Final

CITY OF DEL MAR COASTAL SEDIMENT MANAGEMENT PLAN

Del Mar, CA

Prepared for
City of Del Mar

August 2018

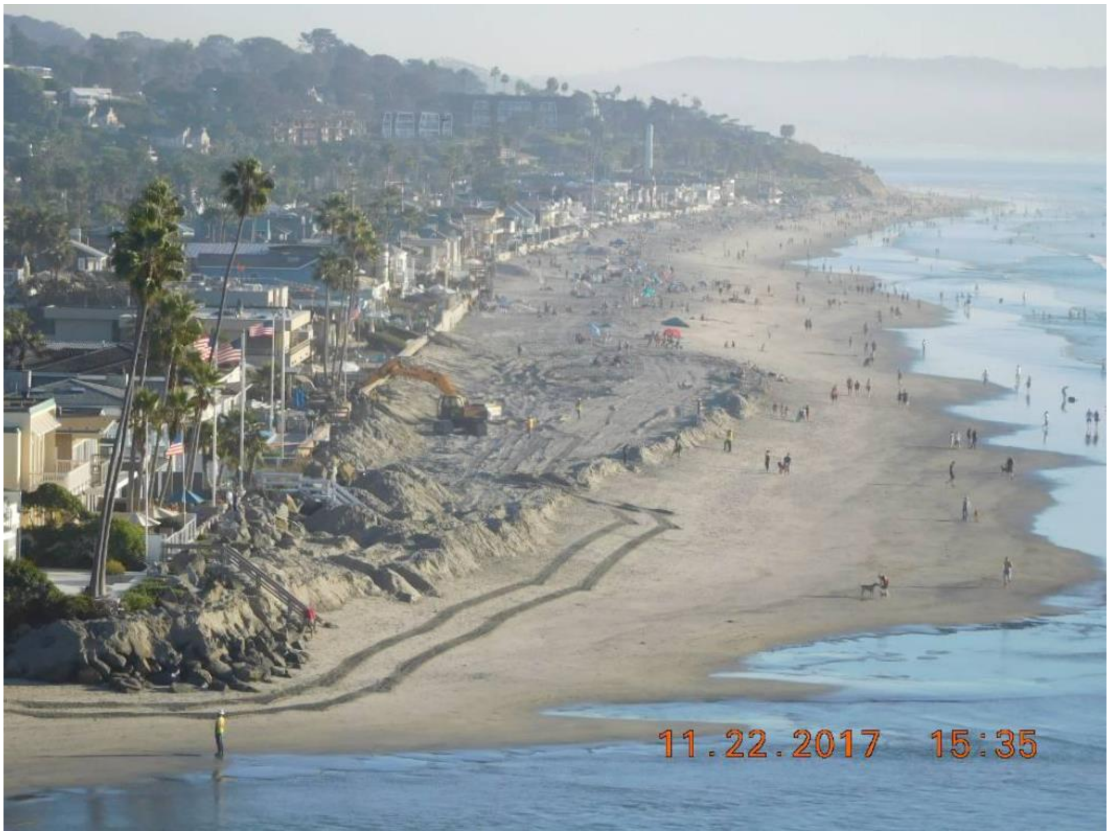

Photo courtesy of Coastal Environments, 2017

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SECTION 1

Introduction and Executive Summary

The Del Mar Vulnerability Assessment Report results showed significant vulnerabilities and risks to Del Mar due to beach erosion and the potential for long-term river channel deposition, which could increase San Dieguito River flooding (ESA 2016). The goal of this Del Mar Sediment Management Plan is to inform the development of sediment management adaptation measures to reduce these risks. The Sediment Management Plan will serve as a companion document to the Adaptation Plan and Local Coastal Plan Amendment. Preparation of a Sediment Management Plan is consistent with the California Coastal Commission (CCC) Policy Guidance's discussion of the need for sediment management planning in Local Coastal Plans.

