: Noble Consultants, 2001

One opportunistic sand replenishment project has been undertaken in the Silver Strand Cell since the placement of the RBSP fill material at Imperial Beach in 2001. Approximately 301,000 cy of material dredged from San Diego Harbor were placed offshore, south of the pier in Imperial Beach between October 2004 and February 2005 (Ryan, 2005). Because the project commenced after the Fall 2004 Survey was completed, the entire nourishment quantity is attributed to the 2005 Monitoring Year. This amount equates to an average annual nourishment rate of about 60,000 cy/yr during the RBSP Monitoring period.

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

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

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

Mission Beach Littoral Cell

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

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 cy 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 cy for beach replenishment in Carlsbad. The only non-opportunistic beach fill activity occurred at Moonlight Beach, where approximately 1,000 cy of purchased sand was placed as a protective berm each year from 1996 through 2000.

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

Beach, where the aforementioned practice of adding 1,000 cy per year to construct a protective berm was continued in 2001 and 2002. In 2003, 2004 and 2005, the berm was created from material already present on the beach rather than from imported material (Weldon, 2006).

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

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

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

Table 4. Non-RBSP Beach Nourishment in the Oceanside Littoral Cell, November 2000 through October 2005

Project	Date	Sediment Source	Placement Location	Nourishment Quantity (cy)
Moonlight Beach Nourishment	2001	Inland (non-opportunistic)	Encinitas	1,000
Moonlight Beach Nourishment	2002	Inland (non-opportunistic)	Encinitas	1,000
Average Annual Nourishment Rate in the Oceanside Cell (Nov 00 – Oct 04) = <1,000 cy/yr				

Source: Frenken, 2002; Keeley, 2003; Keeley, 2004; Weldon, 2006

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, Oceanside Harbor and San Elijo Lagoon 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. A form of bypassing has been conducted at San Elijo since 1994 in conjunction with the entrance channel maintenance activities. The sediment quantities bypassed at each site between November 1993 and October 2000 (pre-RBSP) are shown in Table 5. The values for San Elijo Lagoon should be regarded as first-order estimates because maintenance records do not segregate bypass quantities from entrance channel breaching quantities (Gibson, 2005).

Relatively high bypass rates, averaging 252,000 and 143,000 cy/yr, were maintained at Oceanside and Agua Hedionda, respectively. At San Elijo Lagoon, the estimated average bypass rate was 14,000 cy/yr. The average rate at Batiquitos was only 2,000 cy/yr. The relatively low rate at Batiquitos may be explained by the aforementioned lagoon restoration project. The entrance channel was first opened to continuous tidal exchange in late 1995 (Webb, 2004), and the restoration project was not completed until 1997. In consequence, the years preceding the RBSP represented a transition period for the lagoon, and the low bypass rate at Batiquitos should be regarded as anomalous.

The sediment quantities bypassed at each site during the RBSP Monitoring Period (November 2000-October 2005) are presented in Table 6. At Oceanside Harbor, bypass operations were conducted in each of the five Monitoring Years. The average rate of 283,000 cy/yr exceeded the pre-RBSP rate by 31,000 cy/yr.

At Agua Hedionda, where bypassing typically occurs every second year, such operations were undertaken in 2001, 2003, and 2005. The average rate during the four-year RBSP Monitoring Period, 228,000 cy/yr, was higher than the pre-RBSP rate of 143,000 cy/yr. It is noteworthy that the unusually high quantity of material bypassed in 2001, 429,000 cy, was dredged prior to or concurrent with the start of the RBSP nourishment program.

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	6,000
	2000	South of Entrance	4,000
	Average Annual Bypass Rate at Batiquitos Lagoon = 2,000 cy/yr [(1)]		
Agua Hedionda Lagoon	1994	Carlsbad	159,000
	1996	Carlsbad	443,000
	1997	Carlsbad	197,000
	1999	Carlsbad	203,000
	Average Annual Bypass Rate at Agua Hedionda Lagoon = 143,000 cy/yr		
Oceanside Harbor	1994	Oceanside	483,000
	1995	Oceanside	161,000
	1996	Oceanside	162,000
	1997	Oceanside	130,000
	1998	Oceanside	315,000
	1999	Oceanside	187,000
	2000	Oceanside	327,000
	Average Annual Bypass Rate at Oceanside Harbor = 252,000 cy/yr		
San Elijo Lagoon	1995	South of Entrance	6,000
	1996	South of Entrance	8,000
	1997	South of Entrance	31,000
	1998	South of Entrance	12,000
	1999	South of Entrance	17,000
	2000	South of Entrance	23,000
	Average Annual Bypass Rate at San Elijo Lagoon = 14,000 cy/yr		

Sources: Dillingham, 2002; Tucker, 2002; Ryan, 2003; Gibson, 2005

Note: [(1)] Rate computed for the three-year period following lagoon restoration (1998 to 2000).

At Batiquitos, bypassing was undertaken only in 2001. Although the resulting average rate of 9,000 cy/yr during the RBSP Monitoring period exceeded the pre-RBSP average of 2,000 cy/yr, the latter figure is anomalously low for the reasons presented above. In addition, 75,000 cy of sediment were dredged from the lagoon in 2003 but used to enhance least tern nesting sites within the lagoon rather than for bypassing (Dillingham,

2004). Hence, the bypass rate could have been substantially higher during the RBSP Monitoring Period if this material had been returned to the littoral system.

Table 6. Sand Bypassing in the Oceanside Littoral Cell November 2000 through October 2005

Bypass Project	Date	Placement Location	Bypass Quantity (cy)
Batiquitos Lagoon	2001	South of Entrance	45,000
	Average Annual Bypass Rate at Batiquitos Lagoon = 9,000 cy/yr		
Agua Hedionda Lagoon	2001	Carlsbad	429,000
	2003	Carlsbad	337,000
	2005	Carlsbad	375,000
	Average Annual Bypass Rate at Agua Hedionda Lagoon = 228,000 cy/yr		
Oceanside Harbor	2001	Oceanside	80,000
	2002	Oceanside	400,000
	2003	Oceanside	438,000
	2004	Oceanside	220,000
	2005	Oceanside	275,000
	Average Annual Bypass Rate at Oceanside Harbor = 283,000 cy/yr		
San Elijo Lagoon	2001	South of Entrance	23,000
	2002	South of Entrance	18,000
	2003	South of Entrance	32,000
	2004	South of Entrance	30,000
	2005	South of Entrance	20,000
	Average Annual Bypass Rate at San Elijo Lagoon = 25,000 cy/yr		

Sources: Dillingham, 2002; Tucker, 2002; Hughes, 2003, Ryan, 2003, 2005, 2006; Gibson, 2005, 2006; Shiffer, 2006

During the five-year RBSP Monitoring Period, the estimated average bypass rate at San Elijo was 25,000 cy/yr. Although this rate exceeded the pre-RBSP average of 14,000 cy/yr, the higher rate is attributable at least in part to a conscious increase in the level of maintenance activities commencing in 2000. This change reflects an increase in the funding available to conduct such activities (Gibson, 2005).

2.3. The RBSP Monitoring Period in Perspective

Table 7 compares the environmental conditions that prevailed during the RBSP Monitoring Period with those in the recent past. Although the precipitation and streamflow

recorded in 2005 greatly exceeded the pre-RBSP averages, the wave energy and storm frequency were below average. When the five-year RBSP Monitoring Period is considered, only the streamflow in the San Luis Rey River exceeds the pre-RBSP average. The implications are threefold:

- The mild wave conditions helped to prolong the life of the beach fills.
- The scant precipitation and low streamflows were inadequate to deliver significant quantities of beach-quality sediment to the coast until the last year of the RBSP Monitoring Period.
- The low streamflows were inadequate to flush coastal sediment from the lagoon entrances in the Oceanside Cell until the last year of the RBSP Monitoring Period.

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	9.8	95%
Streamflow[3] (cfs)			
San Luis Rey River	49.3	61.2	124%
San Diego River	43.4	34.3	79%
Wave Climate[4]			
Energy Index	126	99	79%
Storms w/ H_s>7 ft	9.7	6.8	70%
Storms w/ H_s>10 ft	3.3	1.2	36%

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 (2001-2005).
(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.

As indicated above, the only non-RBSP nourishment provided during the RBSP Monitoring Period was 2,000 cy (less than 1,000 cy/yr) at Moonlight Beach, and 301,000 cy (60,000 cy/yr) at Imperial Beach. As a result, approximately 97% of the RBSP fill material

(2,040,000 cy) may be regarded as compensating for the average annual nourishment of 408,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, consisting of only 64,000 cy, represents incremental nourishment. The Mission Beach Cell has been the greatest beneficiary of incremental nourishment, having received 140,000 cy. The Silver Strand Cell has received an incremental 55,000 cy, but the Oceanside Cell has incurred a deficit of 130,000 cy. (It should be noted that, due to rounding, the sum of the incremental nourishment volumes shown above equates to 65,000 cy, rather than the reported value of 64,000 cy.)

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

Littoral Cell	Historical Average[1] (cy/yr)	RBSP Average[2] (cy/yr)		Difference[3] (cy/yr)	
		Without RBSP	With RBSP	Without RBSP	With RBSP
Silver Strand	73,000	60,000	84,000	(13,000)	+11,000
Mission Beach	2,000	0	30,000	(2,000)	+28,000
Oceanside	393,000	0	367,000	(393,000)	(26,000)
Total	468,000	60,000	481,000	(408,000)	+13,000

Notes: (1) Historical Average based on the period 1993-2000.
(2) RBSP Average based on the RBSP Monitoring Period (2001-2005).
(3) Difference represents RBSP Average minus Historical Average.

Figure 10 shows a time history of the average annual nourishment rate in each littoral cell during the RBSP Monitoring Period. The Mission Beach and Oceanside Cells are characterized by declining rates during the five-year period due to the lack of nourishment other that the RBSP. At the end of the period, the nourishment rate in the Mission Beach Cell remained well above the comparatively small pre-RBSP rate. The net result in the Oceanside Cell was a deficit of 26,000 cy/yr relative the pre-RBSP nourishment rate. In the Silver Strand Cell, the deficit incurred in 2002 remained below the pre-RBSP average until it was erased by the 2005 nourishment activities.

It is noteworthy that the Oceanside Cell incurred a nourishment deficit in 2005 for the first time since placement of the RBSP fill material. This circumstance, which has resulted from the virtual cessation of nourishment activities since 2001, increases the potential for reversing the improvements that resulted from the RBSP. Conversely, the incremental nourishment provided to the Mission Beach and Silver Strand Cells suggests that these beaches will be able to sustain the benefits derived from the RBSP over a longer period of time.

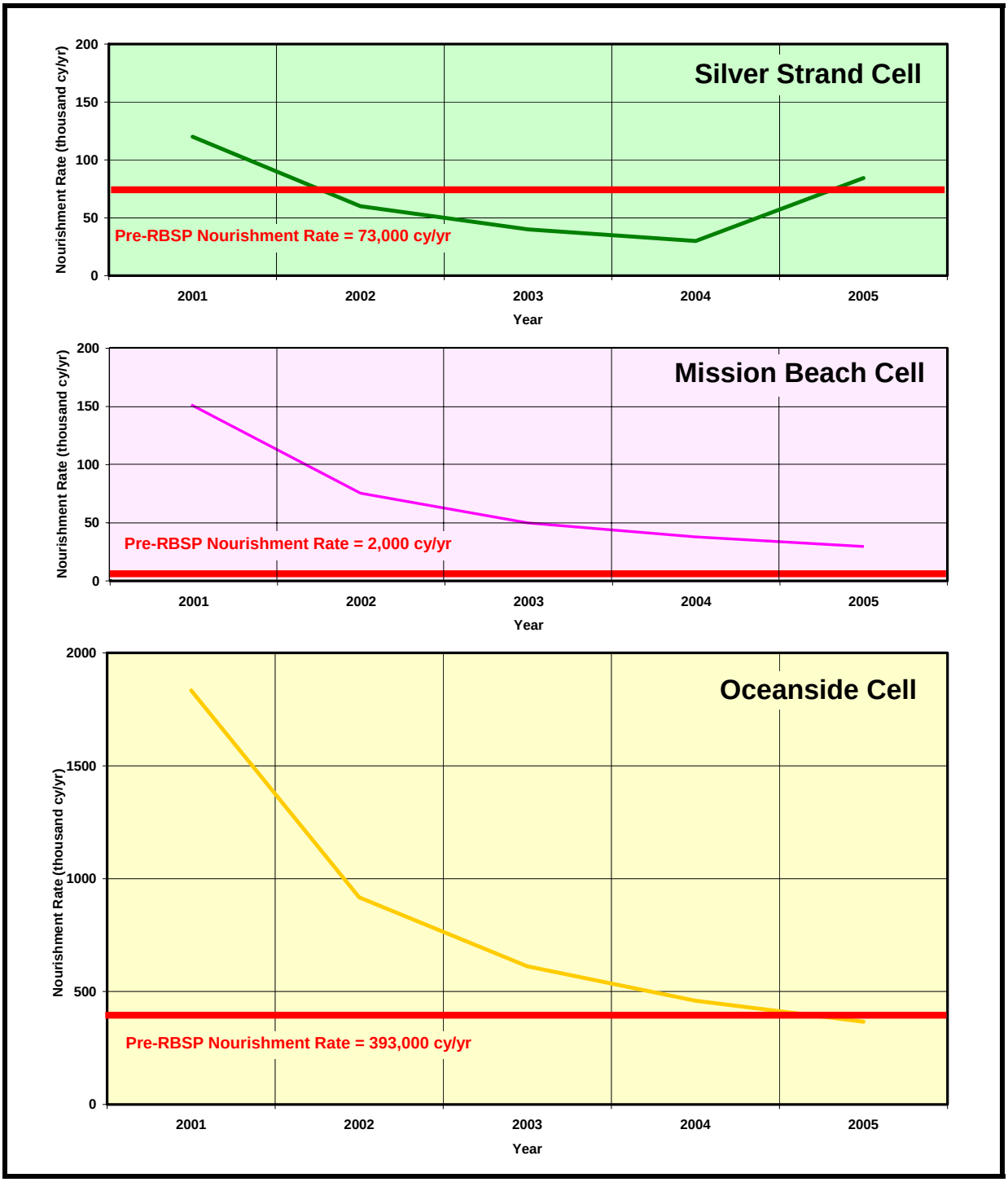


Figure 10. Time History of Nourishment Rates During the RBSP Monitoring Period

The sand bypass rates at Batiquitos, Agua Hedionda, Oceanside Harbor, and San Elijo during the RBSP Monitoring Period are displayed with the average values from the

seven prior monitoring years in Table 9. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the two rates is not meaningful. At Oceanside, Agua Hedionda and San Elijo, the RBSP rates exceeded the prior values by 31,000, 85,000, and 11,000 cy/yr, respectively. This increase in the bypassing rate constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor, both north and south of Agua Hedionda, and south of San Elijo Lagoon.

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	9,000	n/m[4]
Agua Hedionda	143,000	228,000	85,000
Oceanside Harbor	252,000	283,000	31,000
San Elijo	14,000	25,000	11,000

Notes:
(1) Historical Average based on the period 1993-2000.
(2) RBSP Average based on the RBSP Monitoring Period (2001-2005).
(3) Difference represents RBSP Average minus Historical Average
(4) Difference not meaningful because Historical Average bypass rate was derived from the period during and immediately after lagoon restoration.

3. MONITORING METHODS

As indicated in Section 1, the general objective of the 2005 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 monitor the fate of nourishment material introduced under SANDAG's RBSP, including their impacts on the region's beaches and lagoon entrances.

Although the two program components, beach monitoring and lagoon entrance monitoring, resembled those in the years preceding the RBSP, both were expanded in 2001 to develop more detailed information about the outcome of the nourishment activities. The underlying rationale was to provide coverage of each of the twelve receiver beaches, enhanced coverage of four of these sites (North Carlsbad, Leucadia, Mission Beach, and Imperial Beach), and enhanced coverage of the three unstabilized lagoon entrances in the Oceanside Cell (San Elijo, San Dieguito, and Los Peñasquitos). The program was further enhanced in 2002 by adding four beach profile transects and removing one transect of questionable utility. The 2003 and 2004 monitoring programs were identical to that undertaken in 2002. In 2005, in deference to budgetary constrains, the beach and lagoon monitoring components were reduced by eliminating those elements deemed to be of marginal utility. Specifically, the monthly beach width measurements were discontinued and the lagoon entrance topographic surveys were terminated following the Spring survey.

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 and oblique aerial photography. As indicated above, the monthly beach width measurements were omitted from the 2005 monitoring program.

3.1.1. Semi-Annual Beach Profile Surveys

Beach profile data were obtained in the Spring and Fall of 2005, corresponding to the transitions between the winter and summer wave seasons, along 61 previously established transects. The locations of the transects are listed in Table 10, and illustrated in Figures 11a and 11b.

Table 10. Beach Profile Transect Locations

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

Notes:
(1) Transect crosses RBSP nourishment site (red type).
(2) Transect established to support RBSP in 2001.
(3) Transect used for monthly beach width measurements.
(4) Transect added to monitoring program in 2002.
(5) Transect locations shown in Figures 11a and 11b.

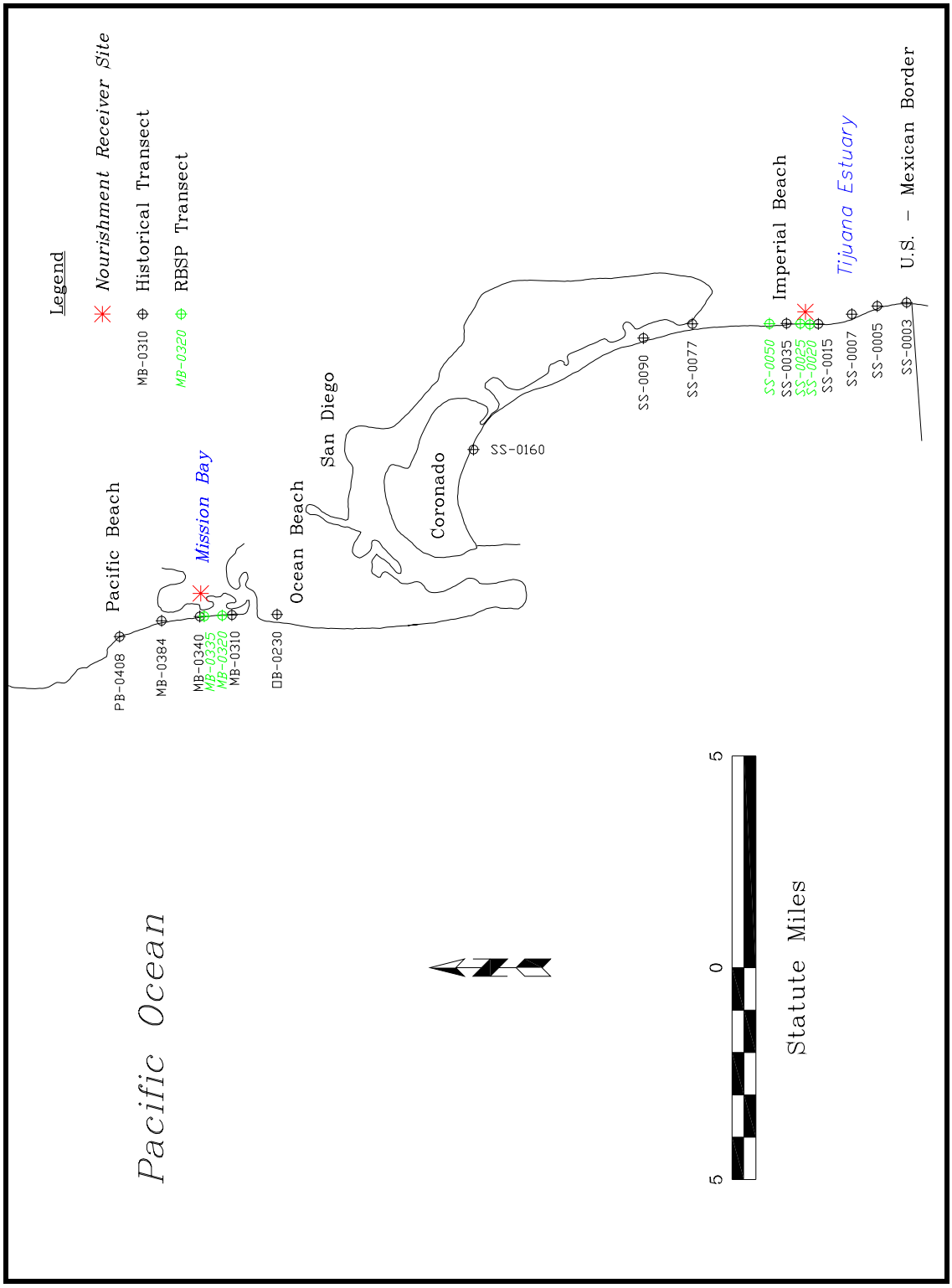


Figure 11a. Beach Profile Transects in the Silver Strand and Mission Beach Littoral Cells

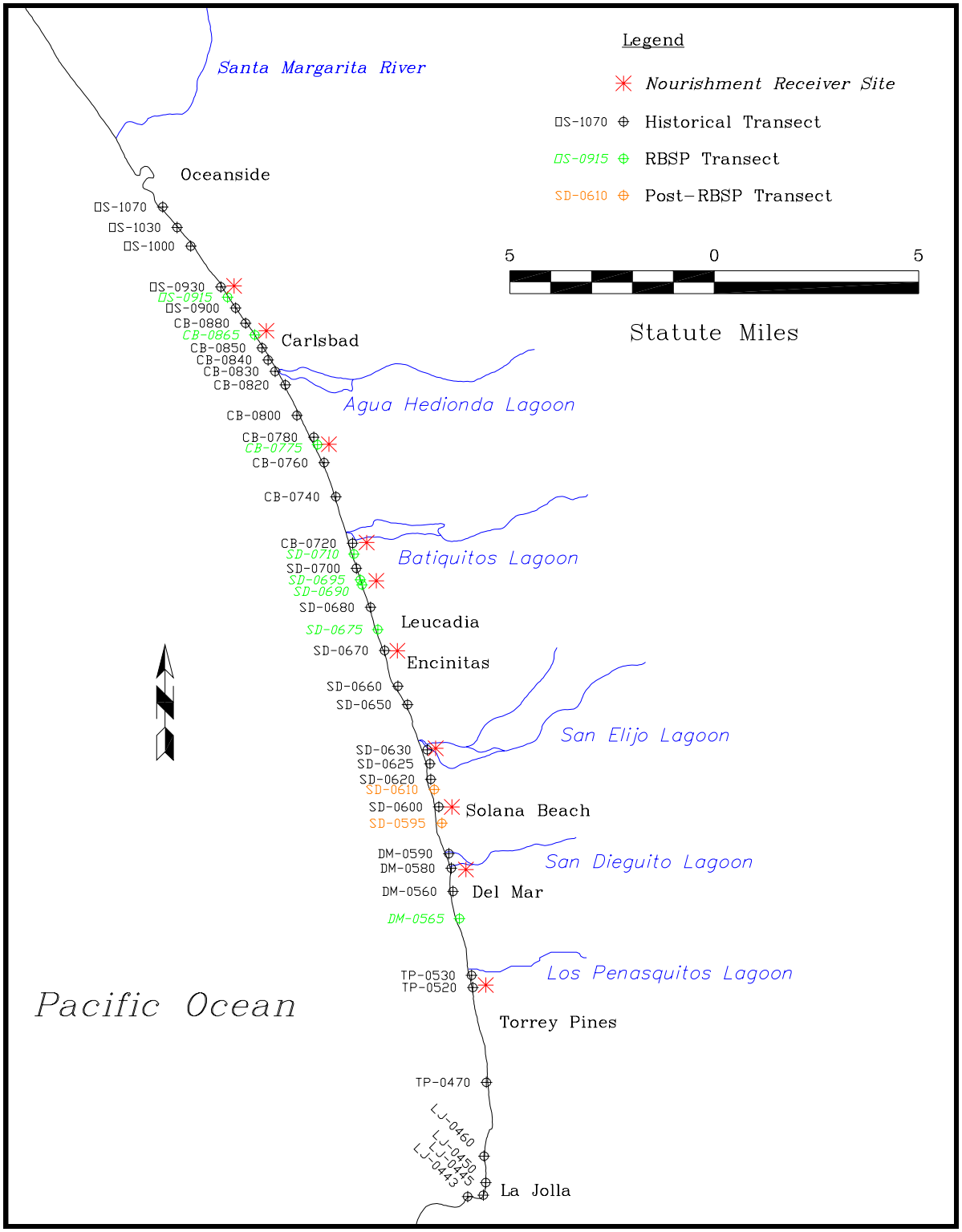


Figure 11b. Beach Profile Transects and Lagoon Entrances in the Oceanside Littoral Cell

The Spring 2005 beach survey activities were conducted in the Silver Strand and Mission Beach Littoral Cells on May 4 and 5, respectively. The survey resumed in the Oceanside Cell on May 10 and concluded on May 13. Conditions were favorable, consisting of light winds and seas less than 3 ft.

The Fall 2005 beach profiling activities commenced in the Oceanside Littoral Cell on October 11 and continued through October 13. The Mission Beach Cell transects were surveyed on October 14. Following a brief interruption due to inclement weather, field activities were concluded in the Silver Strand Cell on October 20. The Fall profile data were acquired under favorable conditions that typically included light winds and seas less than 3 ft.

The data acquisition and processing methods used for the 2005 profile surveys are described below. The methods remained similar to those employed in previous SANDAG and city monitoring programs (Leidersdorf, *et al.*, 1999). In consequence, the results are directly comparable.

Data Acquisition

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

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

Bathymetric data were acquired with a digital acoustic echo sounder operated from a shallow-draft inflatable survey vessel. To improve the resolution of the sonar system, particularly in areas of localized vertical relief, two additional devices first introduced in 2002 were used again in 2005: (1) a dynamic motion sensor to provide real-time corrections for vessel heave, and (2) a ruggedized field computer to log sounding and position data. The

position data were acquired with a GPS unit receiving real-time corrections (DGPS) broadcast from the U.S. Coast Guard Station on Point Loma.