This Sediment Management Plan includes the following:

- **Current and future conditions sediment budget**. Rates and patterns of deposition and erosion with future sea-level rise for the San Dieguito Lagoon and Del Mar Beach system were assessed based on estimates of river sediment load, lagoon channel deposition, inlet dynamics, and beach and bluff erosion. The results of this analysis are presented in Section 2 (current conditions) and Section 3 (future conditions).
- **Lagoon channel dredging plan.** Based on the sediment budget assessment, a potential program for river flood management with lagoon channel dredging was developed. The lagoon channel dredging plan is presented in Section 4.
- **Beach nourishment plan.** A beach nourishment plan was developed to identify and evaluate potential sand sources, including reuse of lagoon dredge material, and to optimize sand placement at the Del Mar beach to reduce risks with sea-level rise. The beach nourishment plan is presented in Section 5.
- **Planning-level cost estimate.** A cost estimate for dredging and beach nourishment was developed and is presented in Section 6.

The Sediment Management Plan analysis, presented in the subsequent sections, leads to the following conclusions:

- The existing San Dieguito Lagoon mouth dredging and beach nourishment program performed by Southern California Edison (SCE) for the San Dieguito Lagoon Restoration (San Onofre Nuclear Generating Station (SONGS) Mitigation) is not expected to maintain the Del Mar beach in a walkable condition in the future with projected sea-level rise. In the near-term, strategically placing dredged sand based on forecast wave conditions could help keep more of the sand on Del Mar Beach and reduce the amount of sand that may be transported back into the lagoon.
- The potential scale of beach nourishment could involve placing about 1 million cy of sand roughly every 10 years on the Del Mar Beach with up to 5 ft of sea-level rise. This could cost

approximately $21 to $22 million every 10 years. This scale of nourishment is comparable to the amount of beach nourishment San Diego Association of Governments (SANDAG) performed for the entire San Diego coast in the Oceanside Littoral Cell (OLC) for Regional Beach Sand Project (RBSP) I and II. In the near-term, up to 400,000 cy of sand would be needed every 10 years, at a cost of approximately $9 million every 10 years. While beach nourishment is likely to be feasible for lower amounts of sea-level rise, the feasibility of larger scale beach nourishment with sea-level rise of about 3 to 5 ft at Del Mar is uncertain, primarily due to uncertainties in the regional demand and availability for sand sources. Additionally, the existing sea walls and revetments would likely need to be raised in conjunction with beach nourishment to maintain the existing level of flood management for North Beach.

The above estimate of beach nourishment assumes that beaches to the north and south of Del Mar would implement similar scales of beach nourishment or that sand retention structures would be installed in Del Mar to retain sand. Otherwise, assuming that other beaches are not nourished and sand retention structure are not implemented, large-scale beach nourishments in Del Mar are not expected to be affective because placed sand is not expected to persist for long due to high potential for placed sand to be transported down and upcoast.

For reference and comparison, note that the sand needs for the OLC for the midcentury are estimated to be approximately 2.2 million cy per year or 22 million cy every 10 years using methods outlined in Flick and Ewing (2009). This is more than thirty times greater than the potential scale of Del Mar Beach at midcentury and greater than documented sources of sand in the region.