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

Data Processing

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

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

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

The adjusted soundings were thinned to a nominal interval of 10 ft to produce a manageable file size suitable for developing beach profile plots. The resulting x, y, z data (easting, northing, and elevation) were inserted into the CAD drawing containing the wading data. As indicated above, the field work was conducted in such a manner as to provide substantial overlap between the wading and bathymetric portions of the survey. The processed data were examined in this region to insure that the two data sets were

compatible. Once this confirmatory inspection had been completed, only the more detailed data in the region of overlap were retained (typically the bathymetric data). The soundings then were projected onto the transect alignment, and the resulting range and elevation data were used to create a continuous beach profile plot.

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

3.1.2. Semi-Annual Aerial Photography

To augment the beach profile data, oblique aerial photographs of the twelve RBSP receiver sites were acquired at approximately the same time as the Spring and Fall surveys. The photographs were taken from a fixed-wing aircraft circling each site at altitudes of 500 to 700 ft.

The Spring photos were obtained on May 2, two days prior to the start of the beach profile survey activities. The Fall photo mission was conducted on October 31, eleven days following the completion of the survey activities.

3.2. Lagoon Entrance Monitoring

The Spring portion of the 2005 lagoon entrance monitoring effort was virtually identical to those conducted in the previous four years, and included 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 scope of the lagoon monitoring component was reduced in Fall 2005 by discontinuing the topographic surveys. 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 (Spring 2005)

The lagoon entrance surveys were conducted in Spring 2005 in conjunction with the beach profile data collection activities. The work was performed on May 5, 13, and 16.

In the case of Agua Hedionda and Batiquitos Lagoons, where the entrances are stabilized by jetties, an electronic total station and conventional wading techniques were used to obtain two profiles across each channel. One profile was located at the jetty tips, while the other was located at the seaward edge of the coast road bridge.

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

All of the lagoon entrance data were processed in the manner described above for the wading portion of the beach profile surveys. As indicated above, the topographic survey component was removed from the program following the Spring 2005 survey.

3.2.2. Semi-Annual Oblique Aerial Photography

Oblique aerial photographs of the five lagoon entrances were obtained in the Spring and Fall, during the same missions used to photograph the RBSP receiver sites (May 2 and October 31). 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 700 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 -0.2 to +0.1 ft (MLLW) during the Spring overflight, and -0.1 to +0.2 ft during the Fall overflight.

3.2.3. Monthly Inspections and Photography

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. In addition to photographs from repeatable locations, the site visits included notes on whether the channels were open to tidal exchange.

4. MONITORING DATA

This section presents the results of the 2005 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 and oblique aerial photography. The results of these activities are provided in Sections 4.1.1 and 4.1.2

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 2005 beach profile data were used in conjunction with data from the prior surveys to create profile plots and compute changes in shoreline position, beach width, and sediment volume. Selected historical data acquired prior to the SANDAG Monitoring Program also were utilized. A summary of the historical beach profile data for the San Diego region known to exist in the public domain is provided in **Appendix A**, while a summary of the recent profile data acquired by SANDAG, Carlsbad, Encinitas, and Solana Beach is provided in **Appendix B**. To facilitate the identification of changes in beach condition attributable to the RBSP, those transects that cross the RBSP fill sites are identified by red type in Appendix B.

Beach profile plots for the nearshore portion of each transect are provided in **Appendix C**, while plots for the entire length of each transect are provided in **Appendix D**. In addition to the Spring and Fall 2005 data, the plots display the profiles from Fall 2004, Fall 2003, Fall 2002, Fall 2001, Spring 2001, and Fall 1984 (when available), and the envelope of all profiles obtained during the SANDAG monitoring period that preceded the RBSP (Spring 1996-Spring 2001, to the extent that data are available). Post-Nourishment (as-built) profiles also are included for the transects that cross or adjoin the RBSP fill sites. These data, which are limited to the subaerial portion of the beach, were provided by Noble Consultants based on aerial photography (2002).

Table 11. Number of Transects Included in Each SANDAG Survey

Survey	Number of Transects
Spring 1996, Fall 1996	24
Spring 1997	37
Fall 1997, Spring 1998, Fall 1998	39
Spring 1999, Fall 1999, Spring 2000	40
Fall 2000	45
Spring 2001, Fall 2001	58
Spring 2002	60
Fall 2002 through Fall 2005	61

When reviewing **Appendices C** and **D**, it is important to recognize that the pronounced vertical relief evident in Fall 2002 and subsequent profiles resulted from the improved survey resolution (Section 3.1.1) rather than from actual changes in the sea bottom. A representative example is provided in Figure 12, which displays the nearshore portion of the recent profiles obtained on Transect CB-0880 in Carlsbad. The most likely explanation for the "jaggedness" evident in the Fall 2002 and subsequent profiles is the presence of exposed rock reefs (which were not identifiable until the on-board dynamic motion sensor and data acquisition computer were added to the equipment suite in 2002). Although the data obtained in such areas can vary somewhat from survey to survey due to differences in the vessel track and wave conditions, the improved resolution afforded by the new technology is beneficial in identifying potential hard-bottom habitat.

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

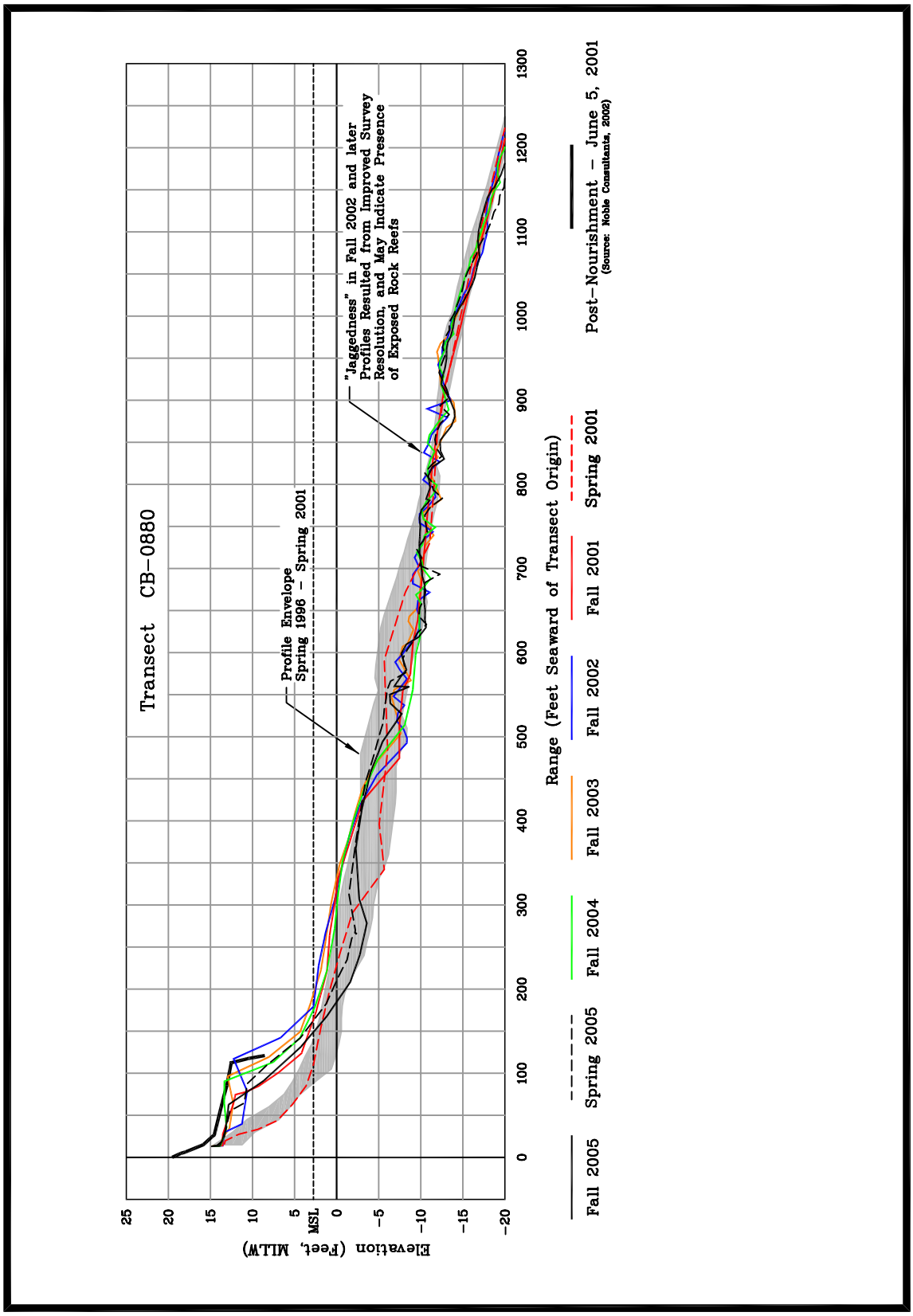


Figure 12. Transect CB-0880 in Carlsbad

Tables and plots of shoreline position and beach width derived from the profile data are provided in **Appendix E**. Data from the following 23 surveys were used to the extent that they were available:

Pre-1984:	Date Varies	2000:	Spring and Fall
1984:	Fall	2001:	Spring and Fall
1989:	Fall	2002:	Spring and Fall
1996:	Spring and Fall	2003:	Spring and Fall
1997:	Spring and Fall	2004:	Spring and Fall
1998:	Spring and Fall	2005:	Spring and Fall
1999:	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 ten most recent summers (1996 through 2005), and nine most recent winters (1996-1997, 1997-1998, 1998-1999, 1999-2000, 2000-2001, 2001-2002, 2002-2003, 2003-2004, and 2004-2005). 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 2005.

MSL Beach Widths

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

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

In the SANDAG annual monitoring reports prepared prior to 2002, the onshore boundary of the control volume for both the shorezone and the beach above MSL was placed at the origin of each transect. In 2002, however, the boundary was modified for seven sites that contain seacliffs: DM-0565, SD-0650, SD-0710, CB-0740, CB-0775, CB-0780, and CB-0850. At these locations, the onshore boundary was moved from the top of the seacliff to its base to eliminate the inaccuracies introduced by profiling a steep, uneven cliff face. All of the volume changes reported in Appendix F have been adjusted to reflect this change, including those pertaining to the prior Monitoring Years as well as to 2002 through 2005.

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

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

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

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

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

The values shown in Table 12 were used without modification in 2002, 2003, 2004, and 2005 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

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

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

(continued)

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

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

Notes:
(1) Transect crosses RBSP nourishment site (shown in red type).
(2) Transect locations are indicated in Figures 11a and 11b.
(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.

throughout the period in which the fate of the RBSP fills remains under investigation. In the case of transects added since the inception of the RBSP Monitoring Period (such as SS-0005 and DM-0560), the range of closure was estimated based on nearby transects 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 26 periods:

Winter:

Fall 1997 to Spring 1998
Fall 1998 to Spring 1999
Fall 1999 to Spring 2000
Fall 2000 to Spring 2001
Fall 2001 to Spring 2002
Fall 2002 to Spring 2003
Fall 2003 to Spring 2004
Fall 2004 to Spring 2005

Summer:

Spring 1998 to Fall 1998
Spring 1999 to Fall 1999
Spring 2000 to Fall 2000
Spring 2001 to Fall 2001
Spring 2002 to Fall 2002
Spring 2003 to Fall 2003
Spring 2004 to Fall 2004
Spring 2005 to Fall 2005

Annual:

Fall 1997 to Fall 1998
Fall 1998 to Fall 1999
Fall 1999 to Fall 2000
Fall 2000 to Fall 2001
Fall 2001 to Fall 2002
Fall 2002 to Fall 2003
Fall 2003 to Fall 2004
Fall 2004 to Fall 2005

Long-term:

Fall 1997 to Fall 2000 (Pre-RBSP)
Fall 2000 to Fall 2005 (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 26 periods as changes in shorezone volume.

4.1.2. Aerial Photographs (Section 5)

Representative aerial photographs obtained at the twelve RBSP receiver sites between 2001 and 2005 are provided in Section 5. A more extensive set of aerial photographs covering the twelve sites was provided to SANDAG in digital form following each overflight.

4.2. Lagoon Entrance Data

Lagoon entrance data acquisition consisted of semi-annual oblique aerial photography at all five entrances, topographic data at all five entrances during Spring 2005 only, and monthly observations and photographs at the unstabilized entrances to San Elijo, San Dieguito, and Los Peñasquitos.

4.2.1. Topographic Data (Appendix G)

The Spring 2005 lagoon entrance monitoring data are presented in graphical form in **Appendix G**. For Agua Hedionda and Batiquitos, all channel cross-sections obtained since Fall 2000 are displayed with those from Spring 2005 to illustrate the changes in configuration. In the case of the three unstabilized entrances (San Elijo, San Dieguito, and Los Peñasquitos), contour maps were prepared to illustrate the condition of the channel at the time of the Spring 2005 survey.

4.2.2. Aerial Photographs (Section 6)

Representative aerial photographs obtained at the five lagoon entrances between 2001 and 2005 are provided in Section 6. A more extensive set of aerial photographs covering the five sites was provided to SANDAG in digital form following each overflight.

4.2.3. Inspection Results (Appendix H)

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 H**.

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 2005 Monitoring Year (November 2004 through October 2005), and the entire RBSP Monitoring Period (November 2000 through October 2005). Section 5.1 provides a regional overview, while Section 5.2 summarizes the performance of the twelve RBSP beach fills. To insure that the findings are directly comparable, all of the statistical characterizations of shoreline and volume changes are derived from the 44 transects with measurements dating back to Fall 2000 (*i.e.*, predating the RBSP Monitoring Period).

5.1. Regional Overview

During the 2005 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, with volume gains and losses nearly balanced among the survey transects. In contrast, the trend toward shoreline retreat first identified in 2003 persisted. The apparent paradox created by a stable shorezone volume and a retreating shoreline may be explained by the fact that sediment continued to move from the subaerial portion of the profile to the submerged portion, but remained within the shorezone.

The predominance of shoreline retreat appears to be attributable to the offshore dispersal of the RBSP fill material coupled with a lack of beach nourishment activities (other than the material placed offshore in the Silver Strand Cell in 2005). Despite above-average precipitation and high streamflows during the 2005 Monitoring Year, the profile data suggest that sediment input from rivers and streams was relatively modest. The stability of the shorezone sediment volume implies that the limited nourishment, lack of substantial riverine sediment input, and relatively mild wave conditions neither added or removed significant quantities of material from the coast.

After three consecutive years of shoreline retreat (2003, 2004, and 2005), the beach widths at most locations in the Silver Strand and Oceanside Cells had diminished to such an extent that they were less than the pre-RBSP values for the first time since placement of the nourishment material. In the Mission Beach Cell, the changes in beach width over the RBSP Monitoring Period were balanced between losses and gains. Notwithstanding the prevalence of shoreline retreat relative to the pre-RBSP condition in two of the three littoral cells, sediment volumes tended to increase over the five-year RBSP Monitoring Period. The greatest shorezone volume gains occurred in the Oceanside Cell. The primary causes of

these gains appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period.

5.1.1. Shoreline and Subaerial Volume Changes

The changes in MSL shoreline position that occurred during the 2005 Monitoring Year and the entire RBSP Monitoring Period are summarized in Figures 13a and b and Table 13. Detailed supporting data appear in Appendix E.

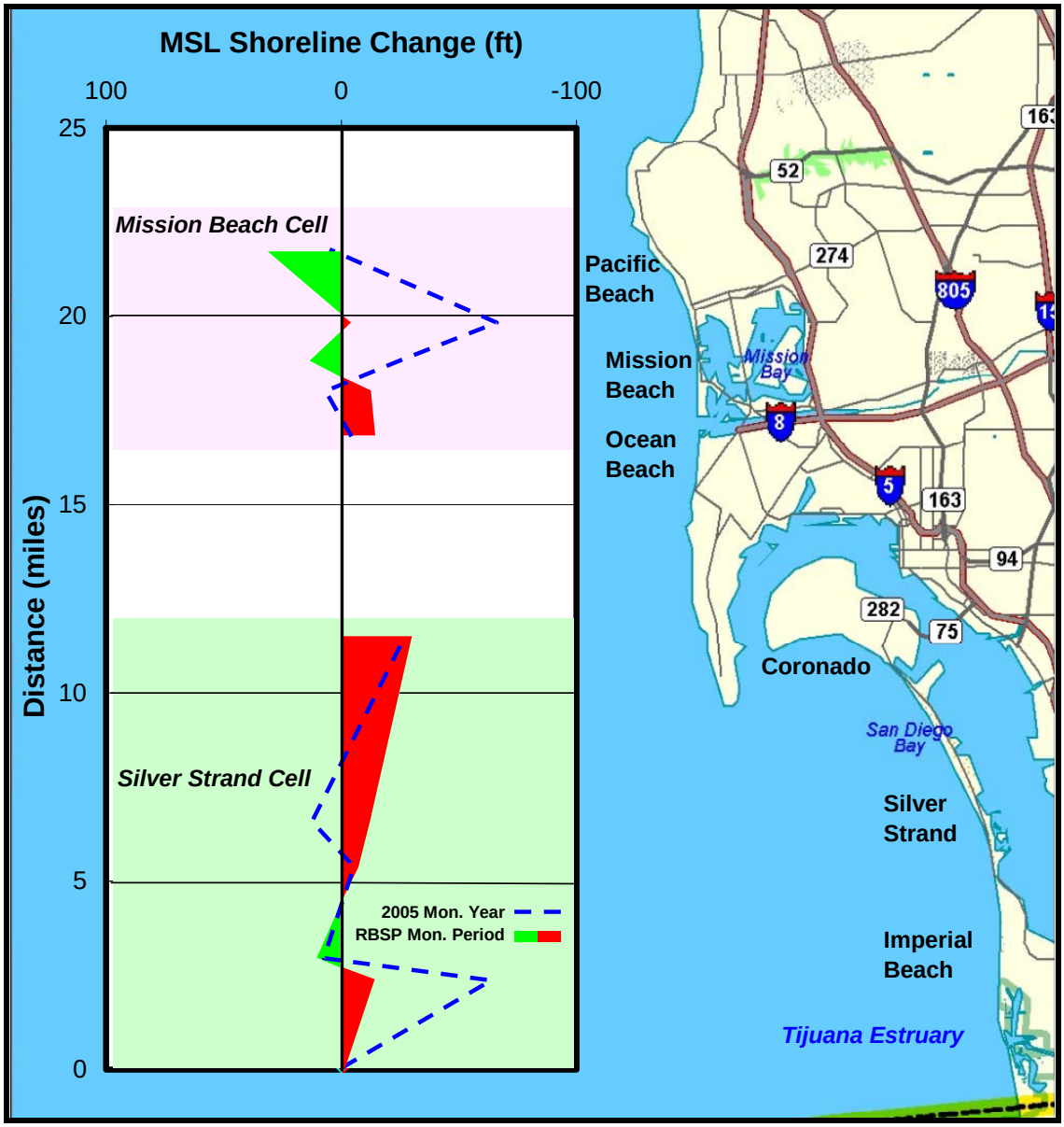


Figure 13a. MSL Shoreline Changes during the 2005 Monitoring Year and RBSP Monitoring Period in the Silver Strand and Mission Beach Littoral Cells

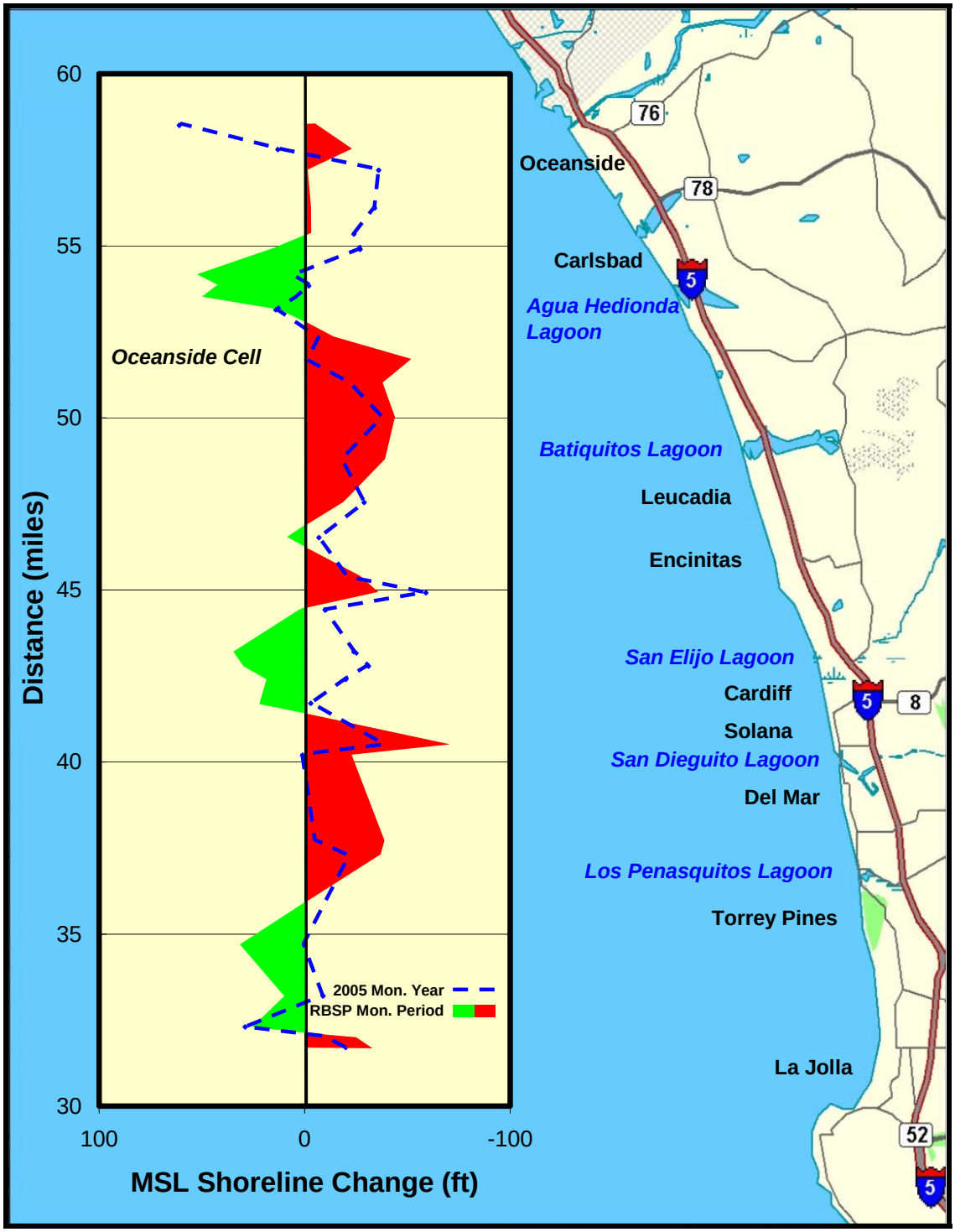


Figure 13b. MSL Shoreline Changes during the 2005 Monitoring Year and RBSP Monitoring Period in the Oceanside Littoral Cell

Table 13. MSL Shoreline Changes during the 2005 Monitoring Year and RBSP Monitoring Period [1]

Littoral Cell	MSL Shoreline Change (no. of transects)			Average Change (ft)
	Advance	No Change[2]	Retreat	
Silver Strand Cell				
2005 Mon. Year	1	3	2	-13
RBSP Mon. Period[3]	1	2	3	-9
Mission Beach Cell				
2005 Mon. Year	0	3	2	-16
RBSP Mon. Period[3]	2	1	2	+3
Oceanside Cell				
2005 Mon. Year	4	13	16	-12
RBSP Mon. Period[3]	11	7	15	-5
All Cells Combined				
2005 Mon. Year	5	19	20	-12
RBSP Mon. Period[3]	14	10	20	-5

Note: [1] Shoreline change statistics are derived from the 44 transects with measurements dating back to Fall 2000.
[2] "No Change" indicates a shoreline change of 10 ft or less.
[3] RBSP Monitoring Period extends from November 2000 through October 2005.

As indicated above, 2005 marked a turning point in that more beaches evidenced shoreline retreat than advance relative to the pre-RBSP condition for the first time since completion of the nourishment activities in 2001. When the three littoral cells are considered together, the breakdown of shoreline changes during the five-year RBSP Monitoring Period is as follows:

- 14 transects (32%) exhibited shoreline advance in excess of 10 ft;
- 10 transects (23%) exhibited essentially no shoreline change (10 ft or less);
- 20 transects (45%) exhibited shoreline retreat in excess of 10 ft.

The average shoreline change during this period was a loss of 5 ft. This value reflects a 9-ft average retreat for the six transects in the Silver Strand Cell, a 3-ft average advance for the five transects in the Mission Beach Cell, and a 5-ft average retreat for the 33 transects in the Oceanside Cell.

Time series of the average shoreline change at the time of each Fall Survey relative to the pre-RBSP condition (Fall 2000) are presented for the three littoral cells and the entire region in Figure 14. Substantial shoreline advance occurred in 2001 in each cell in response to the RBSP. In the Oceanside Cell, additional gains were realized in 2002 as the RBSP fill material dispersed alongshore. Shoreline retreat then followed during the last three years, suggesting an ongoing loss of the fill material from the subaerial beach. A similar pattern is absent in the Mission Beach and Silver Strand Cells, perhaps due to the relatively small nourishment quantities and the use of only one receiver site in each of these cells. The shoreline gain was short-lived in the Silver Strand Cell, but has persisted in the Mission Beach Cell. Despite the recent nourishment at Imperial Beach, shoreline gains in the Silver Strand Cell are conspicuously absent in 2005.

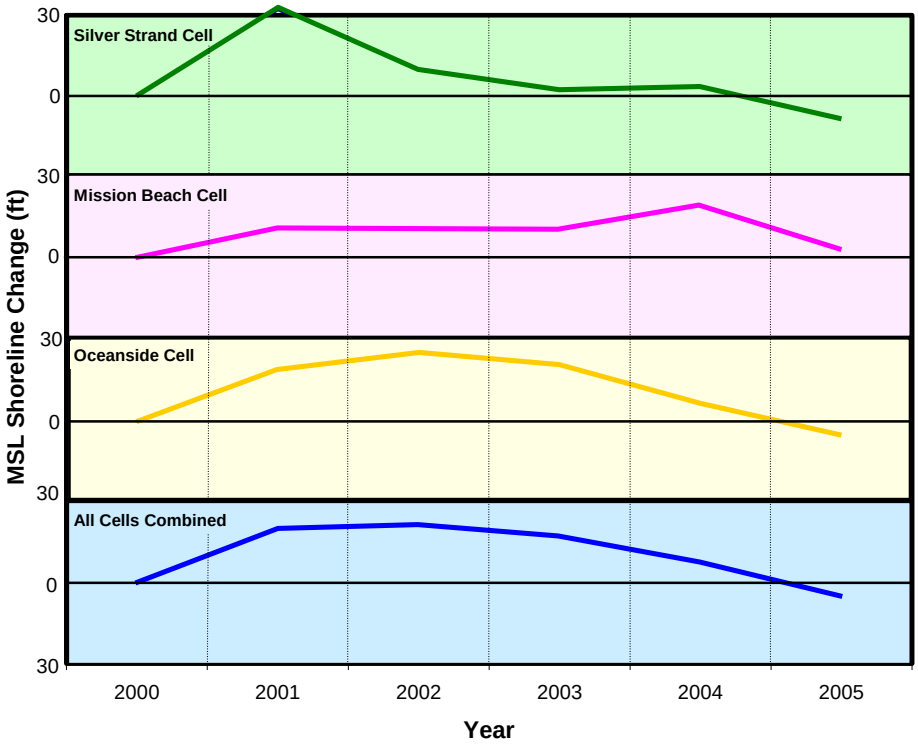
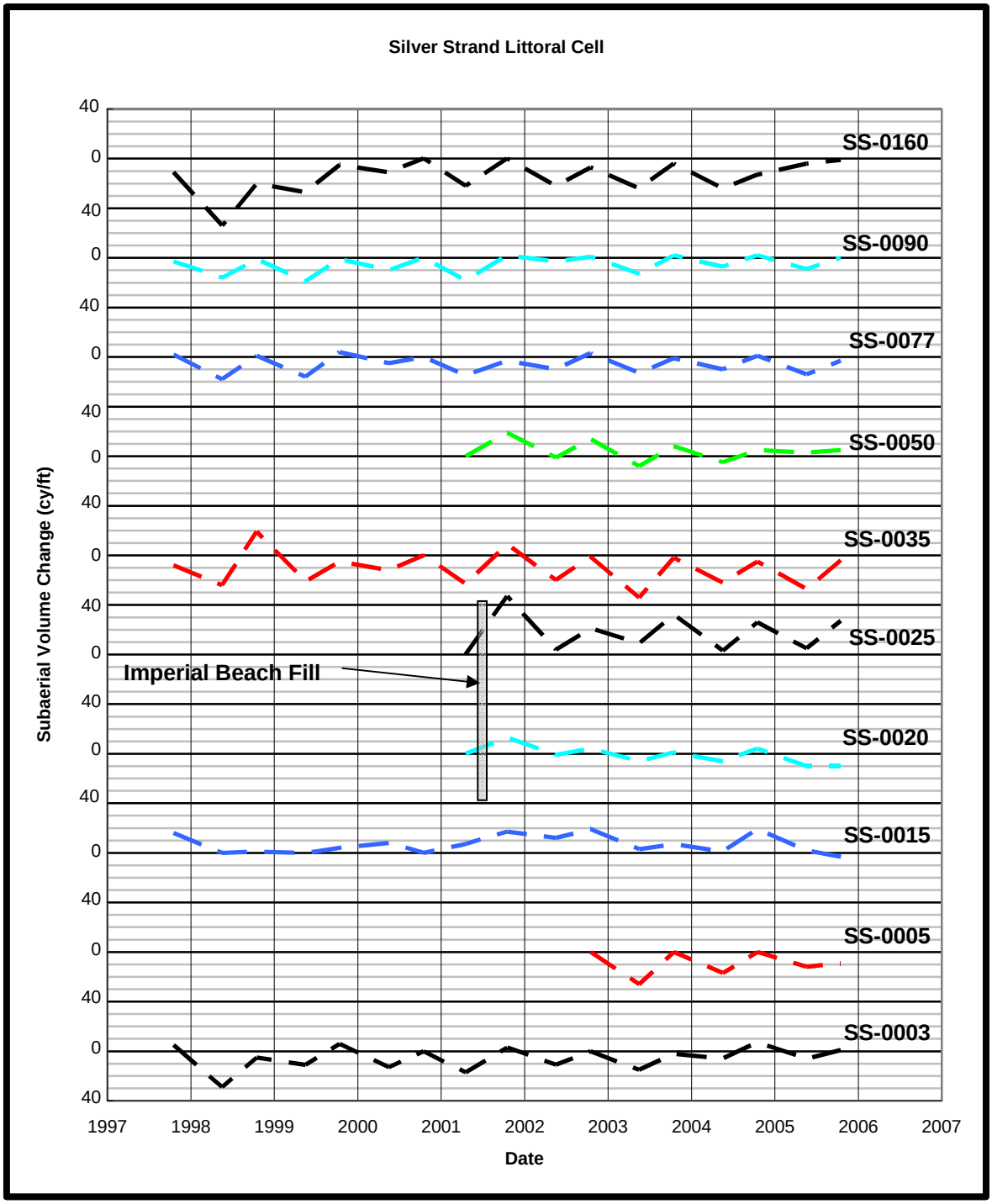


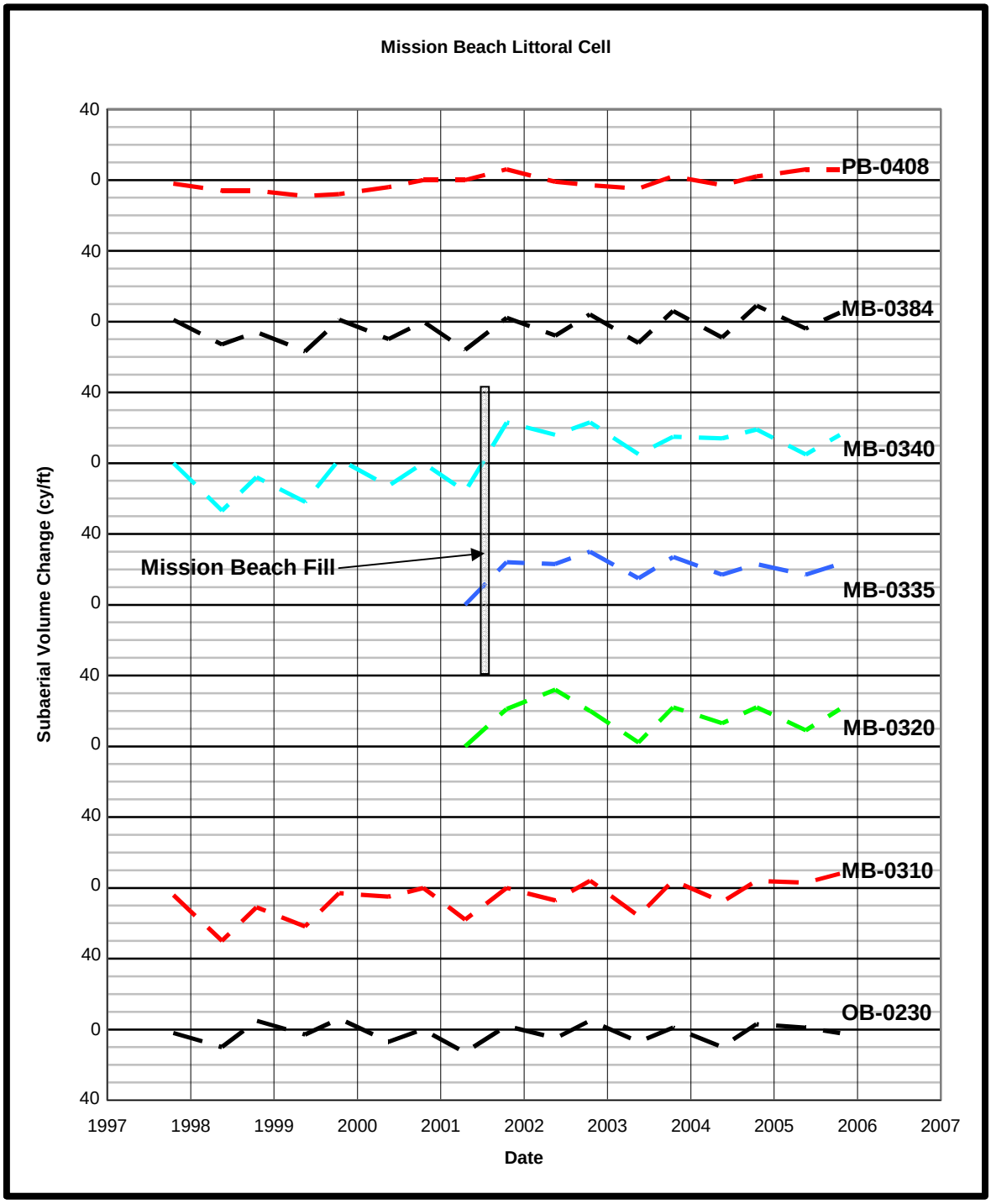
Figure 14. Time Series of Average MSL Shoreline Change Relative to Pre-RBSP Condition

Figures 15a, b, and c present time series of the changes in subaerial sediment volume (above MSL) that occurred between Fall 1997 and Fall 2005. In the case of the 44 transects that pre-dated the RBSP Monitoring Period, the changes were reckoned from the volumes that prevailed in Fall 2000. Hence, if the volume change in Fall 2005 exceeds zero, the subaerial volume has increased during the RBSP Monitoring Period. In the case of the 17 transects that were added to the monitoring program after Fall 2000, the changes were reckoned from the volumes that prevailed at the time of the initial survey.



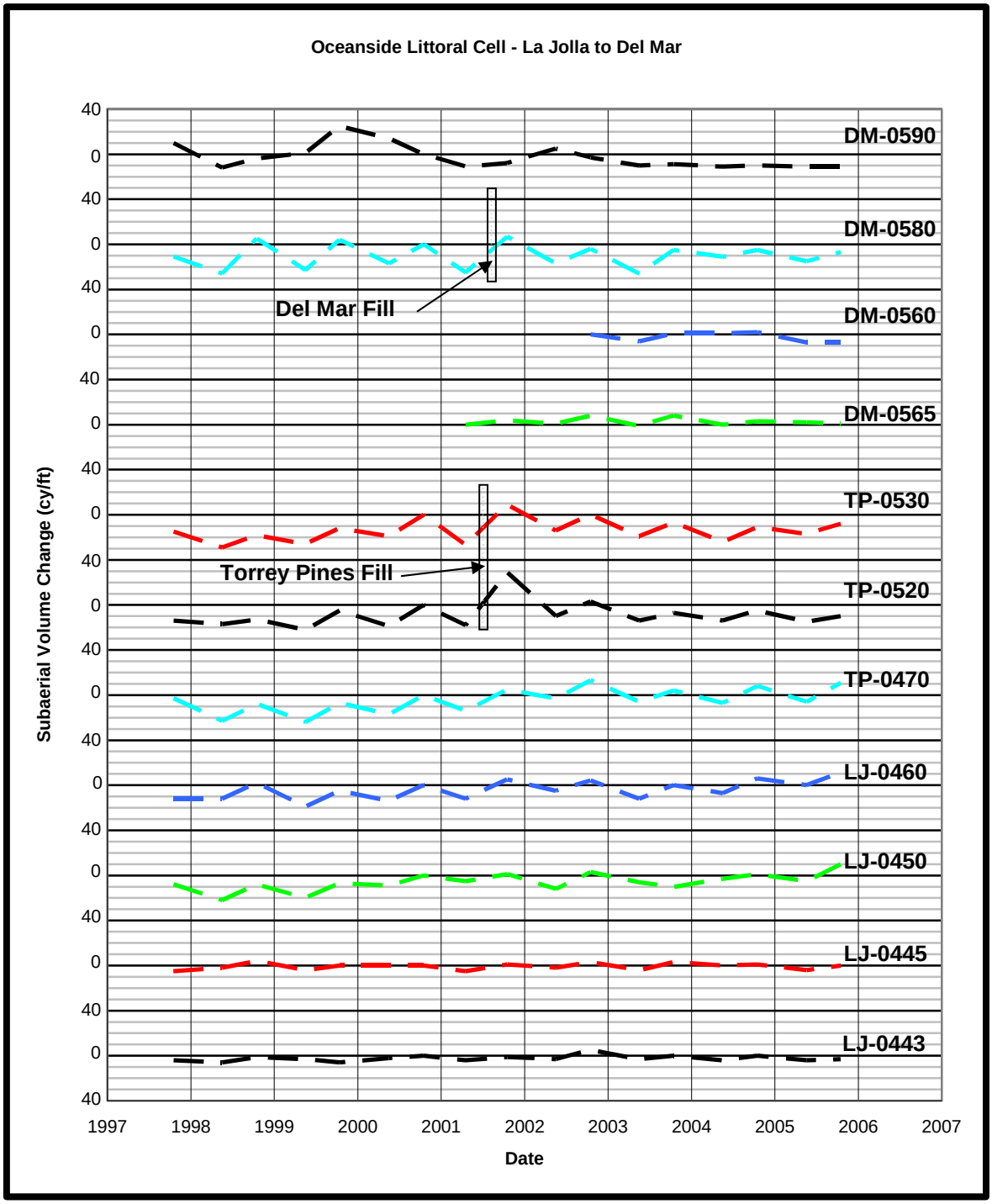
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 15a. Time Series of Subaerial Volume Change in the Silver Strand Littoral Cell



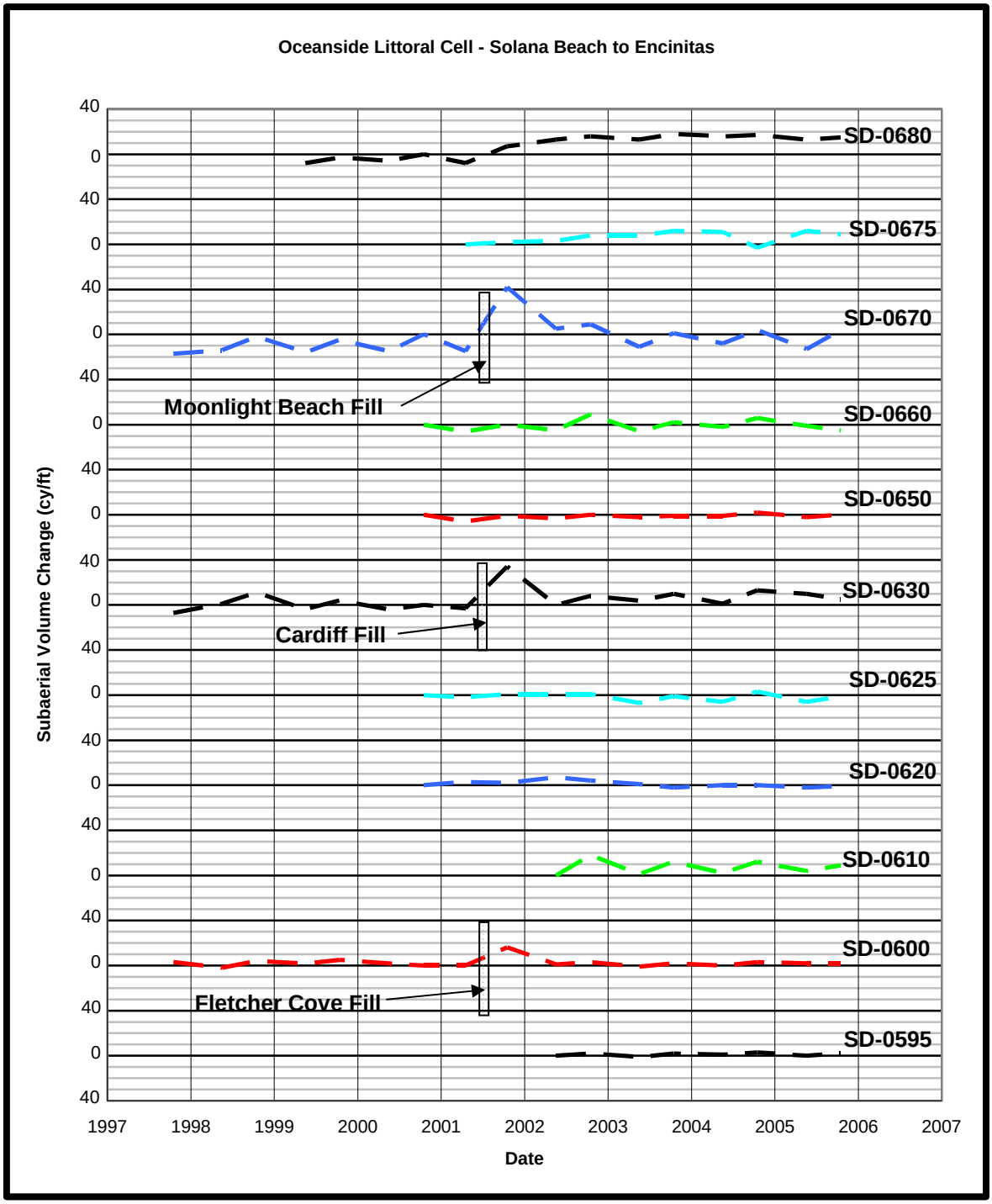
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 15b. Time Series of Subaerial Volume Change in the Mission Beach Littoral Cell



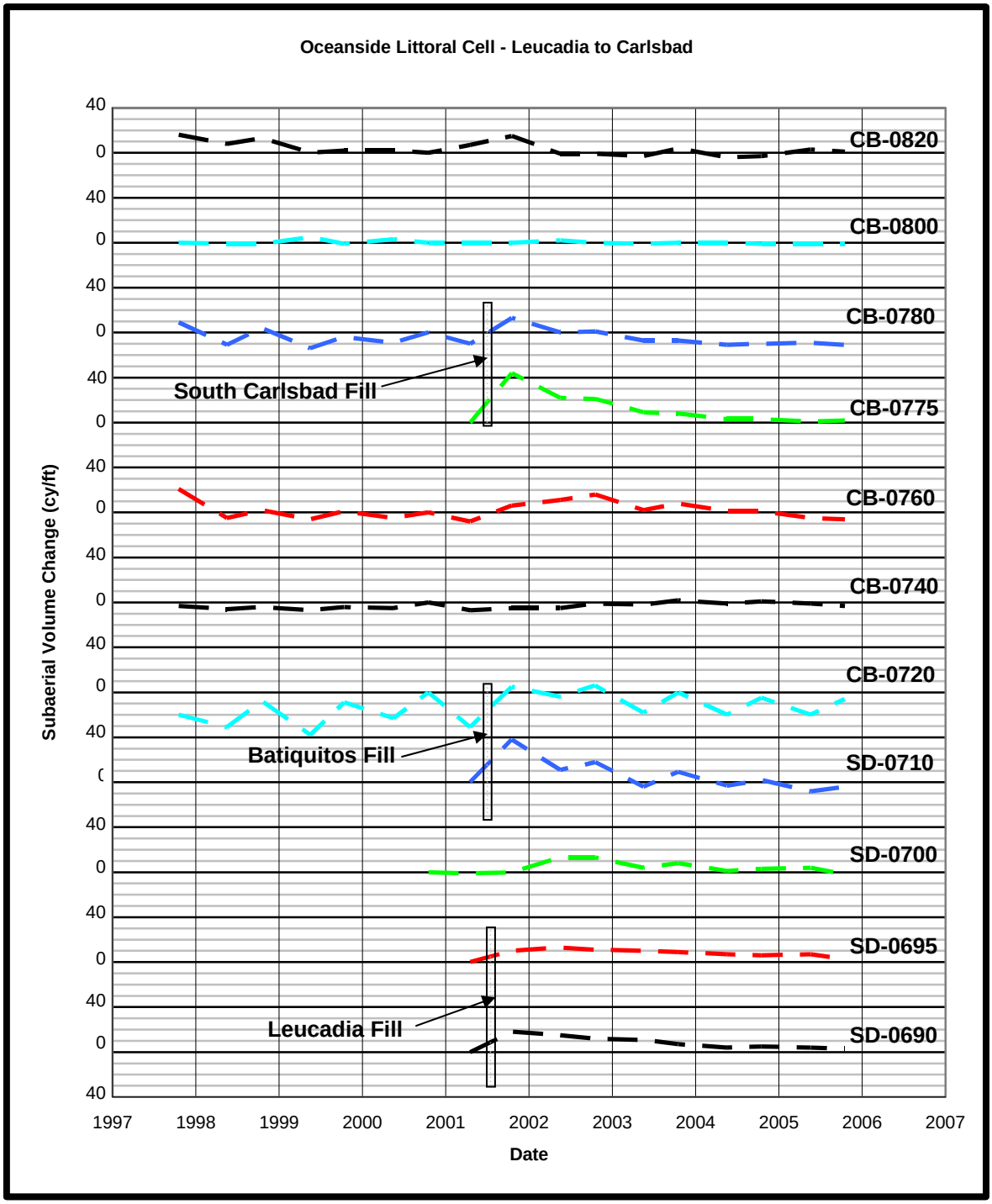
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 15c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 1 of 4)



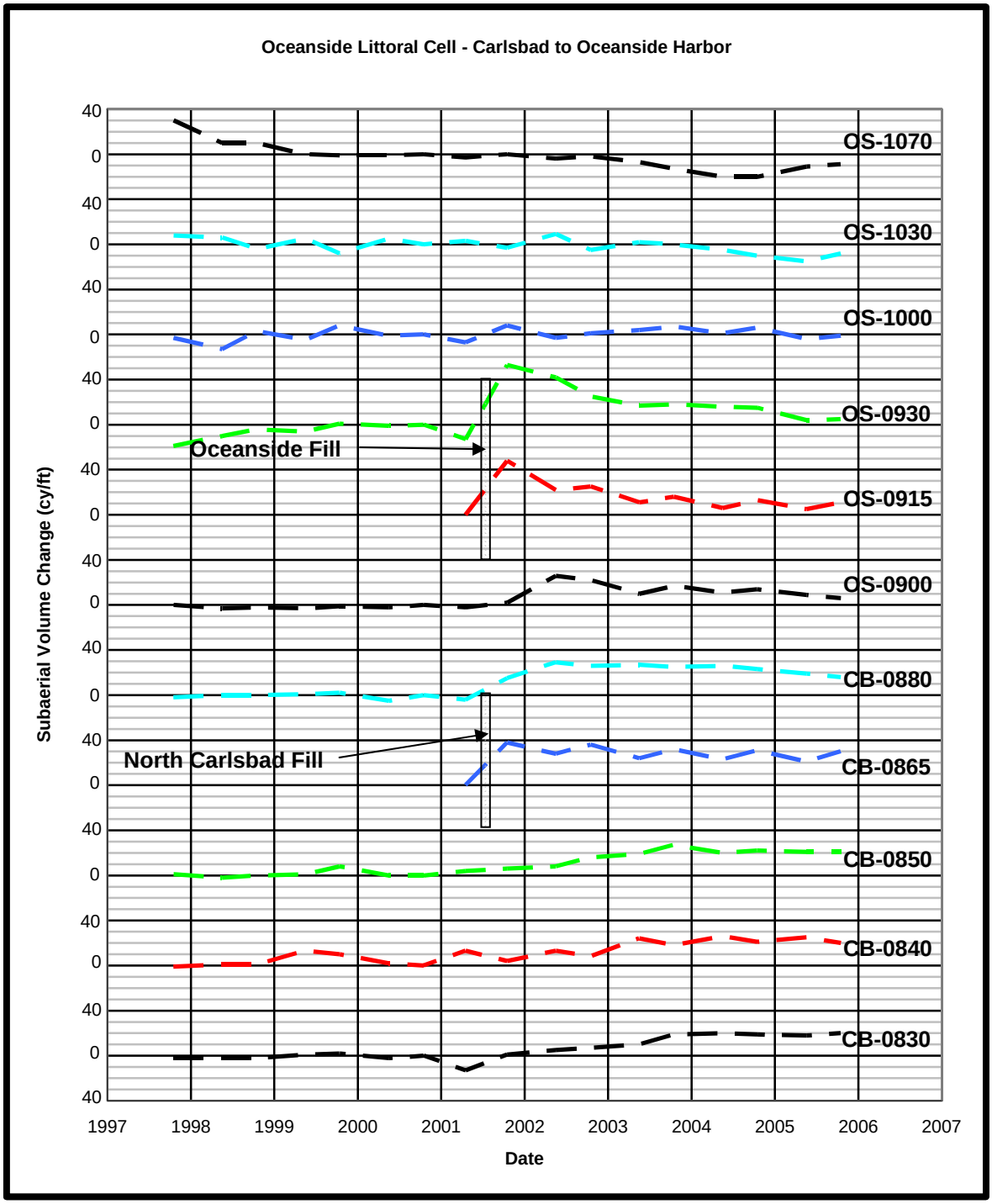
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 15c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 2 of 4)



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

Figure 15c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 3 of 4)



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

Figure 15c. Time Series of Subaerial Volume Change in the Oceanside Littoral Cell (page 4 of 4)

Noteworthy aspects of the time series plots are summarized below:

- A strong seasonal signal is evident on most of the transects, with the subaerial volume increasing during the summer months and decreasing during the winter months. This trend is consistent with the anticipated seasonal oscillation in the direction of cross-shore transport: onshore in summer and offshore in winter.
- A significant increase in subaerial volume occurred at the time of fill placement at all RBSP receiver sites except Del Mar. In some cases, such as Fletcher Cove, the gain was quickly reversed; in others, such as Oceanside, North Carlsbad, Leucadia, and Mission Beach, the subaerial volume at the time of the Fall 2005 survey remained above that which preceded the nourishment program.