- External sources of sand are expected to be required to nourish and maintain the Del Mar Beach. Offshore sources of sand have been identified, mined, and placed to nourish beaches in San Diego County through the SANDAG RBSP. The City of Del Mar could pursue beach nourishment using offshore sources through regional beach nourishment programs or possibly through a City-lead program. It is also possible that sand trapped in the Lake Hodges Reservoir could be dredged, transported, and placed in Del Mar. The City could also establish a Sand Compatibility and Opportunistic Use Program (SCOUP) to opportunistically accept sand that is compatible with placement on the Del Mar beach for small beach nourishment projects (less than 150,000 cy) (California Division of Boating and Waterways, http://dbw.parks.ca.gov/?page_id=29355).
- The City of Del Mar's participation in regional beach nourishment programs such as potential future phases of the SANDAG RBSP has the potential to benefit the City of Del Mar. Planning, designing, permitting, and implementing beach nourishment at a regional scale is likely to be more effective than a City-lead program. Sand placed directly on the Del Mar beach has the potential to better maintain a walkable beach than relying on sand transport from up-coast nourishment.
- Beach nourishment could potentially have some negative effects that may need to be mitigated, including effects to beach ecology, impacts of mining sand sources, and increased deposition of sand in the mouths of San Dieguito Lagoon and Los Peñasquitos Lagoon.
- Constructing sand retention structures, such as multi-benefit offshore reefs, is expected to increase the effectiveness of beach nourishment and may also help to capture sand that transported along the Del Mar shoreline. However, hard structures are not the preferred plan for Del Mar and constructing sand retention structures would have impacts that would likely need to be mitigated, including direct impacts and indirect impacts to sand transport to adjacent beaches (downcoast and upcoast). Coordination with neighboring cities and other jurisdictions would be required for planning sediment retention structures.

SECTION 2

Current Conditions Sediment Budget

An understanding of existing deposition, erosion, and sediment transport patterns is pertinent to determining how sea-level rise may impact Del Mar Beach and the San Dieguito Lagoon. This section covers the existing processes that impact the beach and lagoon and Section 3 details how these processes may change in the future.

One way to understand the existing system is to develop a sediment budget. A sediment budget is a coastal management tool used to understand the balance between sediment added to and removed from a coastal system. When a system has surplus sand, beaches will grow and deposition in a lagoon may increase. When a system is sand-starved, beaches erode.

This section describes the analysis, which builds on the results of the Del Mar Vulnerability Assessment (ESA 2016), to develop a sediment budget for Del Mar.