5.1.2. Beach Widths

In Figures 16a and b, the MSL beach widths measured in Spring 2005 and Fall 2005 are compared with the envelope of widths measured prior to the RBSP (Spring 1996-Spring 2001 or Spring 1997-Spring 2001, to the extent that data are available). At more than 20% of the transects with measurements dating back to 1997 (8 of 38 transects), the beach width in Fall 2005 exceeded that noted in any of the pre-RBSP years. The largest increase relative to the pre-RBSP envelope, 50 ft, occurred in Cardiff on Transect SD-0630 at the time of the Spring 2005 Survey. At only one location, the beach width in Spring 2005 fell below the pre-RBSP envelope: a 23-ft shortfall at Transect OS-1030 (Oceanside).

5.1.3. Shorezone Volume Changes

Figures 17a and b and Table 14 present the volume changes that occurred in the shorezone (inside the range of closure) during the 2005 Monitoring Year and the entire RBSP Monitoring Period. The supporting data are provided in Appendix F.

During the 2005 Monitoring Year, gains and losses in shorezone volume were equally balanced among the 44 transects that pre-dated the RBSP Monitoring Period. The net result was an average gain of +4 cy/ft in the Mission Beach Cell and no change in the Oceanside Cell. This stability is consistent with the absence of sediment input from nourishment activities and sediment removal from severe storm events. It also implies that despite the heavy rainfall in 2005, the rivers and coastal lagoons did not contribute significant quantities of sediment to the shorezone. In Silver Strand Cell, where 301,000 cy of sediment were placed offshore in 2005, the average gain was 26 cy/ft.

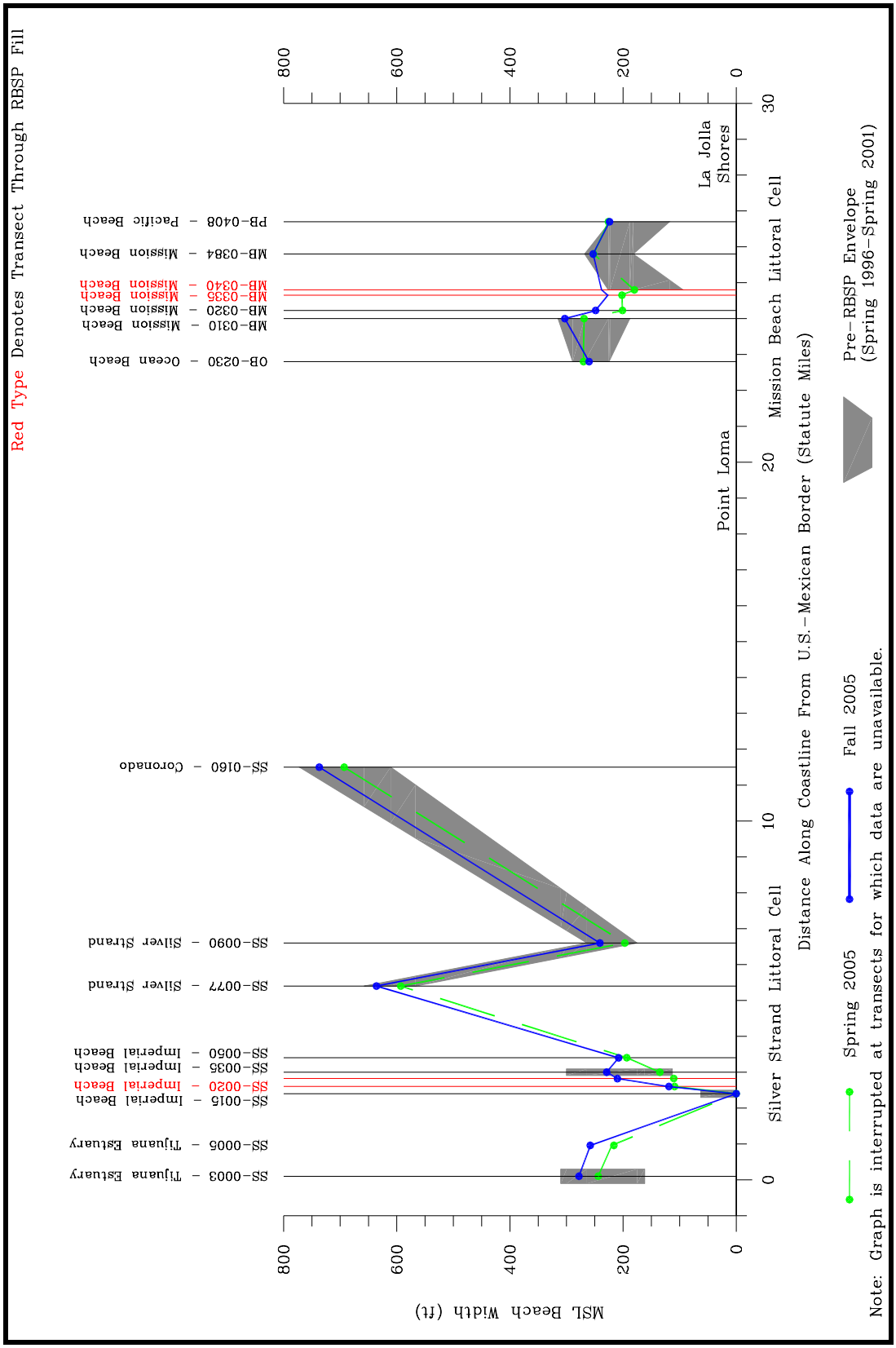


Figure 16a. Comparison of 2005 MSL Beach Widths with the Pre-RBSP Envelope in the Silver Strand and Mission Beach Littoral Cells

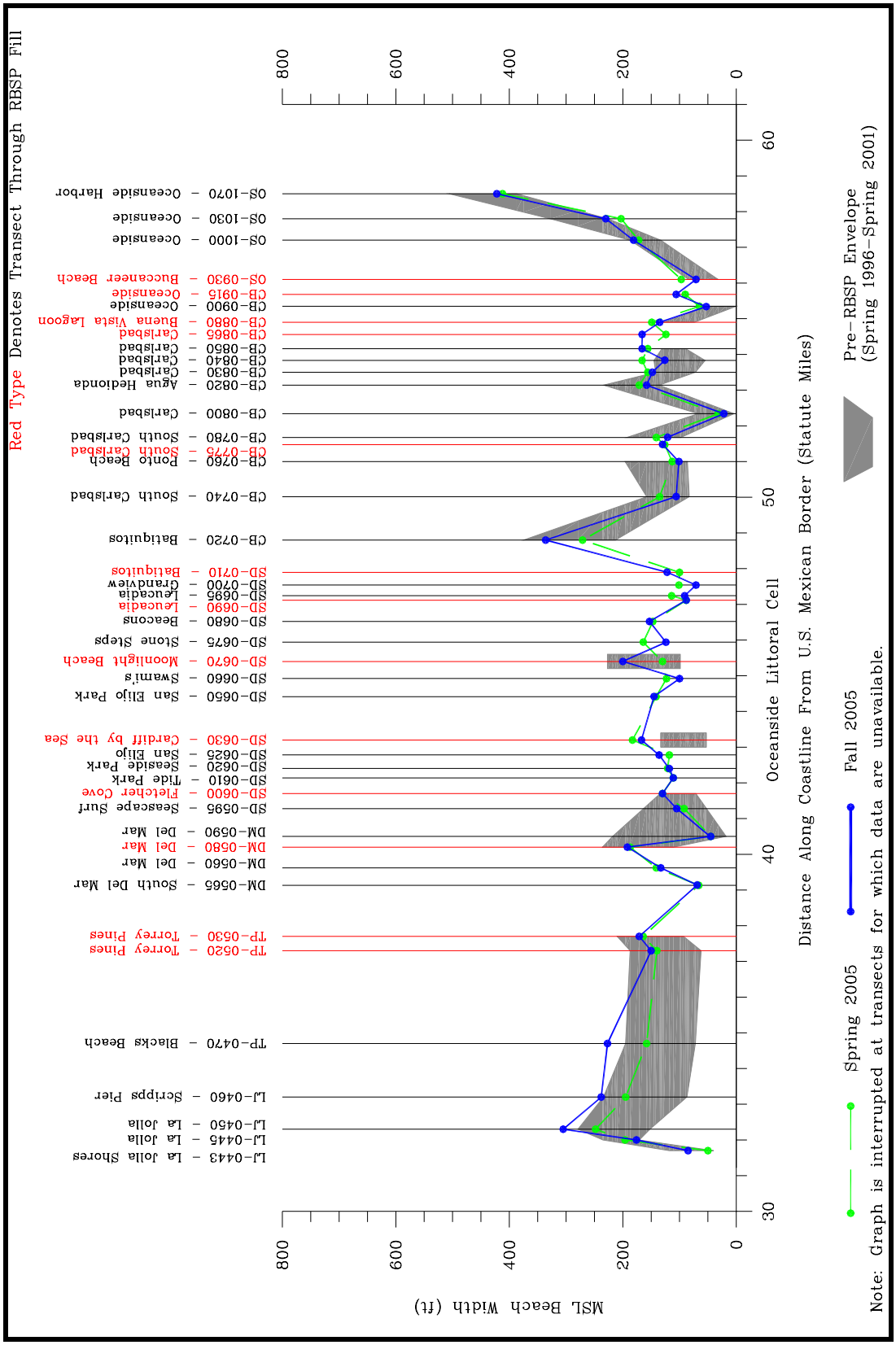


Figure 16b. Comparison of 2005 MSL Beach Widths with the Pre-RBSP Envelope in the Oceanside Littoral Cell

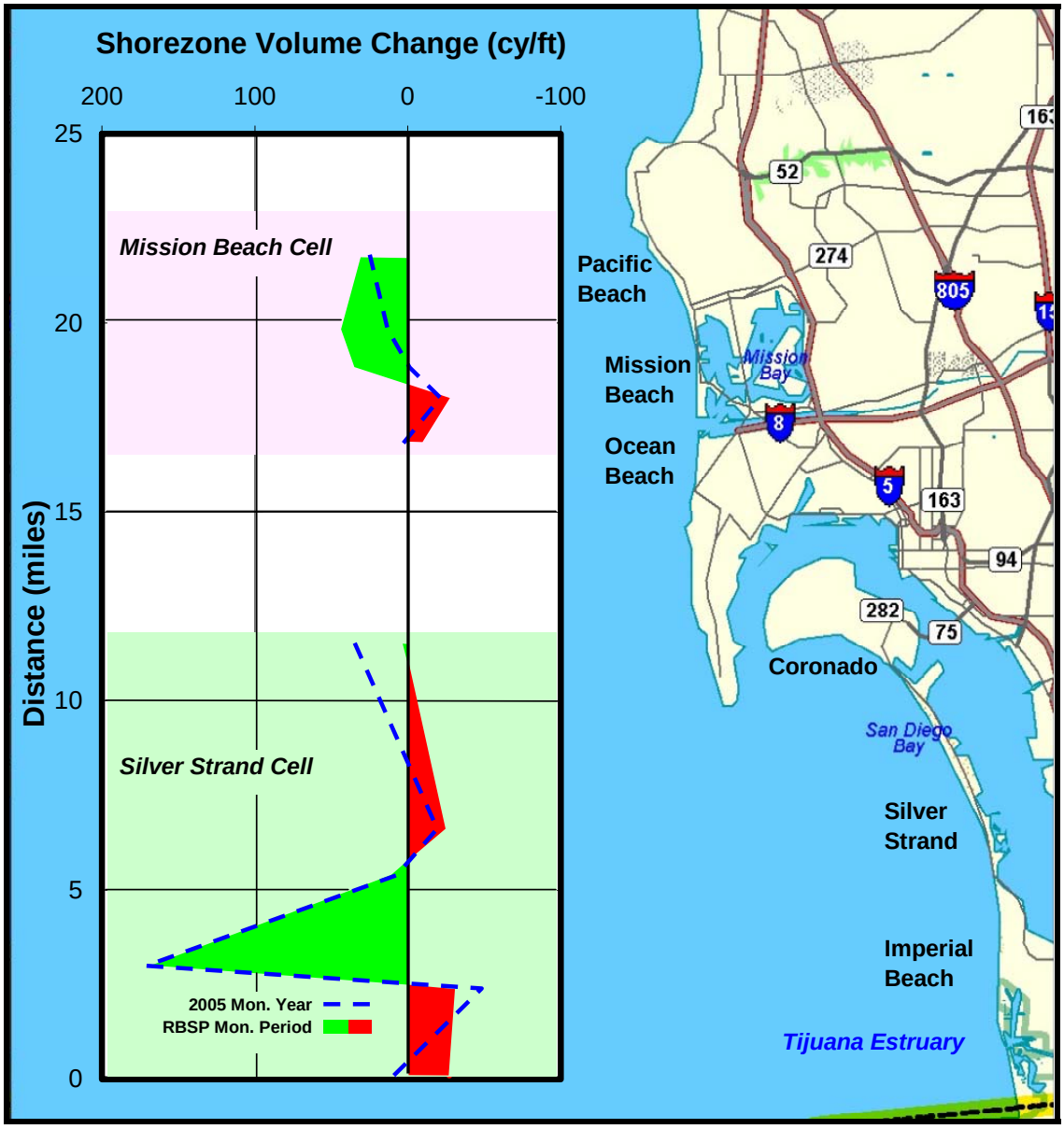


Figure 17a. Shorezone Volume Changes during the 2005 Monitoring Year and RBSP Monitoring Period in the Silver Strand and Mission Beach Littoral Cells

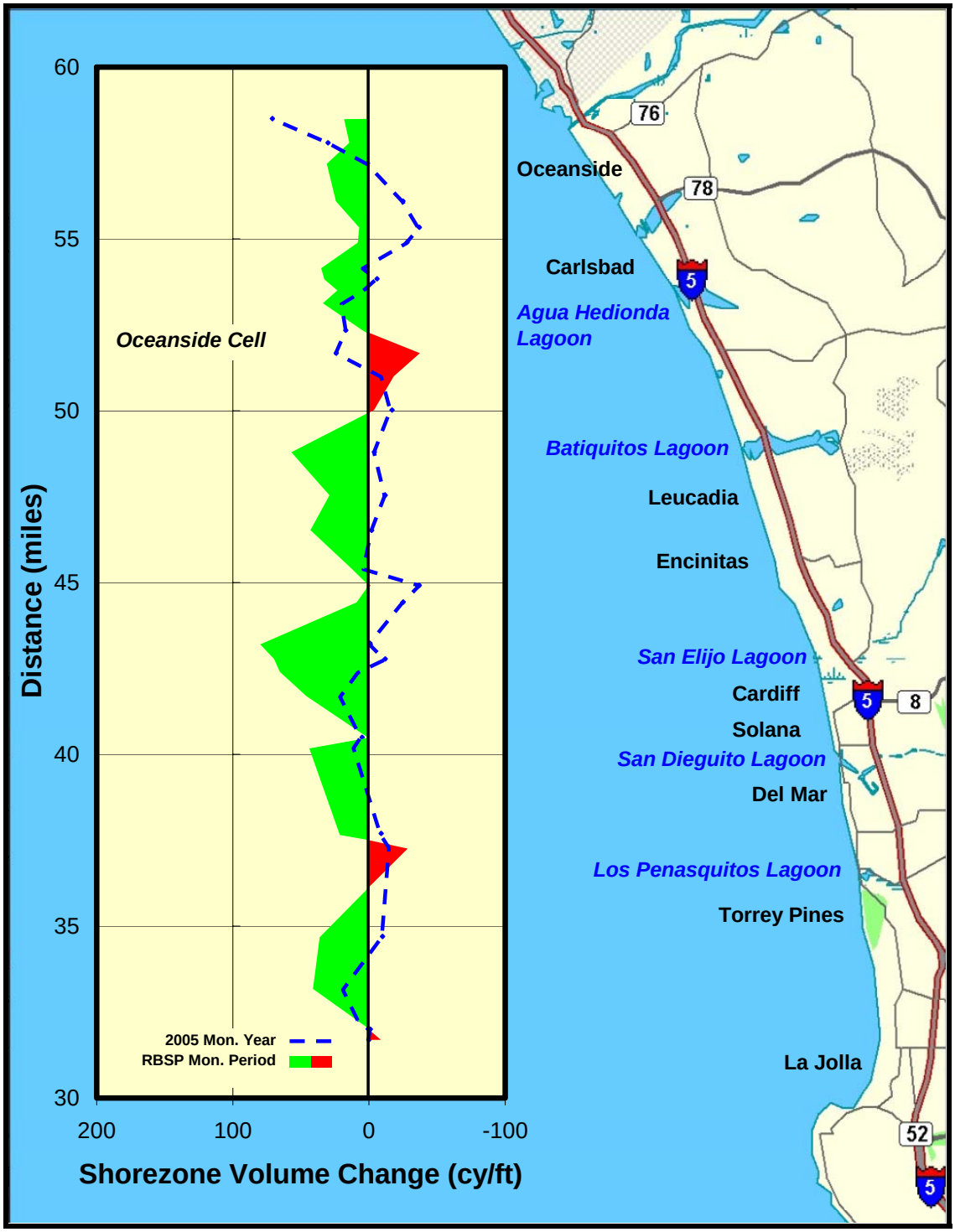


Figure 17b. Shorezone Volume Changes during the 2005 Monitoring Year and RBSP Monitoring Period in the Oceanside Littoral Cell

The lack of significant volume changes in the Oceanside and Mission Bay Cells during the past year contrasts with the net increase in shorezone volume that occurred over the entire RBSP Monitoring Period. When the three littoral cells are considered together, the breakdown of volume changes during the five-year period is as follows:

- 25 transects (57%) exhibited gains in excess of 10 cy/ft;
- 12 transects (27%) exhibited essentially no change (10 cy/ft or less);
- 7 transects (16%) exhibited losses in excess of 10 cy/ft.

Table 14. Shorezone Volume Changes during the 2005 Monitoring Year and RBSP Monitoring Period[1]

Littoral Cell	Shorezone Volume Change (no. of transects)			Average Change (cy/ft)
	Increase	No Change[2]	Decrease	
Silver Strand Cell				
2005 Mon. Year	2	2	2	+26
RBSP Mon. Period[3]	2	1	3	+17
Mission Beach Cell				
2005 Mon. Year	2	2	1	+4
RBSP Mon. Period[3]	3	1	1	+14
Oceanside Cell				
2005 Mon. Year	8	16	9	0
RBSP Mon. Period[3]	20	10	3	+21
All Cells Combined				
2005 Mon. Year	12	20	12	+4
RBSP Mon. Period[3]	25	12	7	+20

Note: [1] Volume change statistics are derived from the 44 transects with measurements dating back to Fall 2000.
[2] "No Change" indicates a volume change of 10 cy/ft or less.
[3] RBSP Monitoring Period extends from November 2000 through October 2005.

The average change in shorezone volume during this period was a gain of 20 cy/ft, reflecting average gains of 21 cy/ft in the Oceanside Cell, 14 cy/ft in the Mission Beach Cell, and 17 cy/ft in the Silver Strand Cell.

Time series of the average shorezone volume change at the time of the Fall Survey relative to the pre-RBSP condition (Fall 2000) are presented for each littoral cell and the entire region in Figure 18. The sediment volume gains that occurred in the Oceanside and

Mission Beach Cells following the RBSP persisted with minimal change through 2005. In the Silver Strand Cell, the shorezone volume decreased following the RBSP, and remained below the pre-RBSP value until after the recent nourishment activities in 2005. The initial losses in this cell may reflect the fact that the two transects located within the Imperial Beach fill do not pre-date the RBSP Monitoring Period. Hence the volume changes at these transects were not included in the statistics. In addition, the 120,000 cy RBSP fill was only modestly larger than the average historical nourishment rate of 73,000 cy/yr (Table 8).

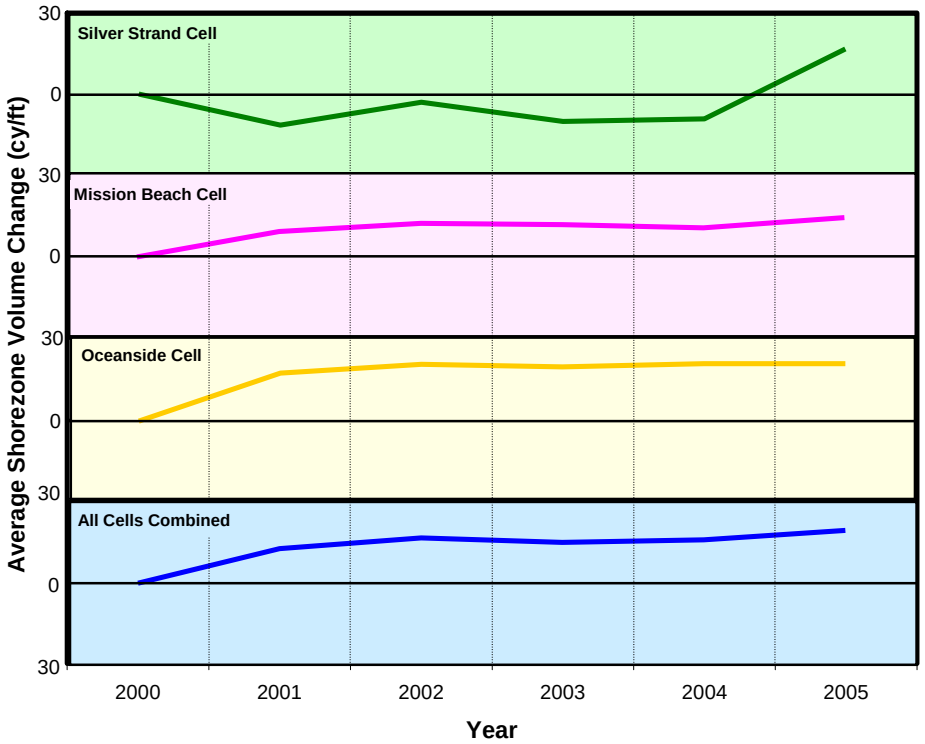
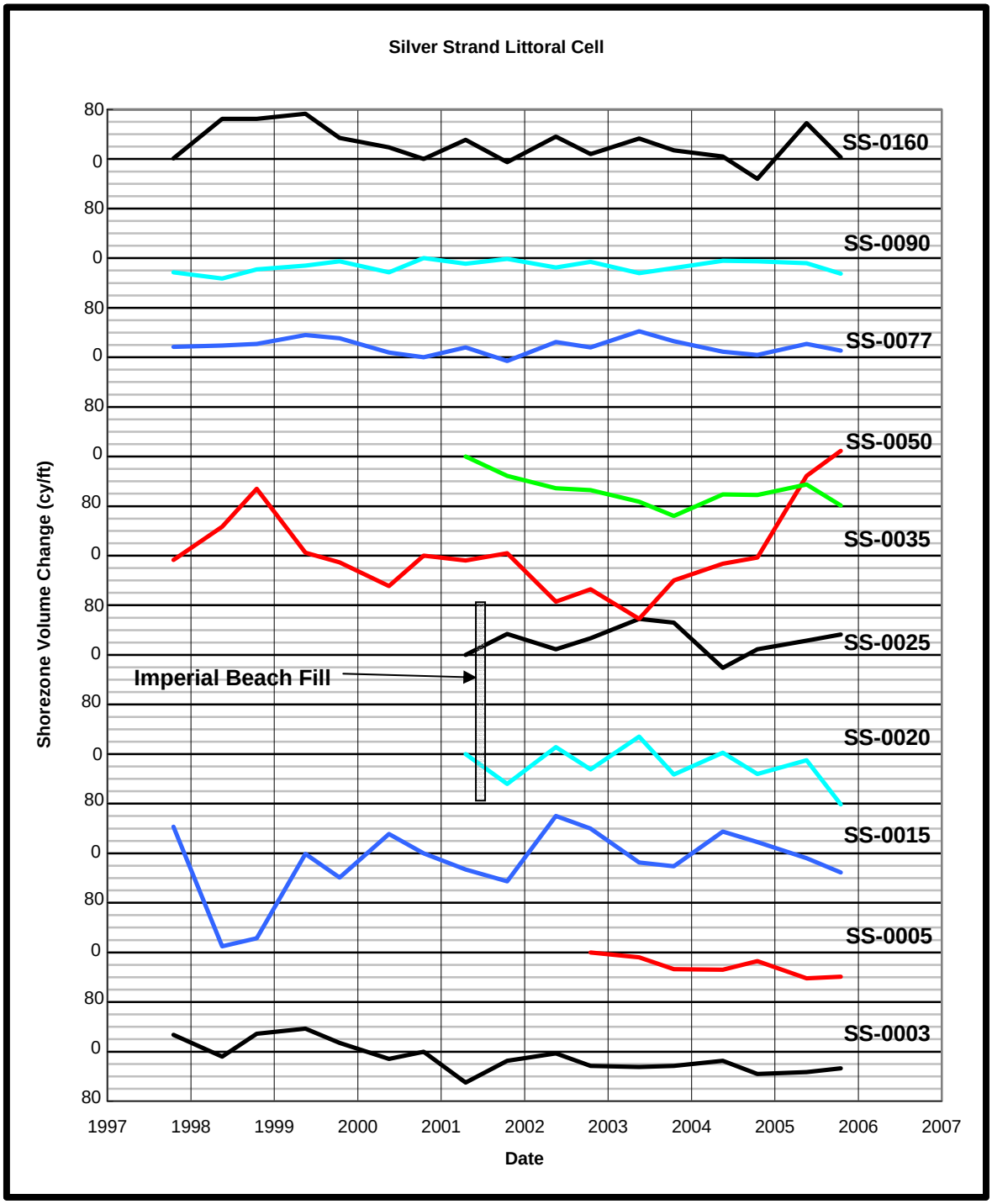


Figure 18. Time Series of Average Shorezone Volume Change Relative to Pre-RBSP Condition