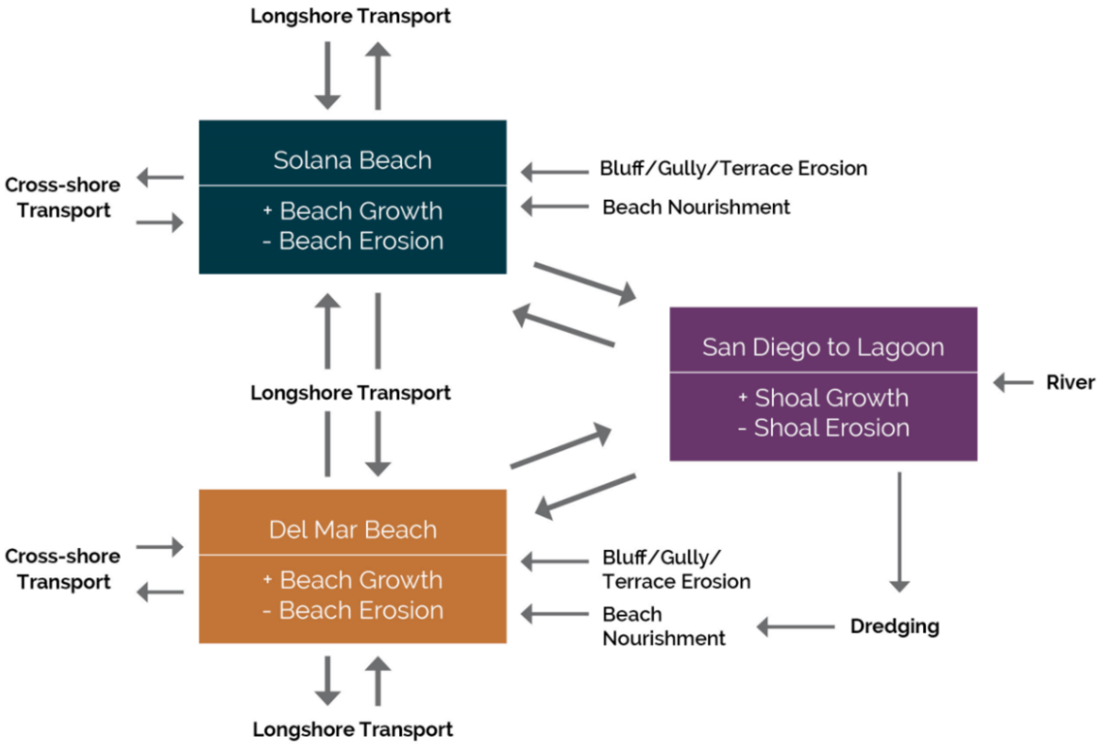
2.1 Del Mar Sediment Budget Terms

Del Mar Beach and the San Dieguito Lagoon do not exist on their own; they are part of a coastal system and are connected to the beaches upcoast and downcoast of Del Mar. In fact, the Del Mar coast is part of the Oceanside Littoral Cell (OLC), which spans approximately 57 miles from Dana Point to Point La Jolla. Del Mar is part of a subcell of the OLC, which extends from the Oceanside Harbor to the La Jolla and Scripps submarine canyons.

To develop a sediment budget for Del Mar, the surrounding areas must be considered. Figure 2-1 shows a diagram of the Del Mar coastal system, which includes the following processes:

- Longshore transport: the movement, driven by waves, of sand along the coastline.
- Cross-shore transport: the movement, also driven by waves, of sand between onshore and offshore.
- Bluff/Gully/Terrace erosion: erosion of sand and gravel from bluffs and more inland areas, such as gullies and terraces, which contribute material to the beach.
- Beach nourishment: human efforts to add sand to the beach, such as the San Diego Association of Governments (SANDAG) Regional Beach Sand Project (RBSP).
- River transport: the movement of sediment from the watershed transported by the river during high flows such as those associated with storm events.
- Dredging: removal of sand from the mouth of the lagoon

The three boxes delineated for the sediment budget (i.e. Solana Beach, Del Mar Beach, and San Dieguito Lagoon) respond to these inputs and outputs. For example, if the inputs are greater than the outputs to one of the beach boxes, the beach will expand. Conversely, if the outputs are greater than the inputs, the beach will erode. The Solana Beach box was defined as the beach area from the mouth of the San Elijo Lagoon down to the mouth of the San Dieguito Lagoon. The Del Mar Beach box was defined as the beach area from the mouth of San Dieguito Lagoon down to the Los Peñasquitos Lagoon. The San Dieguito Lagoon box focused on the mouth of the lagoon, from the beach to the Jimmy Durante Road crossing. Figure 2-2 shows a map of the boxes.



Del Mar Sediment Management Plan / D150347.01

SOURCE: ESA 2018

Figure 2-1
Sediment Transport Processes in Del Mar

The following sections describe the quantification of the different processes, which is then used in Section 2.5 to develop the existing conditions sediment budget.

SOURCE: USGS

Del Mar LCP Update. 150347

Figure 2-2

Del Mar Sediment Budget Boxes

2.2 Sediment Budget Inputs and Outputs

2.2.1 Longshore Transport

Longshore transport is the movement of sand along the coastline by waves. Many studies have been conducted to quantify this movement in the OLC as shown in Table 2-1. Typically, summer waves produce northerly transport, but winter waves, which have more energy, produce transport to the south. In general, studies have found that the sand predominantly moves downcoast (south) through the OLC (U.S. Army Corps of Engineers (USACE) 1991). However, changes in wave direction occasionally result in upcoast sediment transport.

USACE (1991) reviewed previous studies of longshore transport near Oceanside and found approximately 740,000 cubic yards (cy) of sediment moving to the south annually, and 546,000 cy moving to the north. This results in a gross transport (i.e. the sum of movement north and south) of 1,286,000 cy/yr and a net transport (i.e. the difference between movement north and south) of 194,000 cy/yr to the south.