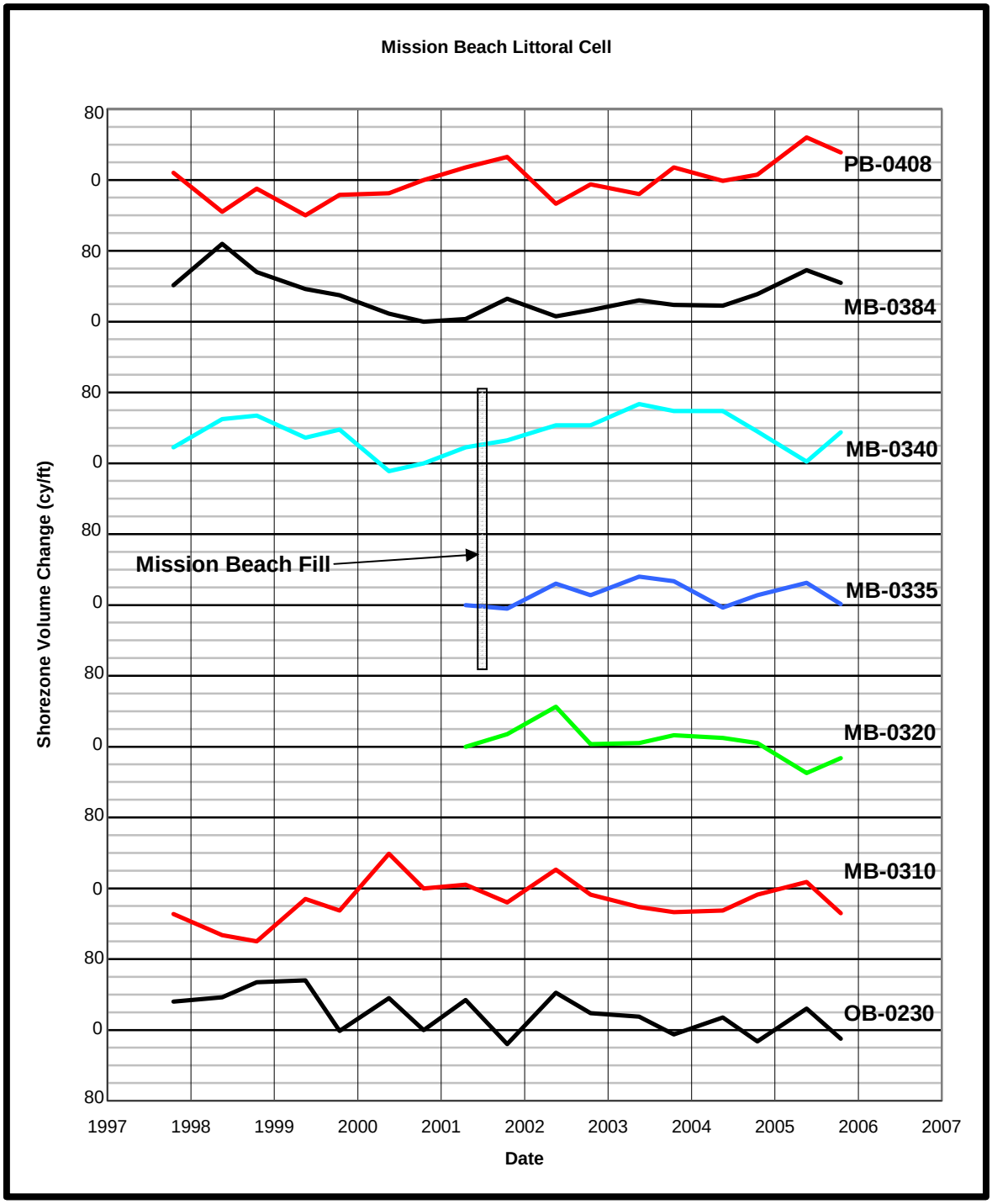
Figures 19a, b, and c present time series of the changes in shorezone sediment volume that occurred between Fall 1997 and Fall 2005. As in the case of Figures 15a, b, and c, the changes were reckoned from the volumes that prevailed at the beginning of the RBSP Monitoring Period (Fall 2000) whenever possible, or from the volumes that prevailed at the time of the initial survey for transects first profiled after Fall 2000. Key points are summarized below:

- A significant increase in shorezone volume occurred at the time of fill placement at each of the twelve RBSP receiver sites. At some of these beaches, such as Torrey Pines, Moonlight, and South Carlsbad, the gains



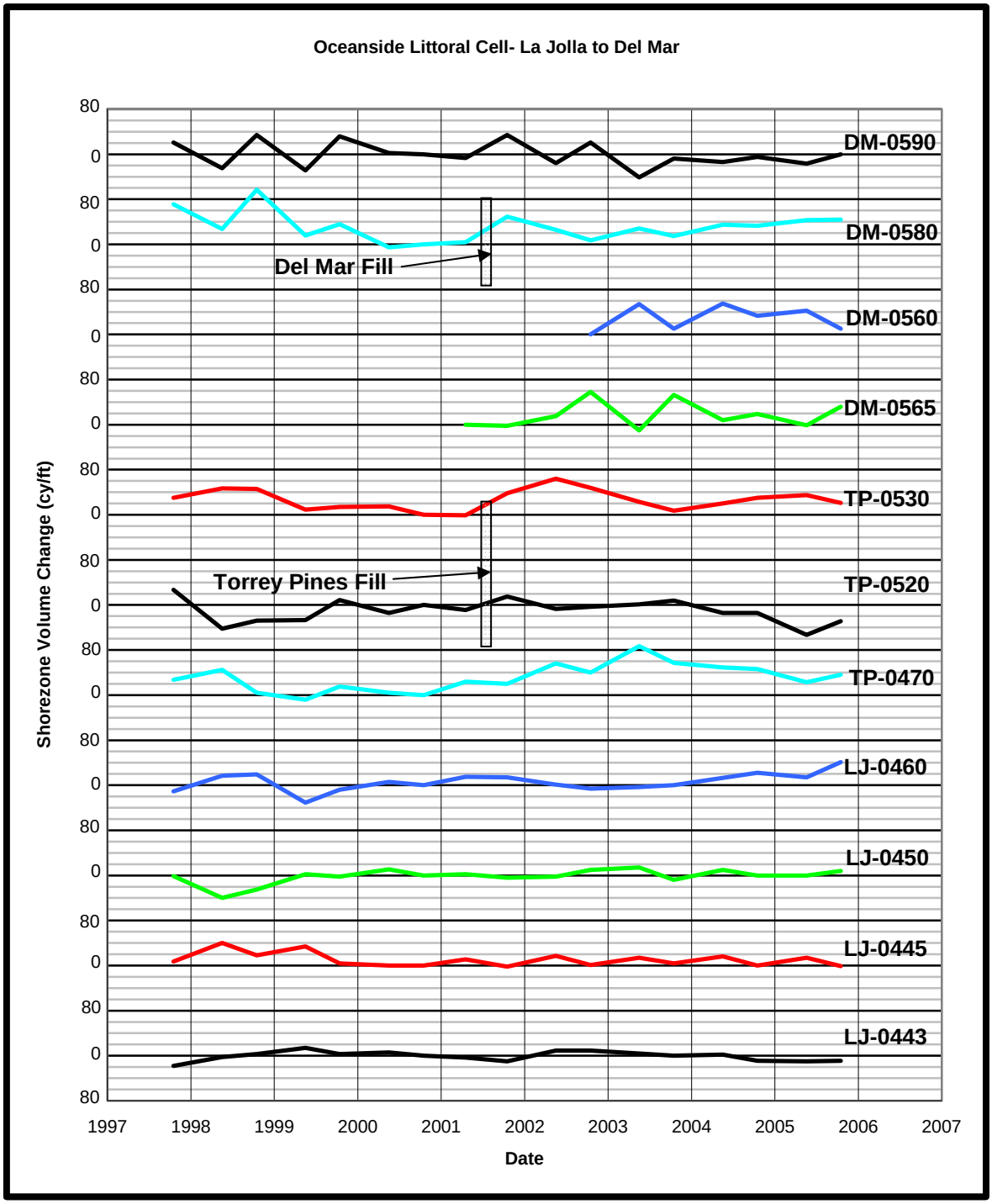
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 19a. Time Series of Shorezone Volume Change in the Silver Strand Littoral Cell



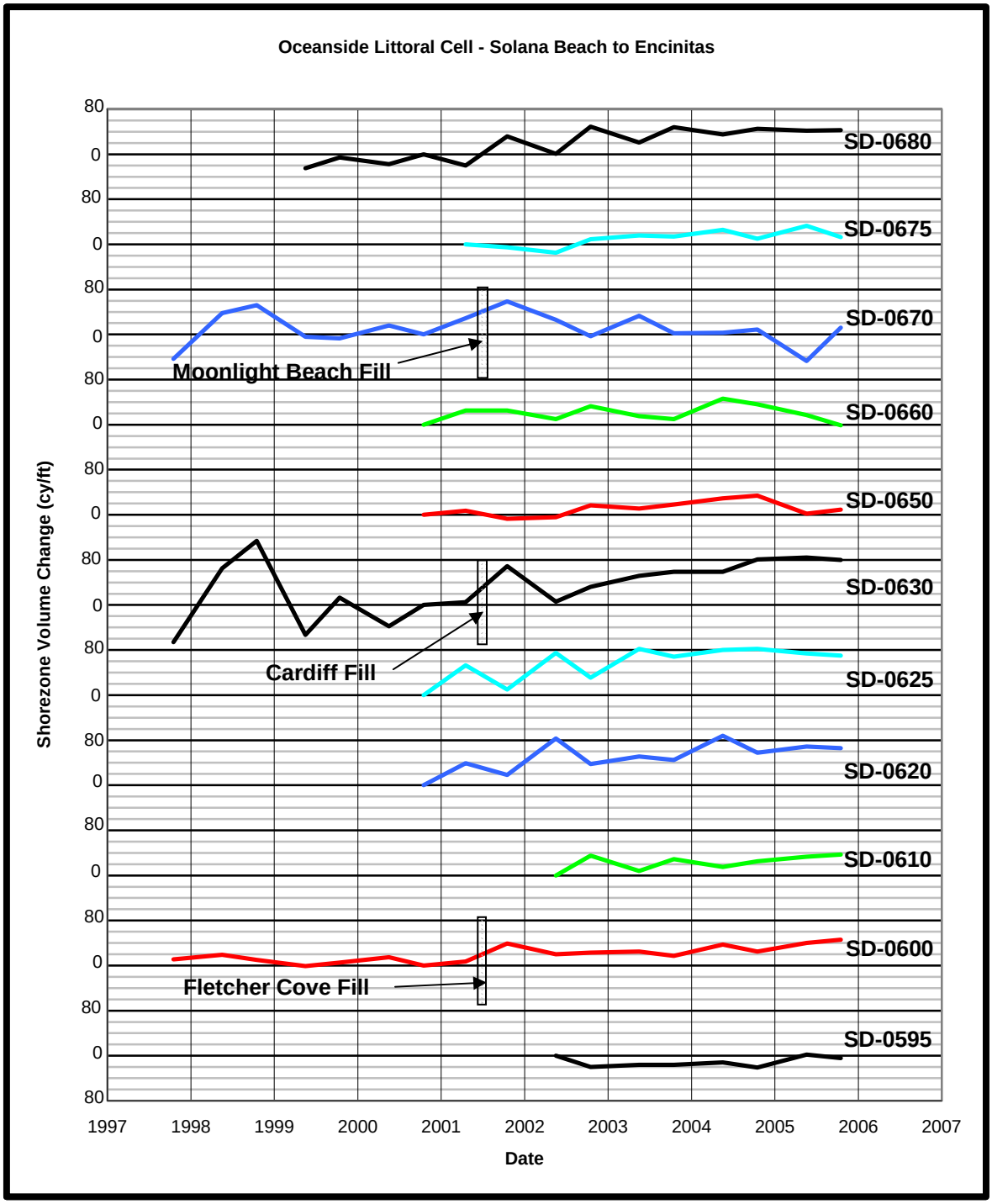
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 19b. Time Series of Shorezone Volume Change in the Mission Beach Littoral Cell



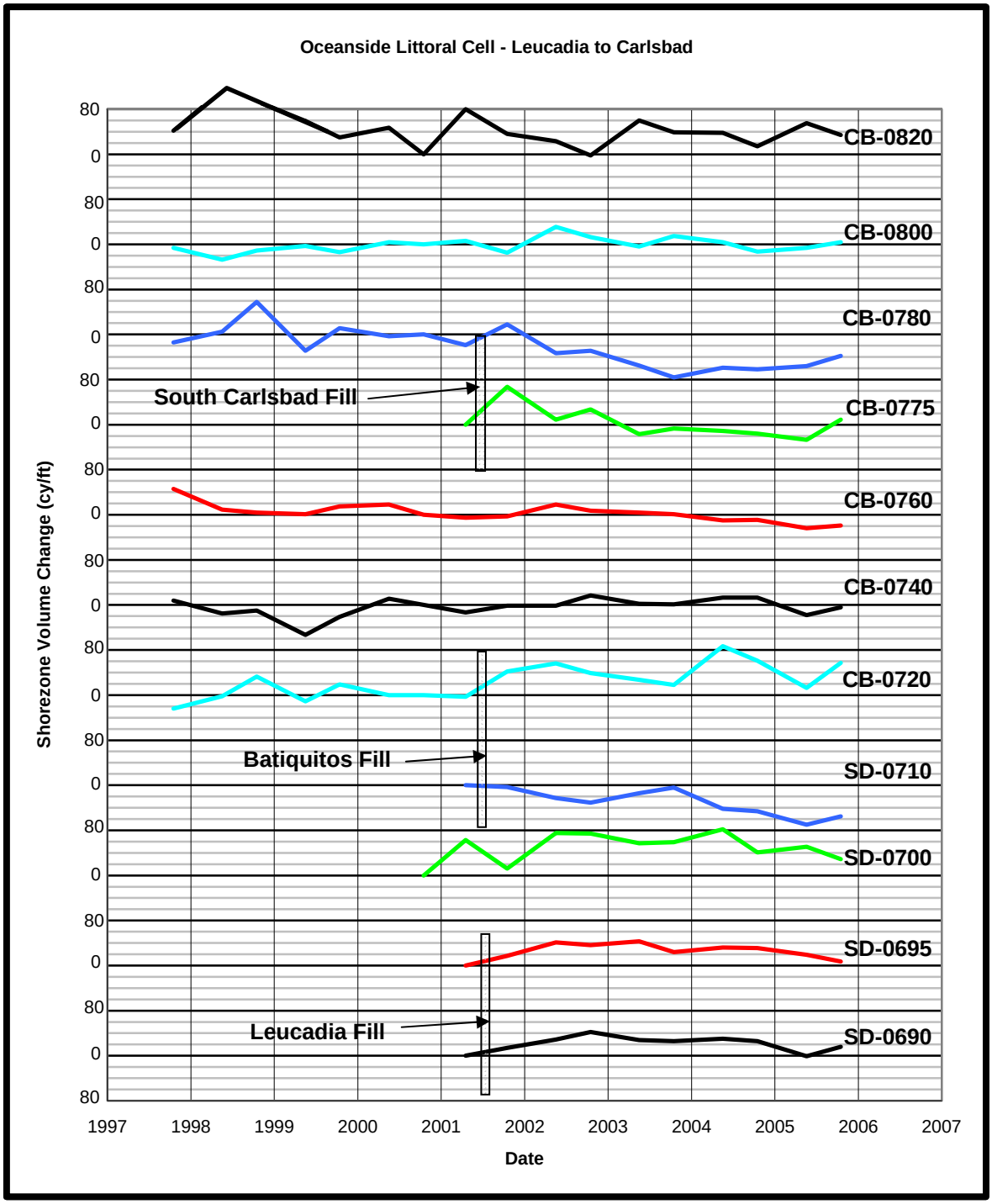
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 19c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 1 of 4)



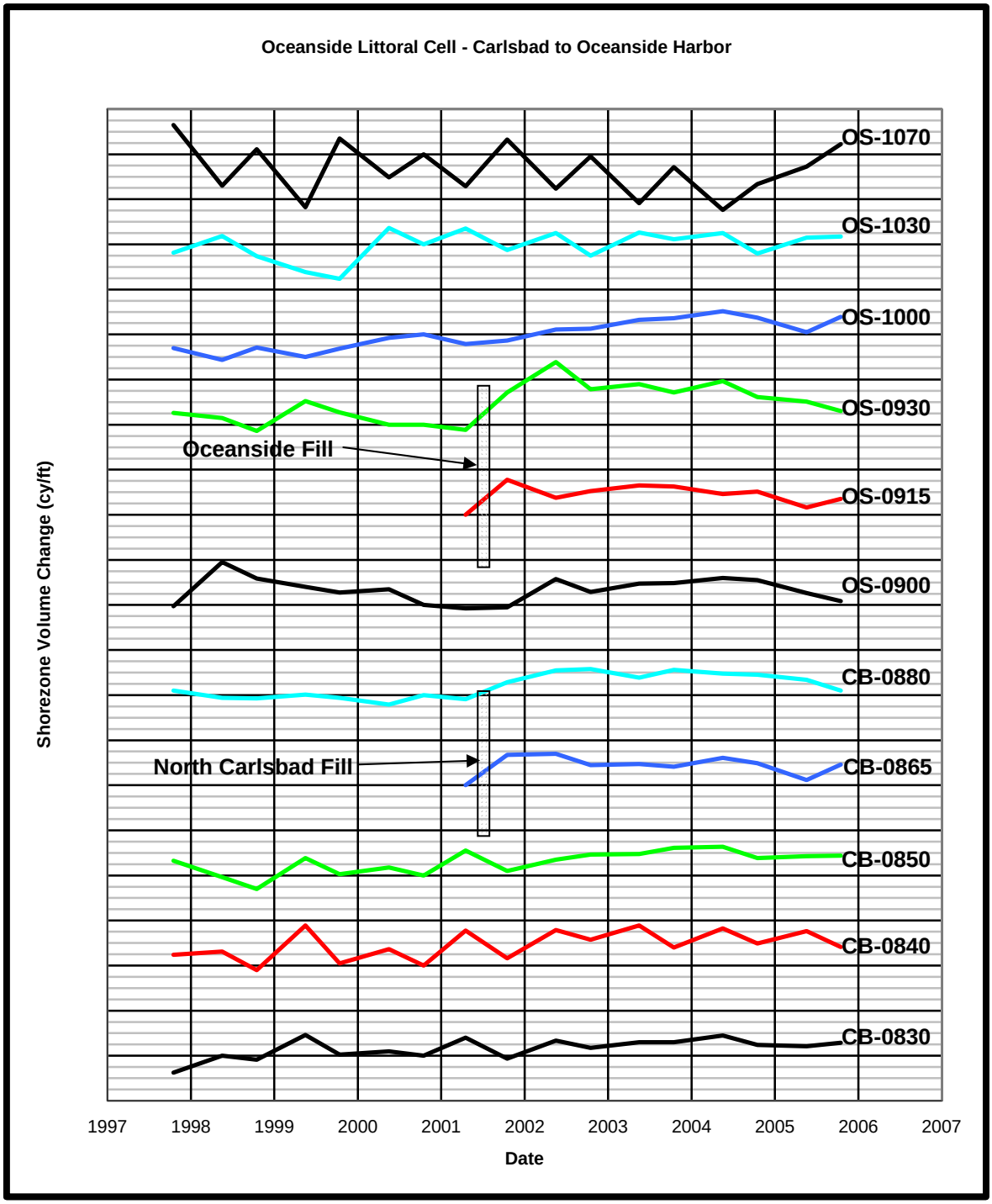
Note: Bar representing RBSP fill is schematic only, and not drawn to scale.

Figure 19c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 2 of 4)



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

Figure 19c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 3 of 4)



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

Figure 19c. Time Series of Shorezone Volume Change in the Oceanside Littoral Cell (page 4 of 4)

were short-lived. At others, such as Oceanside, Del Mar, Fletcher Cove, and Mission Beach and, the gains persisted through the time of the Fall 2005 survey.

- Shorezone volume gains occurred at many of the beaches adjacent to the receiver sites, reflecting lateral dispersal of the fill material. Representative examples include Transects SD-0625 and SD-0620, which are located adjacent to the Cardiff fill, and Transect SD-0680, which is located adjacent to the Leucadia fill.
- The positive impact of the RBSP fill material is most evident in the Oceanside-North Carlsbad area, where prolonged volume gains were recorded on the nine consecutive transects bounded by OS-1000 and CB-0830. These gains suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally along a stretch of coast that extends for more than two miles.
- The 2005 nourishment activities at Imperial Beach produced a substantial shorezone volume gain at Transect SS-0035 between Fall 2004 and Fall 2005. Evidence of the fill is absent from the MSL shoreline data (Figure15a), however, suggesting that the material has not moved from the offshore placement location to the above-water beach.

5.2. RBSP Beach Fill Performance

This section provides an overview of the performance of the RBSP beach fills. As indicated in Section 2, the RBSP provided 2.1 million cy of beach-quality sand to twelve receiver sites located between Imperial Beach and Oceanside. The nourishment quantities at these sites ranged from 421,000 cy at Oceanside to 101,000 cy at Cardiff (Table 1). Nourishment activities were conducted between April 6 and September 23, 2001.

Table 15 and Figures 20 and 21 summarize the performance of the twelve beach fills. The locations of the fills, along with those of all beach profile transects in the vicinity, are shown at the end of this section in Figures 22 through 27. Plates 1 through 12, which provide pre- and post-nourishment photos of each receiver beach, follow the location maps.

Table 15 provides the MSL shoreline change and shorezone volume change that occurred between Spring 2001 and Fall 2005 on an indicator transect selected to characterize each fill site. In those instances where more than one transect crossed the fill, the transect that received the greatest nourishment (as indicated by the Post-Nourishment profile) was adopted as the indicator. To provide a reference against which individual fill performance

can be measured, the table includes the average, maximum, and minimum values of each parameter. It should be noted, however, that the benefits associated with lateral dispersal of the fill material (Section 5.1) are not reflected in the transect-specific data presented in Table 15.

Table 15. RBSP Beach Fill Performance

Receiver Beach	Indicator Transect	MSL Shoreline Change, Spring 01–Fall 05 (ft)	Shorezone Volume Change, Spring 01–Fall 05 (cy/ft)
Imperial Beach	SS-0025	141	33
Mission Beach	MB-0340	86	17
Torrey Pines	TP-0520	51	-20
Del Mar	DM-0580	81	40
Fletcher Cove	SD-0600	40	39
Cardiff	SD-0630	80	75
Moonlight Beach	SD-0670	76	-17
Leucadia	SD-0690	12	16
Batiquitos	SD-0710	-18	-55
S. Carlsbad	CB-0775	18	9
N. Carlsbad	CB-0865	84	37
Oceanside	OS-0930	16	33
Average		***56***	***17***
Maximum		***141***	***75***
Minimum		***-18***	***-55***

Time series of the MSL shoreline change and shorezone volume change at the time of the Fall Survey relative to Spring 2001 are presented for each beach fill indicator transect in Figures 20 and 21. The plots provide an indication of fill persistence at the receiver sites.