Closer to Del Mar, Moffatt and Nichol (1990) estimated net transport rates of 100,000 – 250,000 cy/yr to the south, which is on the same order of magnitude as the USACE 1991 study. Moffatt and Nichol (as well as Inman and Masters 1991) also analyzed net transport rates during different time periods. Both studies found a decrease in longshore transport to 40,000 – 50,000 cy/yr to the south in the 1980s when compared to previous decades. These studies suggest this decrease was related to a more variable wave climate between 1980 and 1990, which increased wave activity from the south, increasing transport to the north, and thus decreasing net transport to the south (USACE 2015a).

In 2001, Coastal Environments estimates the net transport rate in the vicinity of Cardiff Beach. Using wave climate data from 1978 to 1994, they estimated a net transport rate of 56,000 cy/yr to the south, which is comparable to the reduced rates found in Moffatt and Nichol (1990) and Inman and Masters (1991).

These prior reports also note that the computed sand transport based on wave conditions provides an estimate of the potential transport rates which are likely higher than the actual transport rates. The actual sand transport can be limited by the amount of sand available to be moved, as implied by the relatively narrow beaches in the area.

Current studies that are in the research phase are evaluating the divergence of longshore transport to determine if certain beaches are accreting or eroding.

Because longshore transport rates vary with the wave climate (e.g. storm events, El Niño years, etc.), the amount of sand moving along the coast can vary year to year. To capture this variability in the sediment budget, a high (194,000 cy/yr) and low (50,000 cy/yr) net transport rate to the south were used (Section 2.5). It is important to note that quantification of longshore transport is complex and that the estimates used here should be updated as more research becomes available (see Section 2.5 for a further discussion of uncertainty and sensitivity).

TABLE 2-1
LONGSHORE SEDIMENT TRANSPORT ESTIMATES

Source		Transport to South (cy/yr)	Transport to North (cy/yr)	Gross Transport (cy/yr)	Net Transport (cy/yr)	Method/Source
Marine Advisers	1960	760,000	545,000	1,305,000	216,000 To South	Wave energy flux method near Oceanside (in USACE 1991)
Hales	1978	643,000	540,000	1,183,000	102,000 To South	Wave energy flux method near Oceanside
Inman and Jenkins	1983	807,000	553,000	1,360,000	254,000 To South	Wave energy flux method near Oceanside (in USACE 1991)
Tekmarine, Inc.	1987	520,000	414,000	934,000	106,000 To South	South of Oceanside harbor (in USACE 1991)
Moffatt and Nichol	1990				*1945-1977:* 100,000 – 250,000 *1978-1987:* 0 – 40,000 To South	Along Del Mar coastline
USACE	1991	740,000	546,000	1,286,000	194,000 To South	Average of Marine Advisers 1960, Hales 1978, and Inman and Jenkins 1983
Inman and Masters	1991				*1960-1978:* 190,000 *1983-1990:* 50,000 To South	Between Carlsbad Submarine Canyon and Point La Jolla
Coastal Environments	2001				56,000 To South	Near Cardiff, considering wave climate from 1978 to 1994
Patsch and Griggs	2006				146,000 To South	Based on dredging at Oceanside harbor

ESA also calculated potential sediment transport rates in the vicinity of Del Mar, at points shown in Figure 2-3 for 2000 – 2018. Transport rates were calculated for Southern Solana Beach/Dog Beach, Del Mar Beach (south of San Dieguito Lagoon mouth) and near Powerhouse Park. Wave conditions were extracted from the Coastal Data Information Program (CDIP) Model Output Points (MOP) (O’Reilly et al. 2016) in 10-meter-deep water near the shore. The 10-meter nearshore wave heights were substituted for breaking wave heights as an approximation. Equations based on Kamphuis (1991), Mil-Homens et al. (2013), and the Coastal Engineering Research Center (1984) were used in the estimates.

SOURCE: Google Earth, CDIP

Del Mar LCP Update . 150347

Figure 2-3

Sediment Transport Output Points

Table 2-2 shows ESA's transport estimates by shoreline stretch and sand type. In all three locations, the overall net transport was to the south when calculated using the shore angle defined by the line of MOP points down the coast, representing an overall regional shoreline angle. When calculated using the local angle of the wet-dry shoreline, net transport rate directions varied. Where the shoreline is tilted more to the north, such as at the stretch of Del Mar beach located south of the San Dieguito Lagoon inlet, net transport was to the north. These sediment transport calculations are highly sensitive to shoreline angle. The shoreline angle that determines actual sediment transport varies on a wave-by-wave basis depending on the wavelength. An overall approximation is likely something between the MOP point line angle and the angle of the wet-dry shoreline.

Both northerly and southerly transport was present at all three sites, varying in magnitude depending on the season and the shoreline angle. Southerly transport is strongest in the winter, while northerly transport is more prevalent in the summer, due to the seasonal pattern of prevailing swell waves. Winter transport rates were above average during the El Niño winters of 2009-2010 and 2015-2016 for all locations. Overall, Southern Solana Beach/Dog Beach and Del Mar Beach had similar transport rates and seasonal patterns of transport. The Powerhouse Park location appeared to have somewhat greater exposure to waves, resulting in slightly higher northerly and southerly transport rates when compared to the Southern Solana Beach/Dog Beach and Del Mar Beach locations. Note that potential sediment transport rates are likely not realized in the Del Mar area due to limited sediment available to be mobilized and transported.

TABLE 2-2
NET MEAN SAND TRANSPORT ESTIMATES IN DEL MAR[1]

		Powerhouse Park (cy/yr)	Del Mar Beach (South of Inlet) (cy/yr)	South Solana Beach/Dog Beach (cy/yr)
MOP Angle	**Fine-Medium Sand**	150,000 to the South	150,000 to the South	170,000 to the South
	Coarse Sand	100,000 to the South	100,000 to the South	110,000 to the South
Wet-Dry Shoreline Angle	**Fine-Medium Sand**	20,000 to the South (substantial North and South transport)	90,000 to the North	240,000 to the South
	Coarse Sand	10,000 to the South (substantial North and South transport)	70,000 to the North	160,000 to the South

[1] Results shown are averaged Kamphuis and Modified Kamphuis results

2.2.2 Cross-Shore Transport

Cross-shore transport is the movement of sand, driven by waves, between onshore and offshore. When sand is driven onshore, it can build up beach berms. Sand driven offshore can end up in an offshore bar, where it can be later moved back to the beach, or be lost from the system to a submarine canyon. This process is also seasonal and in the winter, storm events erode the shoreline and move sand offshore. Some of the sand is moved south by bottom currents and lost to the La Jolla submarine canyons. In the summer, sand that has not been lost is then pushed back onto the beach by the waves.

Cross-shore transport is one of the more difficult terms to quantify in a sediment budget. There are far fewer studies that quantify cross-shore transport in the OLC. However, Moffatt and Nichol (1990) used offshore surveys to quantify the cross-shore transport in the OLC. They found approximately 260,000 cy/yr net cross-shore transport for the entire littoral cell, with an average of 1 cy/yr per foot of shoreline. For Solana Beach, this represents a loss of 14,500 cy/yr of sand based on the shoreline length. For Del Mar Beach, this represents a loss of 15,700 cy/yr of sand. These values can be thought of as a “loss” of a little less than one foot of beach width per year.

2.2.3 Bluff/Gully/Terrace Erosion

2.2.3.1 Bluff Erosion

Where coastal armoring is not present, erosion of sand and gravel from the bluffs will contribute material to the beach. A study conducted by the California Department of Boating and Waterways (CDBW) and the State Coastal Conservancy (SCC) in 2002 determined that roughly 55,000 cy of sand is contributed to the OLC annually from eroding bluffs. The study also calculated that an additional 12,400 cy/yr of material does not make it to the beach due to coastal armoring.