It should be noted that the MSL shoreline changes shown in Table 15 and Figure 20 reflect not only the effects of the nourishment program, but also a seasonal bias introduced by comparing shoreline positions from Spring (2001) and Fall (2005). Because the shoreline tends to advance during the summer wave season, the gains shown in the table are

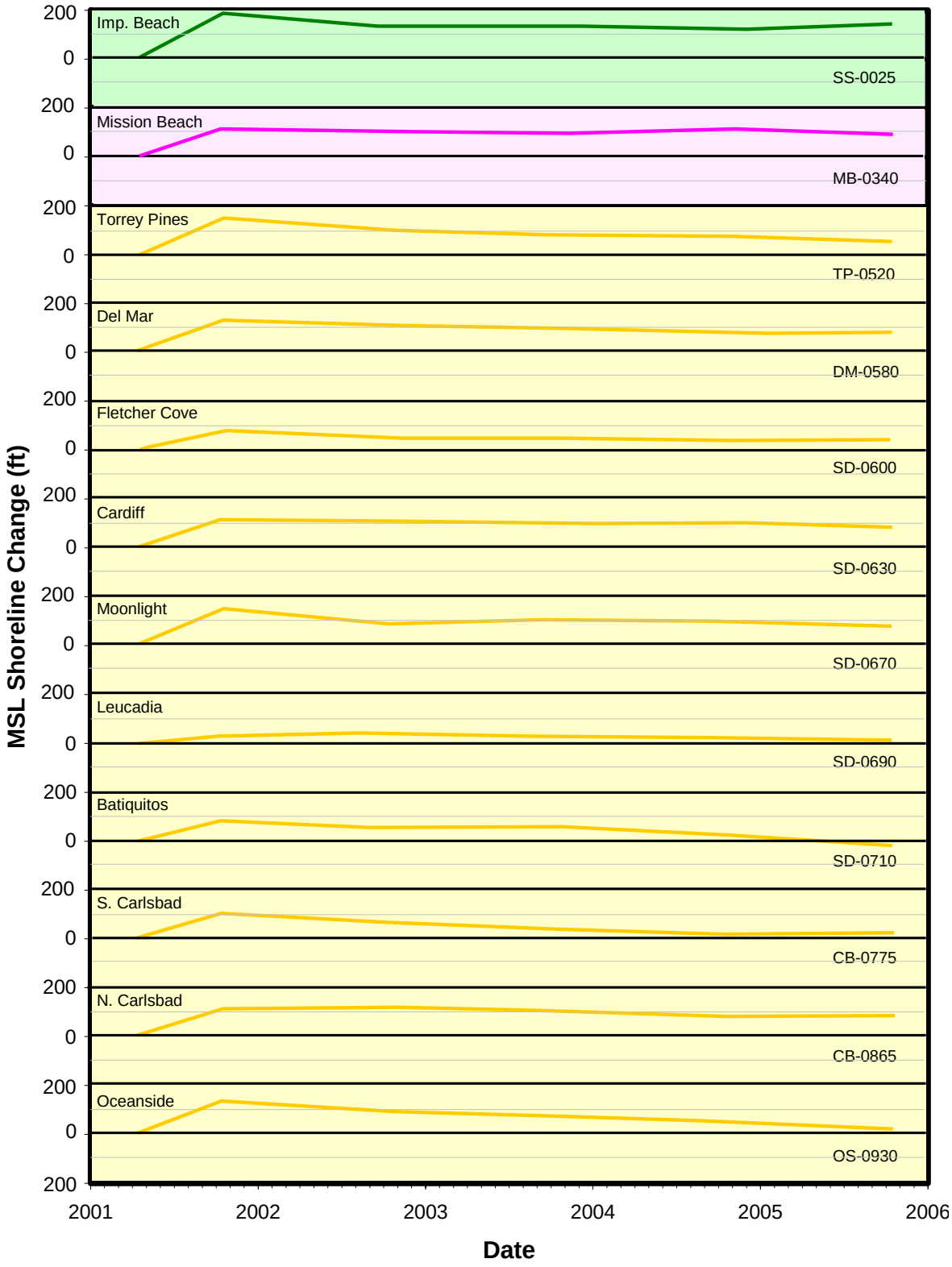


Figure 20. Time Series of MSL Shoreline Change at RBSP Receiver Sites

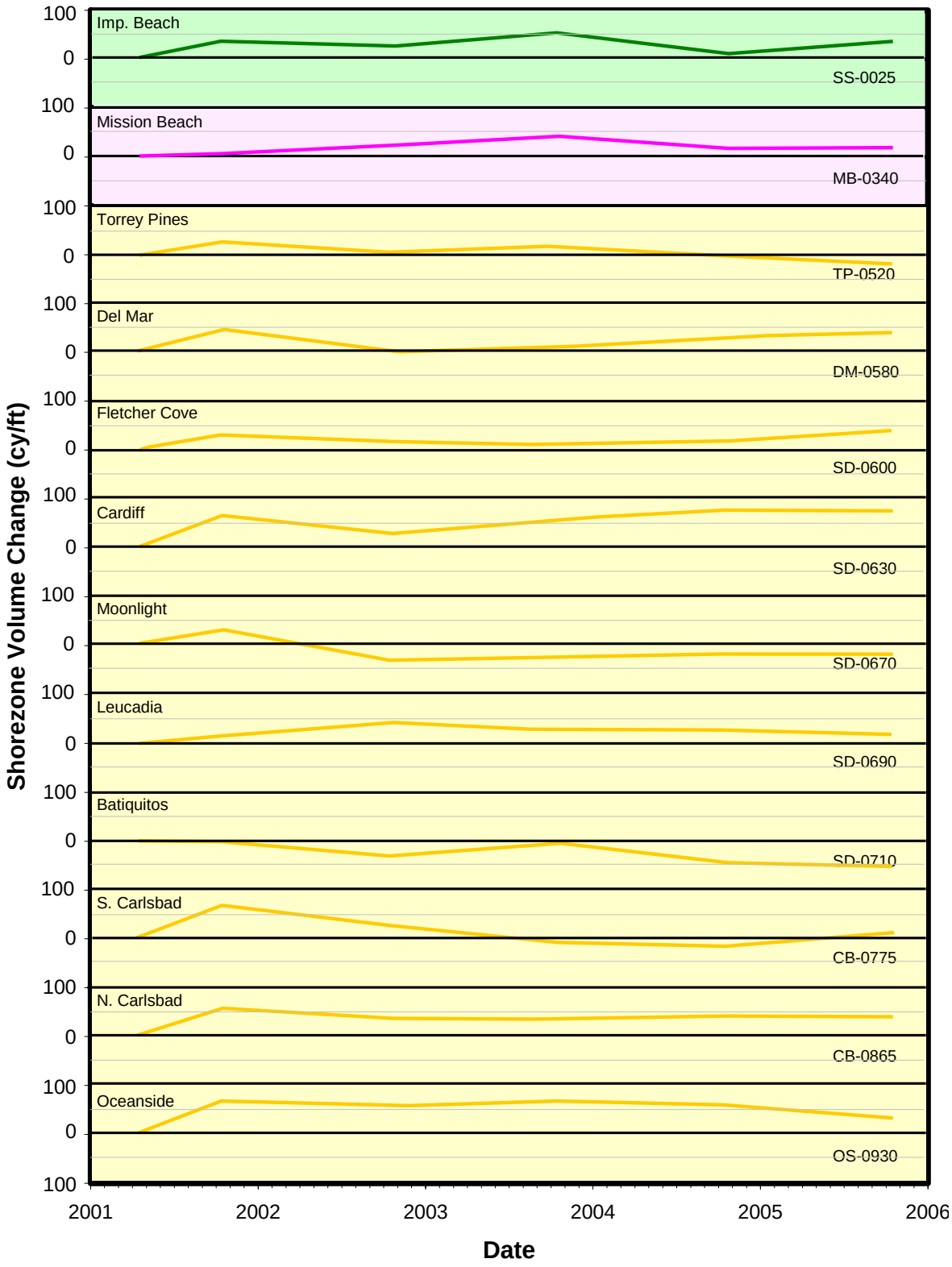


Figure 21. Time Series of Shorezone Volume Change at RBSP Receiver Sites

larger than they would have been without the seasonal bias. The Spring-to-Fall comparison is necessary, however, to bracket the life of the beach fills. The shorezone volumes shown in the table do not reflect a comparable seasonal bias, in that the shorezone encompasses the entire region in which seasonal cross-shore sediment transport may be expected to occur.

The performance of the individual RBSP fills varied considerably. In the majority of cases, however, the receiver beaches experienced an increase in both shoreline position and shorezone volume (Table 15). Between Spring 2001 and Fall 2005, the MSL shoreline advanced at all but one location. The changes ranged from a retreat of 18 ft at Batiquitos to an advance of 141 ft at Imperial Beach, with an average value 56 ft (advance). Shorezone volume loss occurred at only three locations during this period, resulting in an average gain of 17 cy/ft when all twelve sites are considered. The volume changes ranged from a loss of 55 cy/ft at Batiquitos to a gain of 75 cy/ft at Cardiff.

Figure 20 indicates that substantial shoreline advance occurred at all but one of receiver sites in response to the RBSP nourishment activities (the exception being Leucadia). In the Oceanside Cell, a gradual shoreline retreat is evident at most locations following the initial gains. As indicated above, a net shoreline loss occurred at only one location (Batiquitos). A similar trend is absent at the Mission Beach and Imperial Beach sites, where the initial shoreline gains have been largely preserved.

Similar to the shoreline changes, the RBSP nourishment activities produced significant shorezone volume gains at most of the receiver sites at the time of the Fall 2001 Survey. Notable exceptions include Mission Beach and Leucadia (only modest gains), and Batiquitos (slight loss). Many receiver sites in the Oceanside Cell experienced volume losses during the first one to two years following the initial gains. Thereafter, a trend of stability or modest volume gain is evident. This reversal of the earlier losses suggests that lateral dispersal and coalescing of neighboring fills may have occurred. At the Mission Beach and Imperial Beach receiver sites, the volumes fluctuated with no distinct trends.

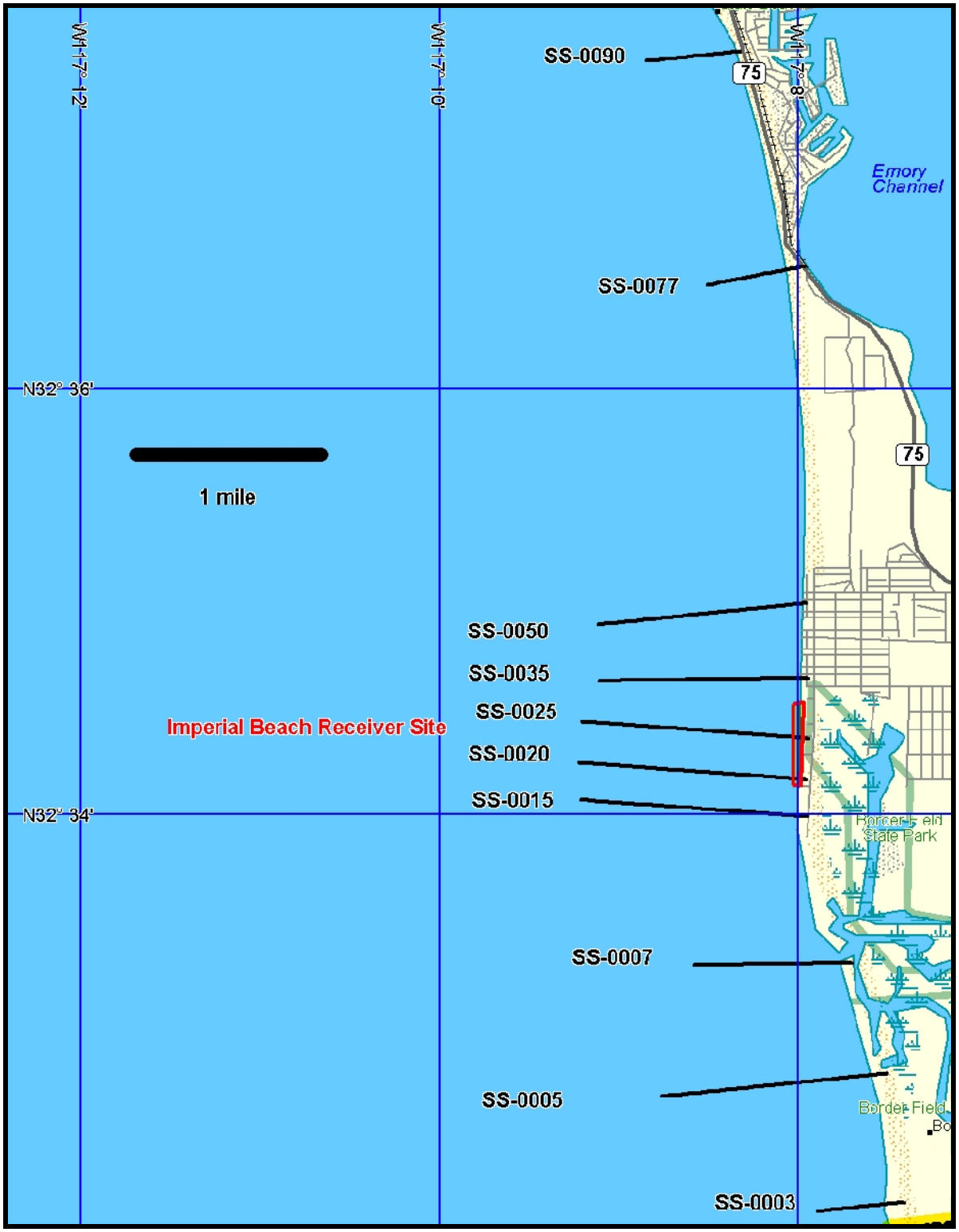


Figure 22. Location Map for Imperial Beach Receiver Site

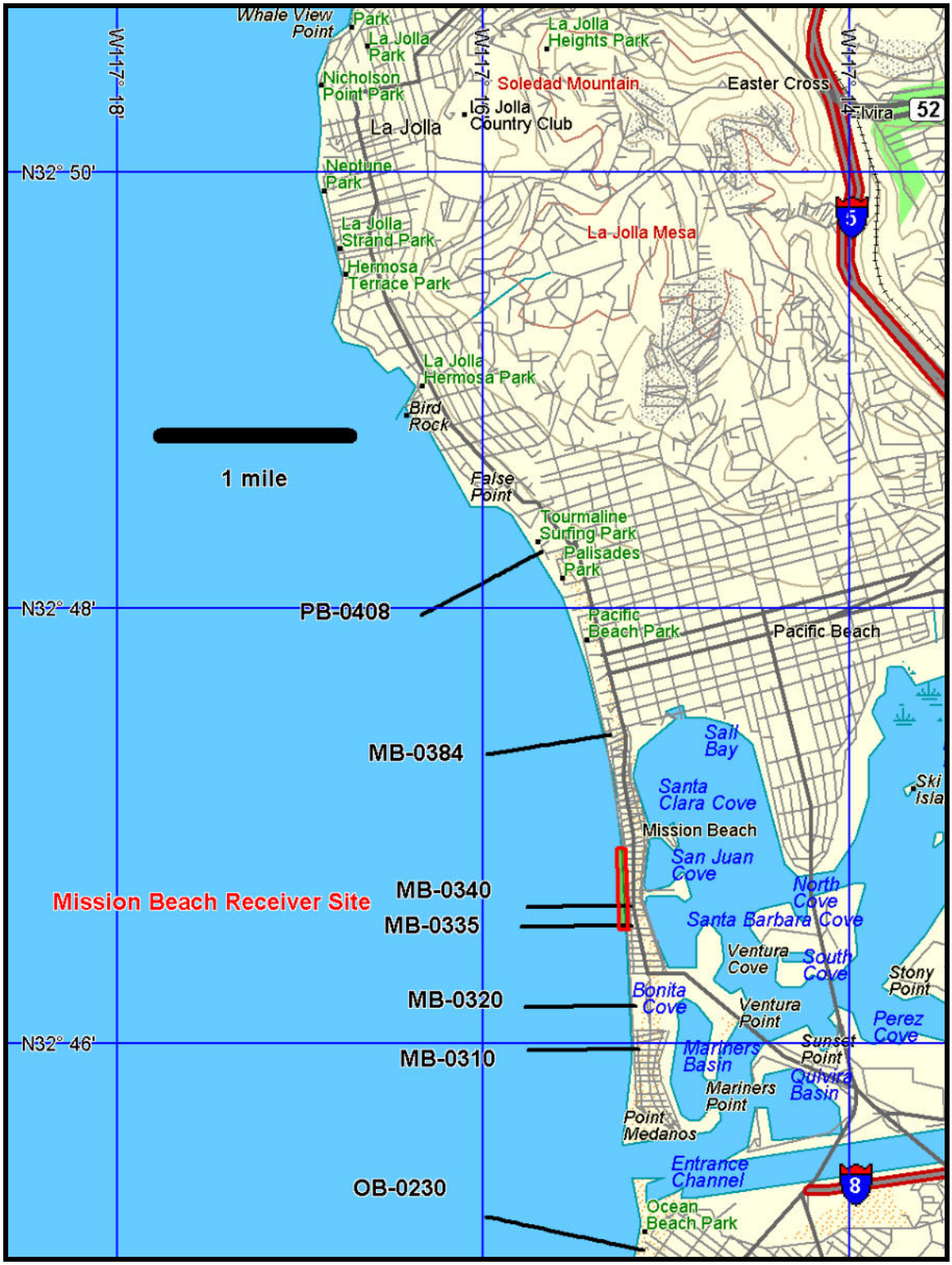


Figure 23. Location Map for Mission Beach Receiver Site

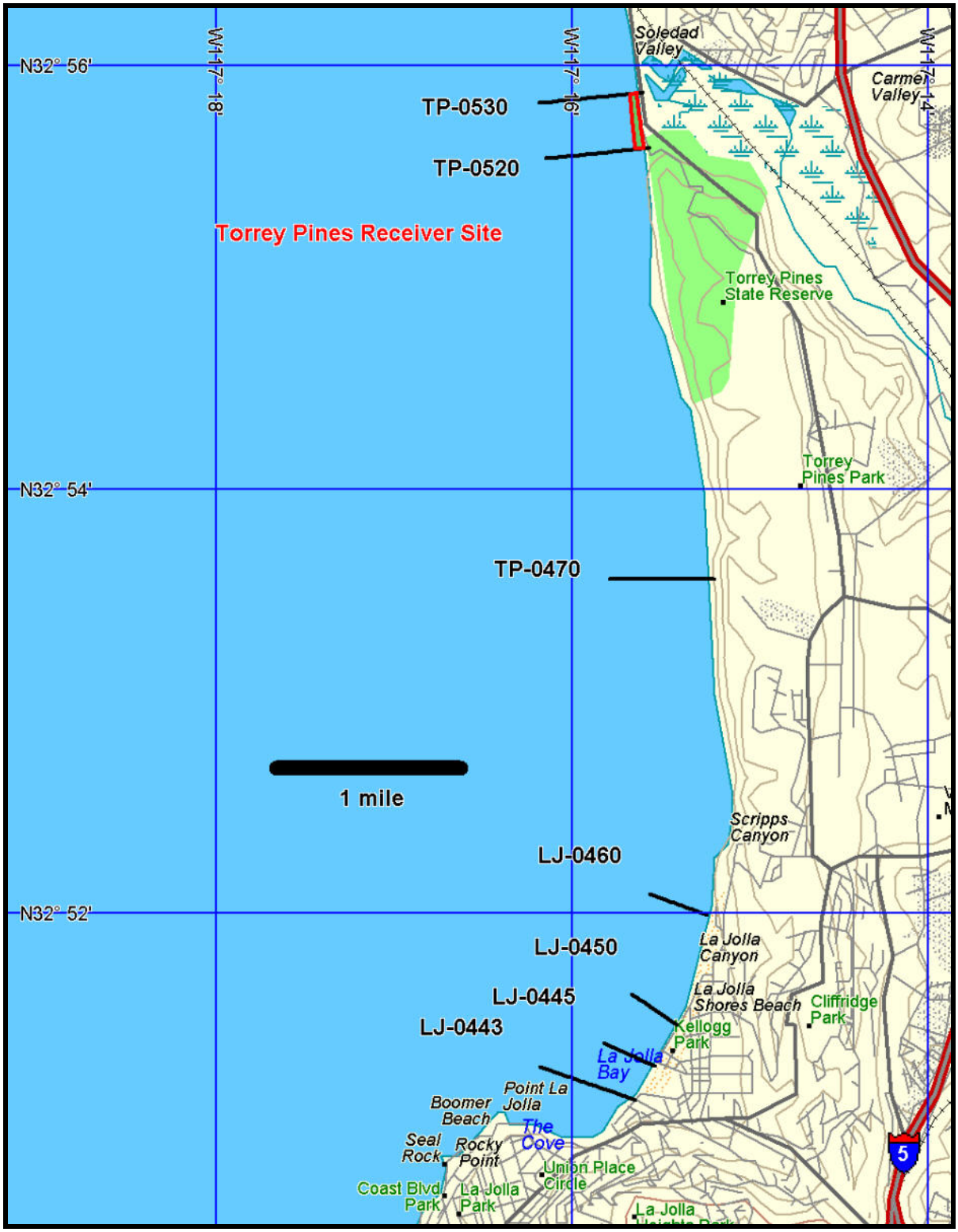


Figure 24. Location Map for Torrey Pines Receiver Site

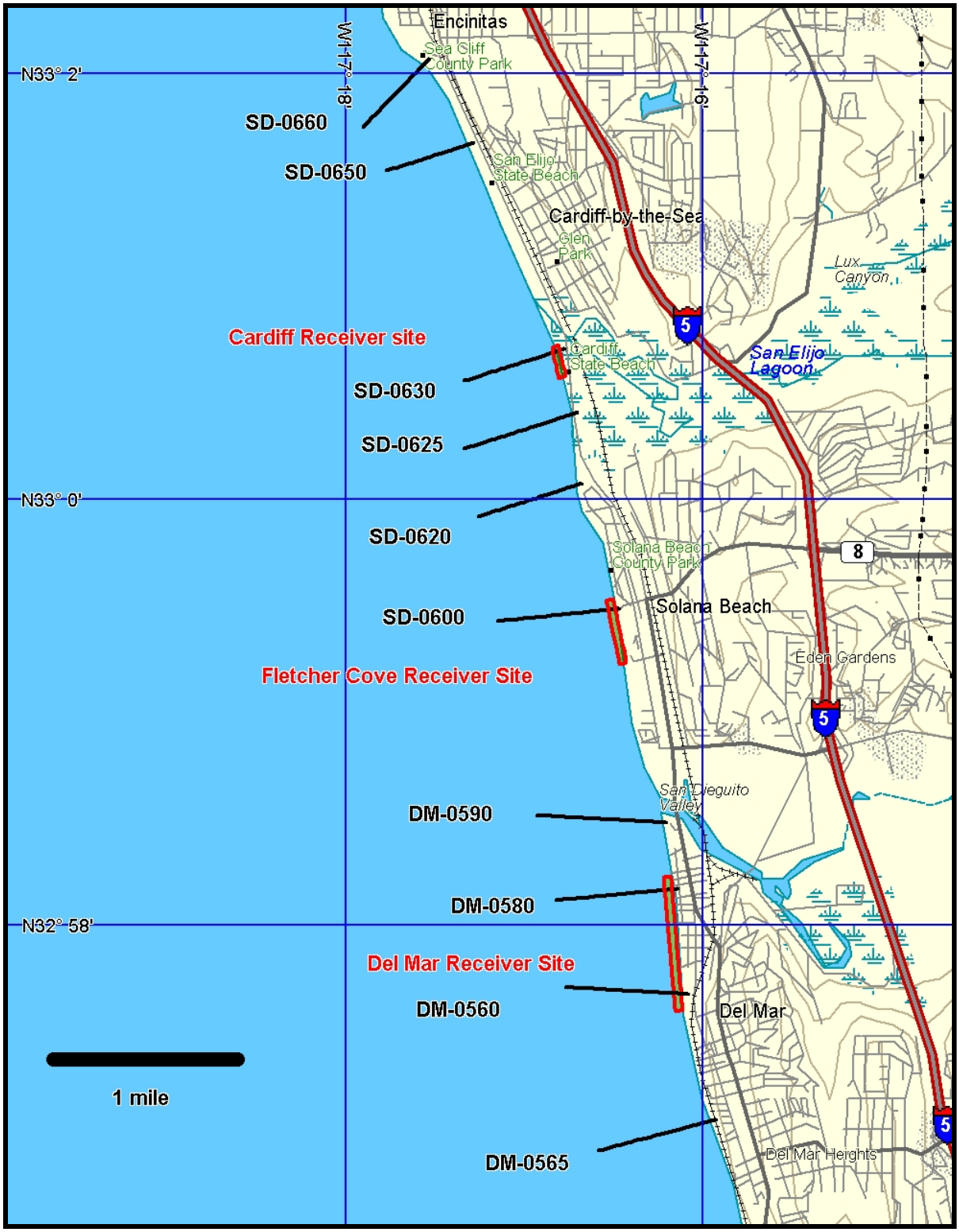


Figure 25. Location Map for Del Mar, Fletcher Cove, and Cardiff Receiver Sites

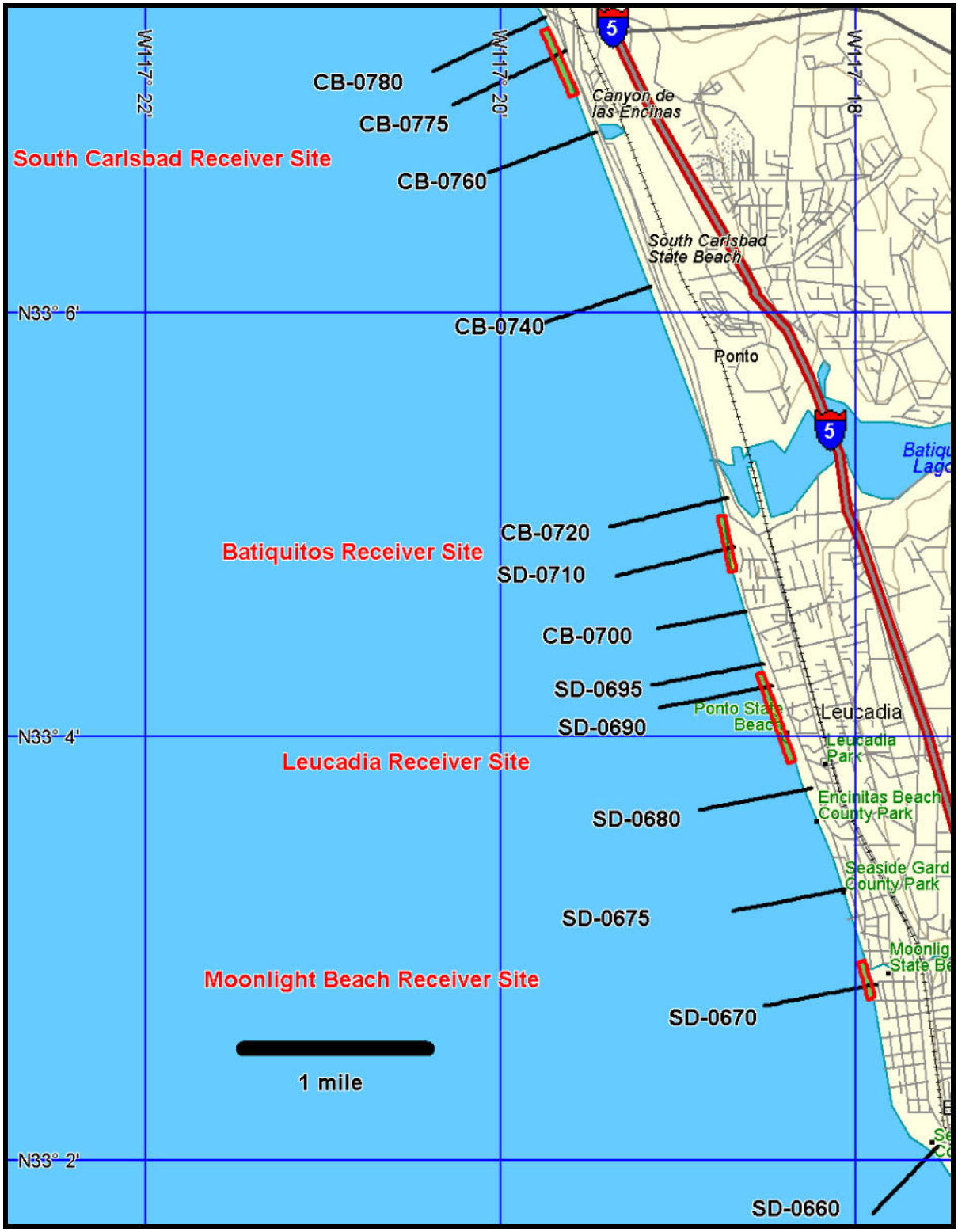


Figure 26. Location Map for Moonlight Beach, Leucadia, Batiquitos, and South Carlsbad Receiver Sites

Figure 27. Location Map for North Carlsbad and Oceanside Receiver Sites

April 2001 (Pre-RBSP)

November 2001 (5.5 months after nourishment)

November 2002 (17.5 months after nourishment)

November 2003 (29 months after nourishment)

October 2004 (40.5 months after nourishment

October 2005 (52.5 months after nourishment)

Plate 1. Imperial Beach Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (6 months after nourishment)

November 2002 (17.5 months after nourishment)

November 2003 (29.5 months after nourishment)

October 2004 (41 months after nourishment)

October 2005 (53 months after nourishment)

Plate 2. Mission Beach Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (6.5 months after nourishment)

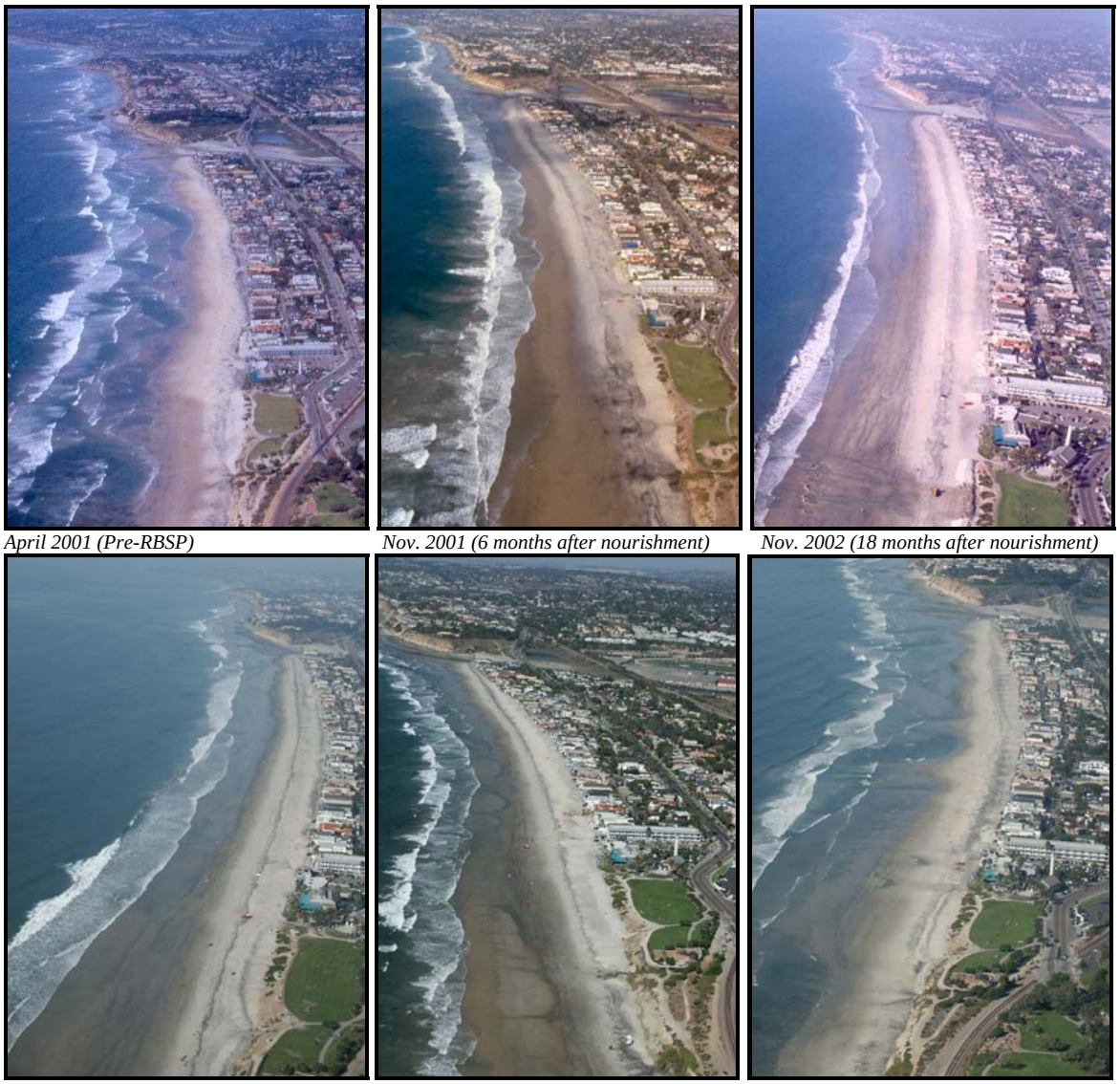
November 2002 (18.5 months after nourishment)

November 2003 (30.5 months after nourishment)

October 2004 (42 months after nourishment)

October 2005 (54 months after nourishment)

Plate 3. Torrey Pines Receiver Site, April 2001 through October 2005



April 2001 (Pre-RBSP) *Nov. 2001 (6 months after nourishment)* *Nov. 2002 (18 months after nourishment)*

Nov. 2003 (30 months after nourishment) *Oct. 2004 (41.5 months after nourishment)* *Oct. 2005 (53.5 months after nourishment)*

Plate 4. Del Mar Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (4.5 months after nourishment)

November 2002 (15 months after nourishment)

November 2003 (28.5 months after nourishment)

October 2004 (40 months after nourishment)

October 2005 (52 months after nourishment)

Plate 5. Fletcher Cove Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (3 months after nourishment)

November 2002 (15 months after nourishment)

November 2003 (27 months after nourishment)

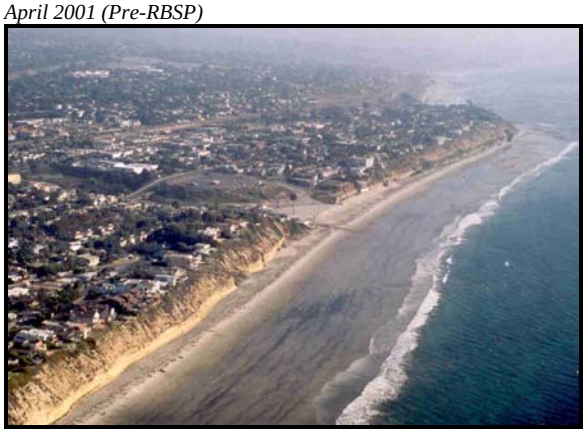
October 2004 (38.5 months after nourishment)

October 2005 (50.5 months after nourishment)

Plate 6. Cardiff Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (3 months after nourishment)



November 2002 (15 months after nourishment)

November 2003 (26.5 months after nourishment)

October 2004 (38 months after nourishment)

October 2005 (50 months after nourishment)

Plate 7. Moonlight Beach Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP) *Nov. 2001 (5 months after nourishment)* *Nov. 2002 (17 months after nourishment)*

Nov. 2003 (29 months after nourishment) *Oct. 2004 (40.5 months after nourishment)* *Oct. 2005 (52.5 months after nourishment)*

Plate 8. Leucadia Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP) *Nov. 2001 (2.5 months after nourishment)* *Nov. 2002 (14.5 months after nourishment)*

Nov. 2003 (26.5 months after nourishment) *Oct. 2004 (38 months after nourishment)* *Oct. 2005 (50 months after nourishment)*

Plate 9. Batiquitos Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (4.5 months after nourishment)

November 2002 (16.5 months after nourishment)

November 2003 (28 months after nourishment)

October 2004 (39.5 months after nourishment)

October 2005 (51.5 months after nourishment)

Plate 10. South Carlsbad Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (3.5 months after nourishment)

November 2002 (15.5 months after nourishment)

November 2003 (27 months after nourishment)

October 2004 (38.5 months after nourishment)

October 2005 (50.5 months after nourishment)

Plate 11. North Carlsbad Receiver Site, April 2001 through October 2005

April 2001 (Pre-RBSP)

November 2001 (1.5 months after nourishment)

November 2002 (13.5 months after nourishment)

November 2003 (25.5 months after nourishment)

October 2004 (37 months after nourishment)

October 2005 (49 months after nourishment)

Plate 12. Oceanside Receiver Site, April 2001 through October 2005

6. LAGOON ENTRANCE CONDITION

Section 6 evaluates the condition of five lagoon entrances in the Oceanside Littoral Cell. In accordance with the practice adopted last year (Coastal Frontiers, 2005) the analysis covers the four-year period between Fall 2001 and Fall 2005 rather than the entire RBSP Monitoring Period. This change was instituted to reflect the conclusion that the RBSP fills exerted no material impact on the lagoon entrances prior to Fall 2001.

An overview is provided in Section 6.1, followed by a discussion of each entrance in Section 6.2. The location of each entrance is indicated in Figure 1.

6.1. Overview

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

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

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

As indicated in Section 2, six consecutive years of below- or near-average rainfall followed the 1997-98 El Niño event (1999 to 2004). In contrast, the 18.1 inches of precipitation that fell during the 2005 Monitoring Year represented the fourth highest annual total on record. As discussed above, if the interior channels were flushed free of sand by heavy precipitation and strong river flows, the lagoons would be inclined to remain open to tidal exchange with only minimal maintenance during the next few years. This outcome is not assured, however, because evidence of significant sediment discharge was lacking in most of the beach profiles obtained in 2005 near the river mouths and lagoon entrances in the Oceanside Cell (Section 5.1).

Figure 28 shows the average percentage of time that each of the five lagoons remained open to tidal exchange prior and subsequent to the RBSP. As indicated in the figure, the pre-RBSP period of record for each lagoon varies from five to 47 years in accordance with the available data. Prior to the RBSP, the two jetty-stabilized entrances, Agua Hedionda and Batiquitos, never closed. In contrast, the three unstabilized entrances closed periodically despite efforts to maintain tidal exchange. The percentage of time open varied widely among these lagoons, with values of 43% at San Elijo, 77% at San Dieguito, and 93% at Los Peñasquitos.

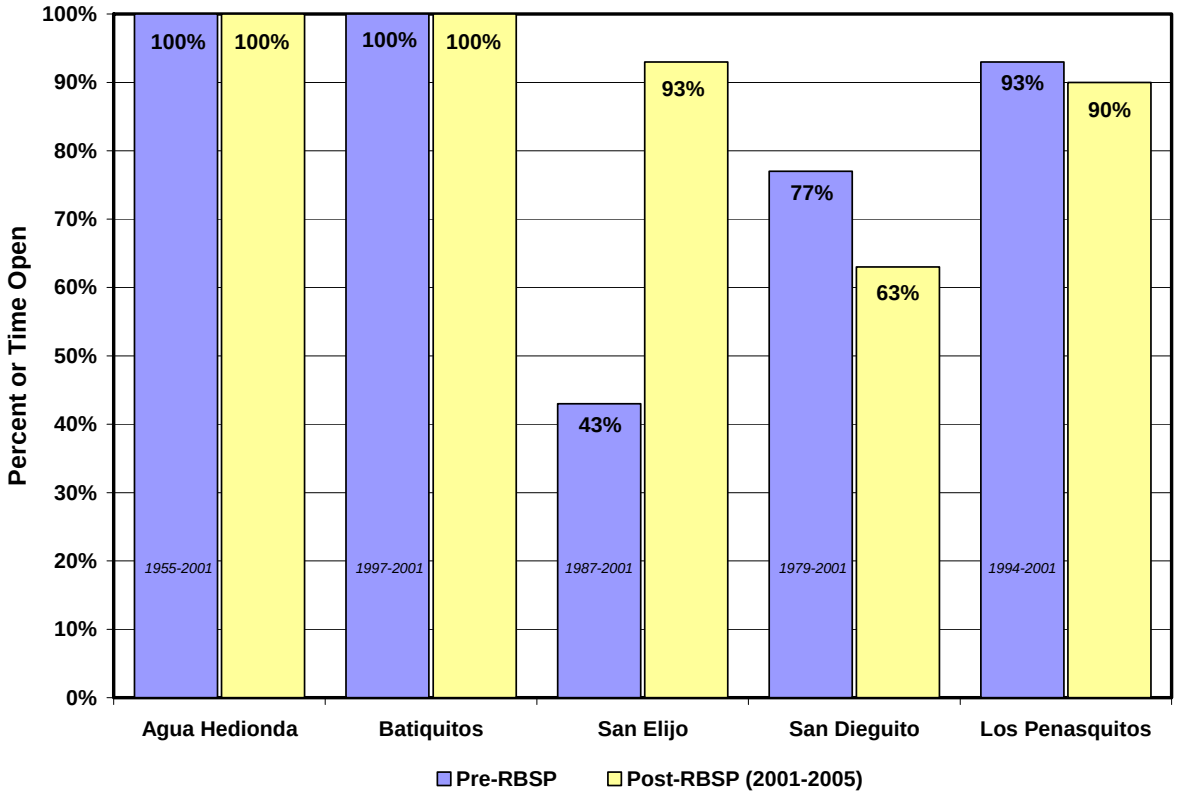


Figure 28. Percentage of Time Lagoon Entrances Open to Tidal Exchange Prior and Subsequent to the RBSP

Subsequent to the RBSP, the two jetty-stabilized entrance channels remained open to the full range of tidal exchange with only minor variations in water depth. As indicated in Figure 29, the unstabilized entrance channels at Los Peñasquitos and San Dieguito closed on seven and five occasions, respectively. At San Elijo, the unstabilized channel closed on only four occasions. As a result, the entrance channel was open to tidal exchange more than the historical average at San Elijo (93% vs. 43%), less than the historical average at San Dieguito (63% vs. 77%), and essentially the same as the historical average at Los Peñasquitos (90% vs. 93%).

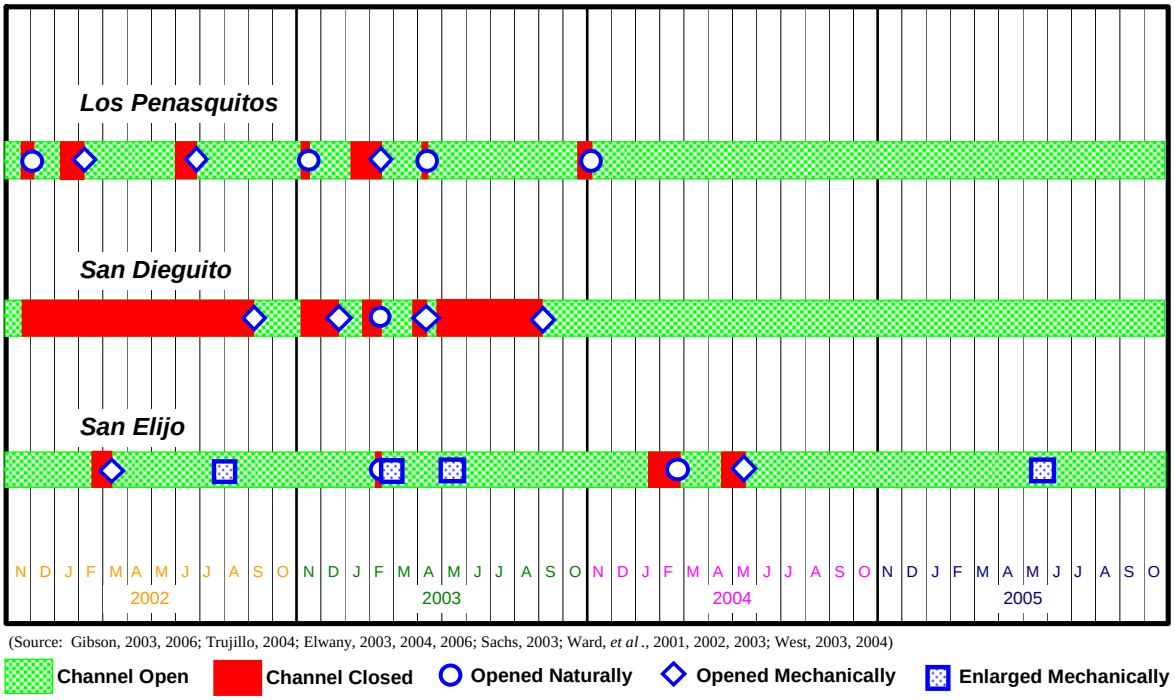


Figure 29. Condition of Unstabilized Lagoon Entrances Following the RBSP

At first inspection, the improved condition of the entrance channels at Los Peñasquitos and San Dieguito appears to be a result of diminishing influence from the beach fills. While this may be a contributing factor, other causes also must be considered. Both entrance channels likely benefited from above-average rainfall and streamflows during 2005. In the case of Los Peñasquitos, a sheetpile structure at the PCH bridge (installed in 2004 as part of the road construction activities) also helped keep the channel open during the 2004 and 2005 monitoring Years

As discussed in Section 2.2, sand bypassing is conducted at three lagoons: San Elijo, Batiquitos, and Aqua Hedionda. For the purpose of evaluating sedimentation in the entrance channels, the overall dredge rate provides a more accurate indicator than the bypassing rate.

The dredge rate includes bypassing operations and, in the case of Batiquitos Lagoon, enhancing least tern nesting sites with dredge spoils. The dredge quantities attributable to sedimentation occurring between November 1993 and October 2001 (pre-RBSP) are shown in Table 16, while those attributable to sedimentation during the post-RBSP period are shown in Table 17. Many of these values were presented previously in Section 2.2.3. The dredge rates following the RBSP (Fall 2001 to Fall 2005) are compared with the pre-RBSP values in Table 18.

Table 16. Lagoon Dredging Attributable to Sedimentation Occurring Between November 1993 and October 2001 (Pre-RBSP)

Bypass Project	Date	Activity	Dredge Quantity (cy)
San Elijo Lagoon	1995	Bypassing	6,000
	1996	Bypassing	8,000
	1997	Bypassing	31,000
	1998	Bypassing	12,000
	1999	Bypassing	17,000
	2000	Bypassing	23,000
	2001	Bypassing	23,000
	Average Annual Dredge Rate at San Elijo Lagoon = 15,000 cy/yr		
Batiquitos Lagoon	1999	Bypassing and Habitat Enhancement	11,000
	2000	Bypassing	4,000
	2001	Bypassing and Habitat Enhancement	49,000
	Average Annual Dredge Rate at Batiquitos Lagoon = 16,000 cy/yr [(1)]		
Agua Hedionda Lagoon	1996	Bypassing	443,000
	1997	Bypassing	197,000
	1999	Bypassing	203,000
	2001	Bypassing	429,000
	Average Annual Dredge Rate at Agua Hedionda Lagoon = 182,000 cy/yr		

Source: Dillingham, 2002; Tucker, 2002; Gibson, 2005

Note: [(1)] Rate computed for the four-year period following lagoon restoration (1998 to 2001).

At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the two dredge rates is not meaningful. At San Elijo, the dredge rate following the RBSP (25,000 cy/yr) exceeded the pre-RBSP average (15,000 cy/yr) by 67%. As explained in Section 2.2, however, the higher rate is partially attributable to an increased level of maintenance made possible by additional funding. The

post-RBSP dredge rate at Agua Hedionda (178,000 cy/yr) was within 3% of the pre-RBSP rate (182,000 cy/yr).

Table 17. Lagoon Dredging Attributable to Sedimentation Occurring Between November 2001 and October 2005 (Post-RBSP)

Bypass Project	Date	Activity	Dredge Quantity (cy)
San Elijo Lagoon	2002	Bypassing	18,000
	2003	Bypassing	32,000
	2004	Bypassing	30,000
	2005	Bypassing	20,000
	Average Annual Bypass Rate at San Elijo Lagoon = 25,000 cy/yr (1)		
Batiquitos Lagoon	2003	Habitat Enhancement	75,000
	Average Annual Bypass Rate at Batiquitos Lagoon = 38,000 cy/yr (2)		
Agua Hedionda Lagoon	2003	Bypassing	337,000
	2005	Bypassing	375,000
	Average Annual Bypass Rate at Agua Hedionda Lagoon = 178,00 cy/yr (3)		

Source: Dillingham, 2002; Tucker, 2002; Hughes 2003; Gibson, 2005, 2006, Shiffer, 2006

Note: (1) Rate computed for the four-year period from Fall 2001 to Fall 2005.
(2) Rate computed for the two-year period from Fall 2001 to Fall 2003.
(3) Rate computed for the four-year period from Fall 2001 to Fall 2005.

Table 18. Comparison of Pre- and Post-RBSP Lagoon Dredging Rates

Location	Pre-RBSP Average(1) (cy/yr)	Post-RBSP Average(2) (cy/yr)	Difference(3) (cy/yr)
San Elijo	15,000	25,000	10,000
Batiquitos	16,000	38,000	n/m(4)
Agua Hedionda	182,000	178,000	-5,000

Notes: (1) Pre-RBSP Average based on the Monitoring Years 1994- 2001, as described in Table 16.
(2) Post-RBSP Average based on the Monitoring Years 2002-2003 for Batiquitos, and 2002-2005 for San Elijo and Agua Hedionda, as described in Table 17.
(3) Difference represents Post-RBSP Average minus Pre-RBSP Average
(4) Difference not meaningful because Pre-RBSP bypass rate was derived from the period during and immediately after lagoon restoration.

6.2. Lagoon Entrance Performance

The performance of each lagoon entrance following RBSP fill placement is evaluated below. To provide a basis for comparison, the pre-RBSP performance also is

summarized. Supporting topographic data are provided in Appendix G, while ground photographs of the three unstabilized channels appear in Appendix H.

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, as well as ongoing maintenance dredging, the lagoon entrance has remained open to tidal exchange since 1955.

Historically, maintenance dredging has been required at intervals of one to two years to remove a flood-tide shoal that forms in the cooling basin. Dredge quantities have ranged from 90,000 to 459,000 cy (Tucker, 2002). Over the 46-yr period preceding the RBSP (1955-2001), an average of 140,000 cy/yr was removed from the lagoon and placed on the adjacent beaches (Note: this figure does not include material derived from basin modifications in 1998 and 1999). As discussed in Section 2.2, the dredging operation returns sediment to the littoral system that has been trapped in the interior basin, and therefore represents sand bypassing.

Maintenance dredging was conducted on two occasions subsequent to the RBSP. Between December 2002 and April 2003, 337,000 cy were removed from the lagoon (Hughes, 2003). In 2005 (January through March), 375,000 cy were removed (Shiffer, 2006). The present bypassing program typically is conducted every two years, with the next operation scheduled for 2007. Applying the quantity bypassed in 2003 and 2005 to a four-year period equates to an average rate of 178,000 cy/yr during the post-RBSP period. This rate was slightly below the pre-RBSP rate of 182,000 cy/yr shown in Table 16.

Plate 13 displays the condition of the north entrance to Agua Hedionda Lagoon on a semi-annual basis from April 2001 to October 2005. In the April 2001 photo, a dredge is evident removing the flood tide shoal from the region landward of the jetties. The next three photos show the progressive return of the shoal, with the feature fully emergent in November 2002. The shoal is not evident in the May 2003, having been removed during the 2002-2003 dredge program, but reappears and grows larger in the next three photos (November 2003 to October 2004). The feature was removed during the 2005 dredging program, and is not visible in the two most recent photos.

April 2001

November 2001

May 2002

November 2002

May 2003

November 2003

April 2004

October 2004

May 2005

October 2005

Plate 13. Agua Hedionda Lagoon North Entrance, April 2001 through October 2005

Figure 30 presents the controlling elevations that were measured in the north entrance channel on a semi-annual basis from Spring 1997 through Spring 2005. ("controlling elevation" refers to the lowest elevation at which water can pass unobstructed between the ocean and the lagoon.) During the period that preceded the RBSP (Spring 1997-Spring 2001), the controlling elevations ranged from -4.3 to -6.2 ft (MLLW). Subsequent to the nourishment activities (Fall 2001 to Spring 2005), the controlling elevations were comparable: -4.9 to -6.3 ft.

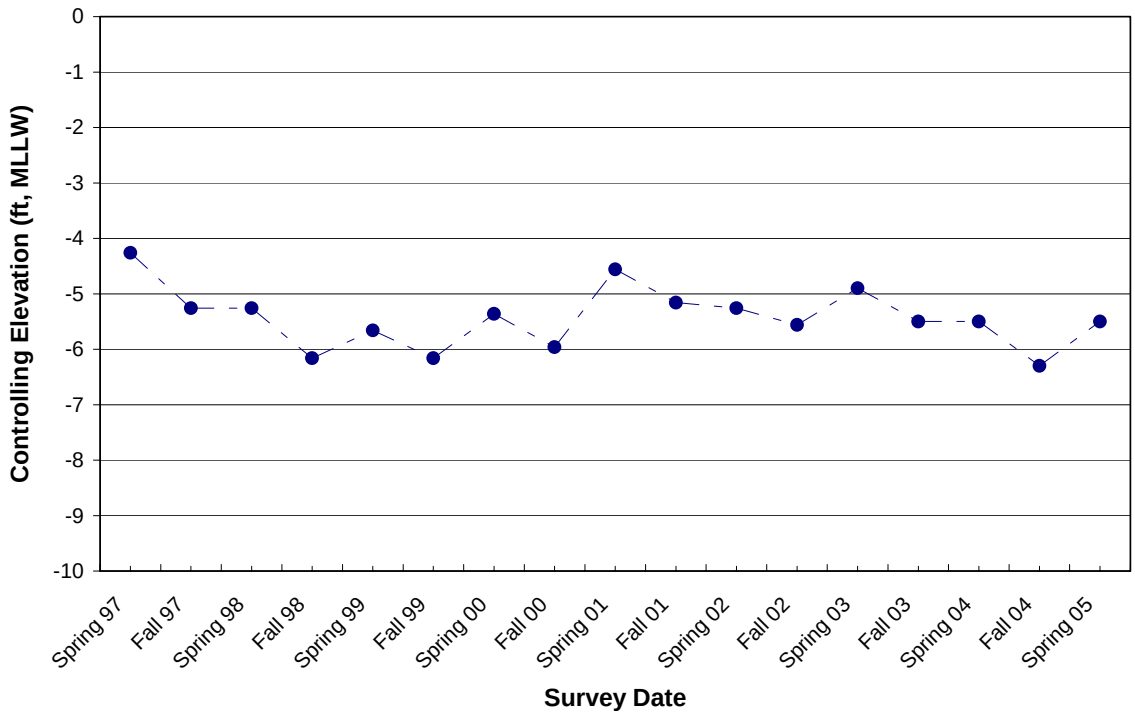


Figure 30. Controlling Elevation for Tidal Exchange in Agua Hedionda Lagoon

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 initial wetland restoration effort, the lagoon has remained open to tidal exchange. Periodic dredging has been required, however, to maintain the tidal prism. As indicated previously in Table 16, an average of 16,000 cy/yr was removed from the lagoon and either placed on the adjacent beaches or used for habitat enhancement prior

to the RBSP. This rate underestimates the long-term dredge requirement, because the major dredge activities associated with the lagoon restoration effort had just been completed.