In 2006, Young and Ashford conducted a more site-specific evaluation of bluff contributions for the OLC and found the bluffs were contributing 100,000 cy of sand annually. Their study looked specifically at the Solana Beach bluffs, the Del Mar bluffs, and the Torrey Pines bluffs and found erosion rates of 8,100, 4,800, and 14,500 cy/yr, respectively. It is assumed for the sediment budget that the net longshore transport is to the south, so Torrey Pines is not analyzed, but it is likely that some amount of the large source of sand from the bluffs, gully, and terrace erosion (see Section 2.2.3.2) at Torrey Pines may be travelling north to Del Mar beach.

2.2.3.2 Gully and Terrace Erosion

Young and Ashford (2006) estimated gully erosion and terrace degradation and found 31,500 cy was contributed to the OLC annually. The study revised and reduced a previous estimate by Robison (1988), which had included periods of severe gully erosion that had occurred due to altered drainage patterns associated with the construction of the coastal highway. Since current regulations limit this type of severe erosion through construction permits, the estimate by Young and Ashford is used in this study.

Young and Ashford (2006) estimated 0 cy/yr of gully erosion from Solana Beach, 700 cy/yr from Del Mar, and 4,600 cy/yr from Torrey Pines.

2.2.4 Beach Nourishment

Beach nourishment involves placing additional sand on a beach to raise the shoreline profile, which, in turn, extends the beach further seaward, creating a wider beach. Sand has been placed on beaches in the OLC for many years through multiple means. In the area, San Elijo, San Dieguito, and Los Peñasquitos Lagoons participate in sand bypassing, which involves removing sand from within the mouth of the lagoon and placing it on the downshore beach. SANDAG has led a regional sand placement program (RBSP) with two placements in 2001 and 2012. Additionally, opportunistic sand placements have occurred when sand has become available through other projects. These three means of sand nourishment are discussed below.

2.2.4.1 Sand Bypassing

Lagoon mouths interact with longshore sand transport, with sand moving into and out of the lagoon mouth due to waves and currents. When in equilibrium, the littoral transport rate is maintained by bypassing across the mouth as well as back out of the mouth during lagoon discharge associated with ebb tidal flows. San Dieguito Lagoon is also the San Dieguito River mouth, where high river flows deliver sand to the beach episodically. Changes to lagoon hydrology and river discharge can, therefore, affect adjacent beaches.

Historically, many of the lagoons in the OLC would close periodically, as sand built up in the lagoon mouth. With one of the bigger watersheds in the region, the San Dieguito Lagoon mouth was frequently connected to the ocean, although it still closed periodically (Beller et al 2014).

With the San Dieguito Lagoon Restoration Project, completed in 2011 by Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and others as mitigation for the San Onofre Nuclear Generating Station (SONGS), California Coastal Commission (CCC) Permit 6-04-088 was established, which requires SCE to maintain the lagoon mouth open and place dredged sand onto Del Mar Beach.

Since 2011, SCE has conducted land-based dredging to remove accumulated sand from the San Dieguito Lagoon inlet and redistributed the sand onto Del Mar Beach. Table 2-3 summarizes the lagoon bypassing for San Dieguito Lagoon, as well as San Elijo and Los Peñasquitos Lagoons. At San Elijo and Los Peñasquitos Lagoons, dredging occurs annually, as the mouths of these lagoons close more frequently. Maintenance dredging at San Dieguito Lagoon is typically around 16,000 cy, although a larger dredging and sand placement (40,000 cy) occurred in 2011 as part of the San Dieguito Lagoon restoration project.