No bypassing operations have been conducted subsequent to the RBSP. However, 75,000 cy of sediment were dredged from the lagoon in 2003 and used to enhance least tern nesting sites within the lagoon (Dillingham, 2004). The resulting dredge rate during the post-RBSP period was 38,000 cy/yr (Table 17). Although this rate exceeded the pre-RBSP average of 16,000 cy/yr, the latter figure is anomalously low as explained above.

Plate 14 illustrates the condition of the Batiquitos Lagoon entrance channel between April 2001 and October 2005. Substantial shoals are evident in the outer and middle basins in all ten photographs, with little change evident over the 54-month period despite the aforementioned dredge programs.

Between Spring 1997 and Spring 2001, the controlling elevations in the entrance channel varied between -5.3 and -6.6 ft (Figure 31). The elevations measured after placement of the RBSP nourishment material, -5.3 to -6.3 ft, lie within this range.

6.2.3. San Elijo

Based on records maintained by the San Elijo Lagoon Conservancy (Gibson, 2003), San Elijo Lagoon was open to tidal exchange only 43% of the 15-year period preceding the RBSP (1987-2001). The average closure frequency during this period was 4.4 times per year, while the frequency of mechanical opening was 2.9 times per year. The difference between these two frequencies is attributable to natural opening of the entrance channel.

Plate 15 shows the condition of the San Elijo entrance channel between April 2001 and October 2005. In February 2002, the channel closed for approximately one month before tidal exchange was restored by mechanical means (Figure 29). Mechanical enlargement of the channel was undertaken in July 2002 to increase the flow. The lagoon then closed for eight days in early February 2003 before re-opening naturally. It remained open for the next 11 months, with mechanical enlargements conducted in February and May 2003. During the 2004 Monitoring Year, the lagoon entrance closed on two occasions (mid-January and mid-April). It opened naturally approximately one month after the January closure, but mechanical intervention was required in May to restore tidal access after the second closure. The entrance channel then remained open throughout the 2005 Monitoring Year, with one mechanical enlargement operation conducted in May 2005.

April 2001

November 2001

May 2002

November 2002

May 2003

November 2003

April 2004

October 2004

May 2005

October 2005

Plate 14. Batiquitos Lagoon Entrance, April 2001 through October 2005

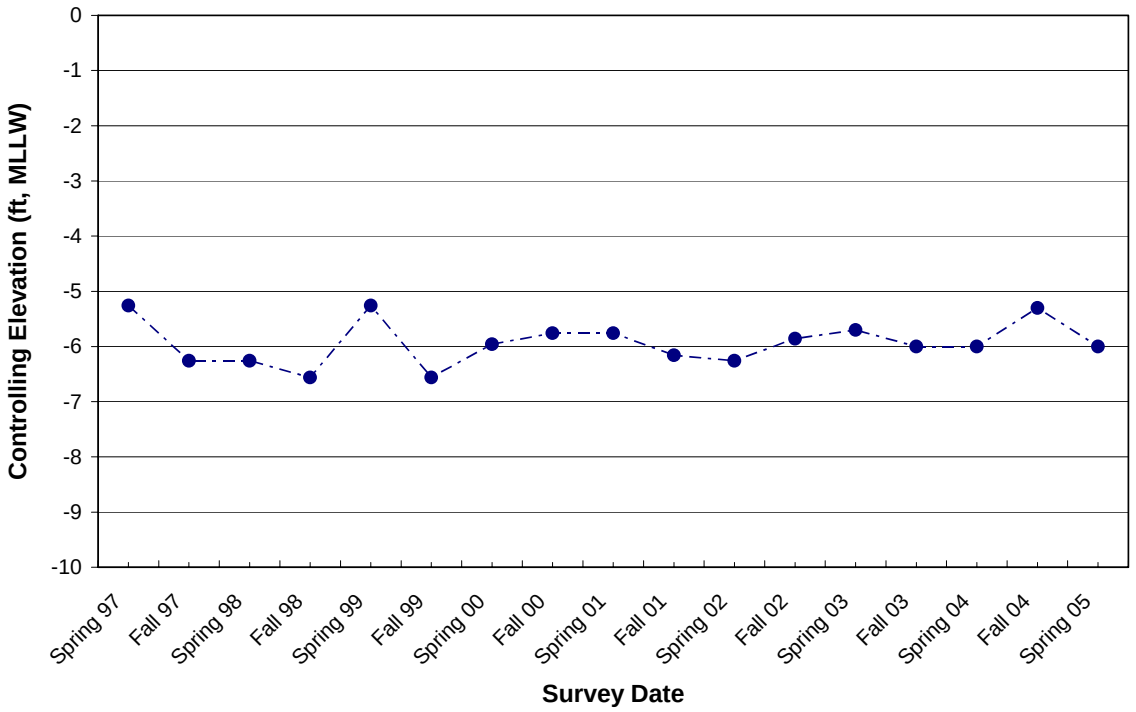


Figure 31. Controlling Elevation for Tidal Exchange in Batiquitos Lagoon

The lagoon was open 93% of the time during the four-year period following the RBSP (Fall 2001 to Fall 2005), greatly exceeding the historical average of 43%. The occurrence of only four closures during this period (1.0 closures per year) also represents a significant improvement relative to the channel's past history of 4.4 closures per year. Similarly, the frequency of channel maintenance (mechanical openings and enlargements) during the post-RBSP period, 1.5 times per year, was well below the historical average of 2.9 times per year. The most plausible explanation for the improved performance of the entrance is the increased dredging within the lagoon made possible by additional funding.

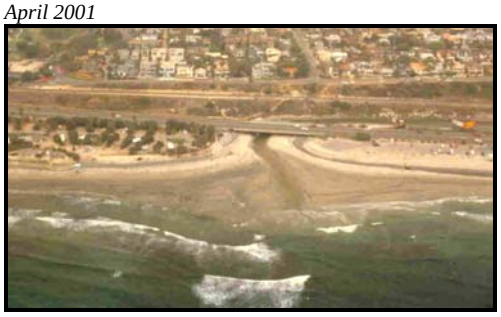
The controlling elevations noted subsequent to the RBSP nourishment activities (Fall 2001 to Spring 2005) ranged from +0.7 to +2.4 ft, near the bottom of the range that prevailed prior to the RBSP (+0.6 to +6.7 ft; Figure 32). The entrance channel condition at the time of the final topographic survey (Spring 2005) is shown in Appendix G.

6.2.4. San Dieguito

Based on data compiled by Elwany, *et al.* (1998; 2003), San Dieguito Lagoon was open to tidal exchange 77% of the time between 1979 and 2001. On average, the channel

April 2001

November 2001



May 2002

November 2002

May 2003

November 2003

April 2004

October 2004

May 2005

October 2005

Plate 15. San Elijo Lagoon Entrance, April 2001 through October 2005

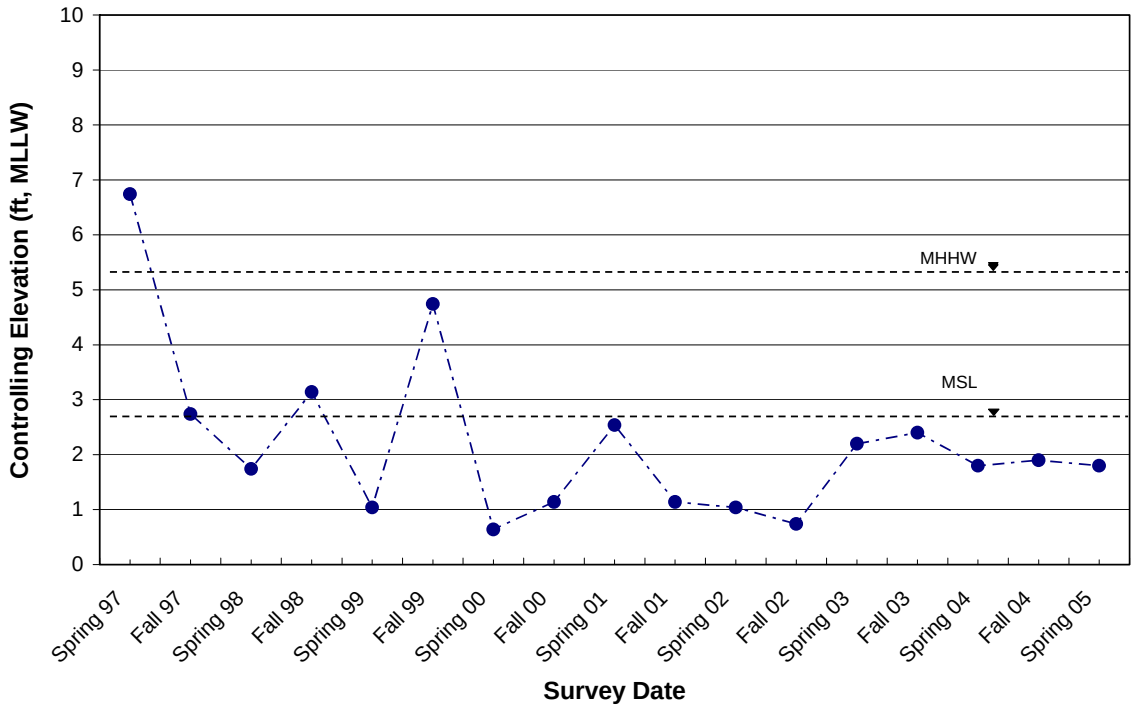


Figure 32. Controlling Elevation for Tidal Exchange in San Elijo Lagoon

closed 0.6 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 five occasions in the first two years that followed the RBSP (Figure 29). The first closure occurred in late November 2001, approximately six months after fill placement at the Del Mar receiver site. The lagoon remained closed to tidal exchange for more than 10 months before mechanical intervention in October 2002. The blocked entrance channel is shown in the May 2002 photo. The entrance closed on four occasions during the 2003 Monitoring Year, requiring mechanical intervention to restore tidal exchange on three of those occasions (December 2002, April 2003, and September 2003). In one instance (February 2003), the entrance channel opened naturally following a period of high rainfall (Elwany, 2004). No closures were recorded during the 2004 or 2005 Monitoring Years. The frequencies of channel closure (1.3 times per year) and mechanical opening (1.0 times per year) during the four-year period following the RBSP exceeded the corresponding historical averages (0.6 and 0.6 times per year, respectively).

April 2001

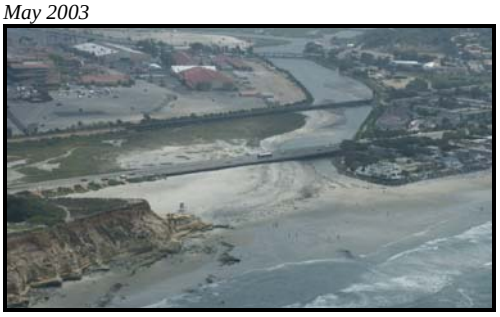
November 2001

May 2002

November 2002

May 2003

November 2003



April 2004

October 2004

May 2005

October 2005

Plate 16. San Dieguito Lagoon Entrance, April 2001 through October 2005

The monitoring data suggest that the November 2001 closure was caused, at least in part, by the northerly transport of sediment from the nearby Del Mar receiver site. Of particular relevance is an accumulation of sediment noted at the waterline of Transect DM-0590 at the time of the Fall 2001 Survey. This transect lies to the north of the Del Mar fill, and immediately south of the lagoon entrance channel (Figure 25). A similar accumulation was observed at the time of the Fall 2002 survey, but was absent in subsequent Fall surveys (2003, 2004, and 2005) – this change suggests the Del Mar fill has been dispersed to a large extent by waves and currents, and no longer exerts a significant impact on the condition of San Dieguito Lagoon.

The entrance to San Dieguito lagoon was open 63% of the time subsequent to the RBSP, slightly below the historical average of 77%. The lower percentage resulted in part from the fact that the lagoon was allowed to remain closed for nearly one year (November 2001 to October 2002). It is likely that climatic conditions also played an important role in the disparity between the two percentages, with three of the past four years characterized by below- to near-average precipitation (Section 2.1.1). In contrast, the pre-RBSP average was derived from a period of above-average precipitation (1979-2001). As discussed in Section 6.1, Elwany, et al. (1998) estimated that San Dieguito Lagoon remains open 66% of the time during periods of above-average precipitation and only 12% of the time during periods of below-average precipitation.

Following the RBSP, the controlling elevations in the entrance channel varied between +1.1 ft and +7.3 ft (Figure 33). Although large, this range lies within the elevations measured prior to the RBSP (+0.7 to +9.1 ft). The entrance channel condition at the time of the final topographic survey (Spring 2005) is shown in Appendix G.

6.2.5. Los Peñasquitos

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

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

2000; 2001; West, 2003). During this period, the entrance closed an average of 2.3 times per year, and was mechanically opened or widened 1.6 times per year.

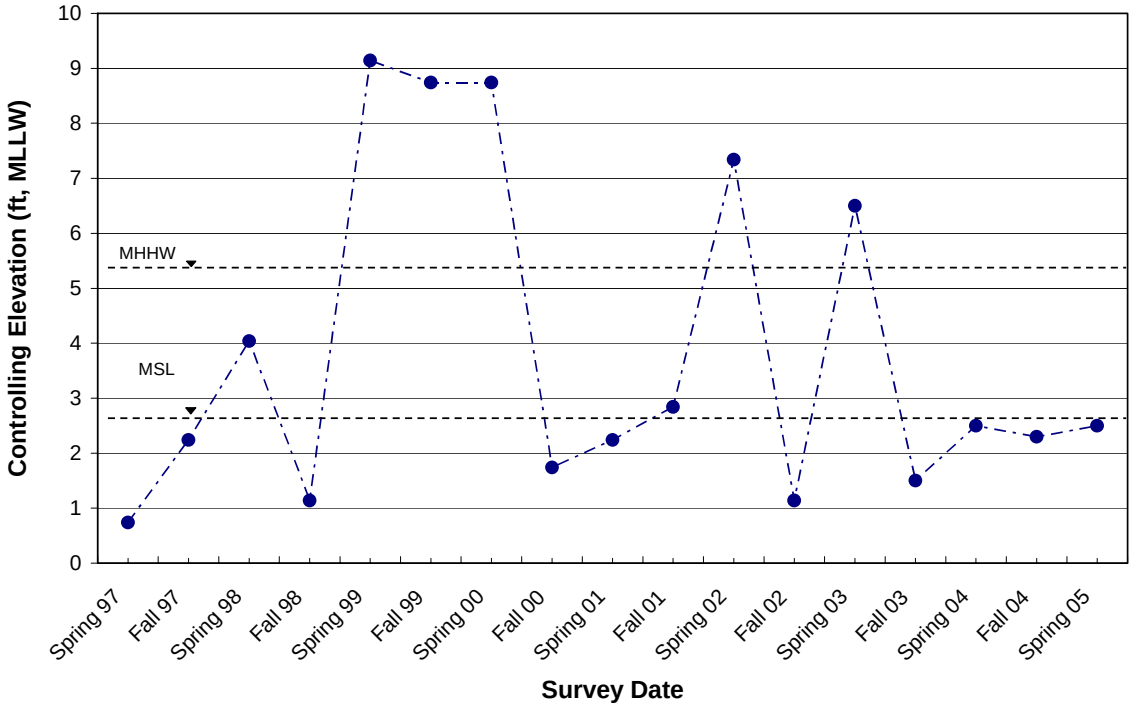


Figure 33. Controlling Elevation for Tidal Exchange in San Dieguito Lagoon

The Los Peñasquitos entrance channel closed on three occasions during the 2002 Monitoring Year and four occasions during the 2003 Monitoring Year (Figure 29). The channel opened naturally following four of these closures, but mechanical excavation was required to re-establish tidal exchange on three other occasions (February 2002, June 2002, and February 2003). The most recent closure, occurring in late October 2003, persisted eight days into the 2004 Monitoring Year before the channel opened naturally. The lack of subsequent closures during the 2004 and 2005 Monitoring Years is likely attributable to construction activities at the PCH bridge, which include a sheetpile structure to confine the lagoon channel. The channel condition at the time of the semi-annual overflights conducted between April 2001 and October 2005 is shown in Plate 17.

The lagoon was open to tidal exchange 90% of the time following the RBSP, closely approximating the historical average of 93%. The frequencies of channel closure (1.3 times per year) and mechanical opening (1.0 times per year) during this period were below the corresponding historical averages (2.3 and 1.6 times per year, respectively).

April 2001

November 2001

May 2002

November 2002

May 2003

November 2003

April 2004

October 2004

May 2005

October 2005

Plate 17. Los Peñasquitos Lagoon Entrance, April 2001 through October 2005

The controlling elevations in the entrance channel measured subsequent to the RBSP nourishment activities ranged from +1.1 to +3.8 ft. Prior to the RBSP, the range was higher: +1.5 to +7.1 ft (Figure 34). The entrance channel condition at the time of the final topographic survey (Spring 2005) is shown in Appendix G.

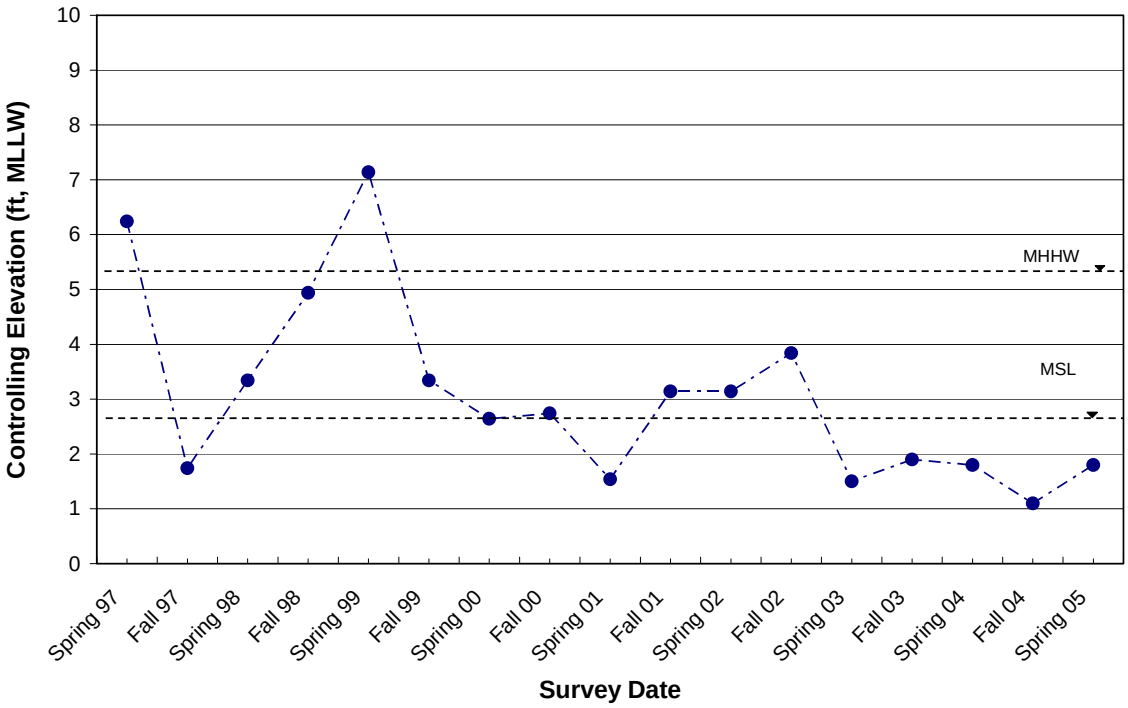


Figure 34. Controlling Elevation for Tidal Exchange in Los Peñasquitos Lagoon

7. CONCLUSIONS

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

1. Although the precipitation and streamflow recorded in 2005 greatly exceeded the pre-RBSP averages, the wave energy and storm frequency were below average. When the five-year RBSP Monitoring Period is considered, only the streamflow in the San Luis Rey River exceeds the pre-RBSP average. The implications are threefold: (1) the mild wave conditions helped to prolong the life of the beach fills; (2) the scant precipitation and low streamflows were inadequate to deliver significant quantities of beach-quality sediment to the coast until the last year of the RBSP Monitoring Period; and (3) the low streamflows were inadequate to flush coastal sediment from the lagoon entrances in the Oceanside Cell until the last year of the RBSP Monitoring Period.

2. The only non-RBSP nourishment provided during the RBSP Monitoring Period was 2,000 cy (less than 1,000 cy/yr) at Moonlight Beach, and 301,000 cy (60,000 cy/yr) at Imperial Beach. As a result, approximately 97% of the RBSP fill material (2,040,000 cy) may be regarded as compensating for the average annual nourishment of 408,000 cy/yr provided from other sources in the years preceding the RBSP. The remaining RBSP material, consisting of only 64,000 cy, represents incremental nourishment. The Mission Beach Cell has been the greatest beneficiary of incremental nourishment, having received 140,000 cy. The Silver Strand Cell has received an incremental 55,000 cy, but the Oceanside Cell has incurred a deficit of 130,000 cy. (It should be noted that, due to rounding, the sum of the incremental nourishment volumes shown above equates to 65,000 cy, rather than the reported value of 64,000 cy.)

   It is noteworthy that the Oceanside Cell incurred a nourishment deficit in 2005 for the first time since placement of the RBSP fill material. This circumstance, which has resulted from the virtual cessation of nourishment activities since 2001, increases the potential for reversing the improvements that resulted from the RBSP. Conversely, the incremental nourishment provided to the Mission Beach and Silver Strand Cells suggests that these beaches will be able to sustain the benefits derived from the RBSP over a longer period of time.

3. The average annual sand bypassing rates at Oceanside Harbor, Agua Hedionda and San Elijo Lagoon during the RBSP Monitoring Period (283,000, 228,000 and 25,000 cy/yr)

exceeded the average annual rates in prior years by 31,000, 85,000, and 11,000 cy/yr, respectively. The increased bypassing rates constituted a direct benefit to the receiving beaches, which were located south of Oceanside Harbor, north and south of Agua Hedionda, and south of the San Elijo Lagoon entrance. At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the historical and RBSP Monitoring Period bypassing rate is not meaningful.

4. During the 2005 Monitoring Year, the volume of sediment in the San Diego County shorezone did not change appreciably, with volume gains and losses nearly balanced among the survey transects. In contrast, shoreline retreat predominated during the one-year period. The apparent paradox created by a stable shorezone volume and a retreating shoreline may be explained by the fact that sediment continued to move from the subaerial portion of the profile to the submerged portion, but remained within the shorezone. The predominance of shoreline retreat appears to be attributable to the offshore dispersal of the RBSP fill material coupled with a lack of beach nourishment activities (other than the material placed offshore in the Silver Strand Cell in 2005). Despite above-average precipitation and high streamflows during the 2005 Monitoring Year, the profile data suggest that sediment input from rivers and streams was relatively modest. The stability of the shorezone sediment volume implies that the limited nourishment, lack of substantial riverine sediment input, and relatively mild wave conditions neither added or removed significant quantities of material from the coast.

5. After three consecutive years of shoreline retreat (2003, 2004, and 2005), the beach widths at most locations in the Silver Strand and Oceanside Cells had diminished to such an extent that they were less than the pre-RBSP values for the first time since placement of the nourishment material. In the Mission Beach Cell, the changes in beach width over the RBSP Monitoring Period were balanced between losses and gains. Notwithstanding the prevalence of shoreline retreat relative to the pre-RBSP condition in two of the three littoral cells, sediment volumes tended to increase over the five-year RBSP Monitoring Period. The greatest shorezone volume gains occurred in the Oceanside Cell. The primary causes of these gains appear to have been the RBSP beach fills, and the relatively mild wave conditions that prevailed throughout the period.

6. The performance of the individual RBSP fills varied considerably. In the majority of cases, however, the receiver beaches experienced an increase in both shoreline position and shorezone volume. In many cases, dispersal of the fill material was accompanied by shorezone volume gains on the downdrift beaches. The positive impact of the RBSP was most evident in the Oceanside-North Carlsbad area, where the monitoring data

suggest that the Oceanside and North Carlsbad fills coalesced and dispersed laterally to benefit more than two miles of shoreline. A similar situation was observed in the Encinitas area involving the Batiquitos and Leucadia fills.

7. The two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth following the RBSP (Fall 2001 to Fall 2005). Of the three unstabilized entrances, San Elijo closed on four occasions, San Dieguito on five, and Los Peñasquitos on seven. It is noteworthy that no closure occurred during the 2005 Monitoring Year. This pronounced variation in closures frequency resulted in the San Elijo entrance channel remaining open to tidal exchange for a greater percentage of time than the pre-RBSP average (93% vs. 43% historically), the San Dieguito channel remaining open for a lesser percentage of time (63% vs. 77% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (90% vs. 93% historically).

8. At San Elijo Lagoon, the dredge rate following the RBSP (25,000 cy/yr) exceeded the historical average (15,000 cy/yr) by 67%. However, the higher rate is attributable, at least in part, to an increased level of maintenance made possible by additional funding. The post-RBSP dredge rate at Agua Hedionda (178,000 cy/yr) was within 3% of the pre-RBSP rate (182,000 cy/yr). At Batiquitos, where lagoon restoration was undertaken during the pre-RBSP monitoring years, comparison of the two dredge rates is not meaningful.

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