TABLE 2-3
SAND BYPASSING

	Sand placed on beaches from:		
Year	**San Elijo Lagoon (cy)**	**San Dieguito Lagoon (cy)**	**Los Peñasquitos Lagoon (cy)**
1995	6,000		22,000
1996	8,000		5,000
1997	31,000		17,000
1998	12,000		8,000

1999	17,000	16,000	8,000
2000	23,000		20,000
2001	23,000		
2002	18,000	16,000	20,000
2003	32,000	16,000	33,000
2004	30,000		5,000
2005	17,000		5,000
2006	18,000	16,000	14,000
2007	19,000		22,000
2008	23,000	16,000	29,000
2009	19,000		23,000
2010	21,000		22,000
2011	23,000	40,000*	23,000
2012	24,000		13,000
2013	26,000		33,000
2014	23,000		48,000
2015	22,000	16,800	23,000
2016	22,000		60,000
2017	N/A	19,000	N/A

*Dredging from San Dieguito Lagoon in 2011 included sand from the mouth as well as material from the construction of the SONGS San Dieguito Lagoon Restoration Project (i.e. excavation of the wetlands).

2.2.4.2 Regional Beach Sand Project

SANDAG has completed two regional sand placements in the San Diego Region. RBSP I occurred from the beginning of April to the end of September in 2001, and placed 2.1 million cy of beach sand on twelve receiver beaches between Oceanside and Imperial Beach, including Del Mar Beach (Table 2-4). In 2012, SANDAG implemented RBSP II, which built upon the efforts of the RBSP I. From September to December 2012, RBSP II placed 1.5 million cy of sand on eight of the previous receiver beaches (Table 2-4). Four of the previous receiver jurisdictions, including the City of Del Mar, opted not to participate in RBSP II.

TABLE 2-4
RBSP SAND PLACEMENT WITHIN THE OLC

Location	RBSP I (2001)		RBSP II (2012)	
	Volume (cy)	Median Grain Size (mm)	Volume (cy)	Median Grain Size (mm)
Oceanside	421,000	0.62	293,000	0.54
North Carlsbad	225,000	0.14 – 0.62	219,000	0.57
South Carlsbad	158,000	0.62	141,000	0.66
Batiquitos	117,000	0.62	106,000	0.59
Leucadia	132,000	0.62	n/a	n/a
Encinitas- Moonlight Beach	105,000	0.34 – 0.62	92,000	0.48
Encinitas- Cardiff State Beach	101,000	0.34	89,000	0.57
Solana Beach- Fletcher Cove	146,000	0.14	142,000	0.55
Del Mar	183,000	0.14	n/a	n/a
Torrey Pines	245,000	0.14	n/a	n/a

Table 2-4 also includes the median grain size of the placed material. The sand placed for RBSP I in Solana Beach, Del Mar, and at Torrey Pines State Beach had a median grain size of 0.14 mm, which is relatively small. For example, sand at Del Mar Beach varies between 0.20 – 0.26 mm, based on sediment sampling between 2004 and 2010 (see Section 2.2.5.2). It was observed that sand from the initial placement disappeared almost immediately, which may be due to the fine grain size. The later RBSP II placed much coarser grain material in the southern OLC, on the order of 0.6 mm, and monitoring showed that the sand stayed on the beaches much longer (Section 2.3.1). A recent study found that RBSP II sand placements constructed with coarser-than-native grain material at Imperial Beach, Cardiff Beach, and Solana Beach were relatively long-lived, resulting in elevated subaerial sand volumes for several years (Ludka et al. 2018).

2.2.4.3 Opportunistic Sand Placement

Three projects have resulted in opportunities for placing sand within the study area. In 1997, the U.S. Navy Homeporting project resulted in 170,000 cy of sand which was placed in the nearshore of Del Mar Beach. In 1998, 51,000 cy was placed in Fletcher Cove, in Solana Beach, as a result of the Lomas Santa Fe Grade Separation. In 1999, another 54,000 cy was placed on Solana Beach due to the North County Commuter Rail Project.

2.2.4.4 Potential Future Nourishment Projects

USACE has partnered with the Cities of Encinitas and Solana Beach on the Encinitas-Solana Beach Coastal Storm Damage Reduction Project, which would place a significant volume of sand on beaches in the area if the project is implemented. An EIS/EIR for the project was completed in April 2015, with an expected date of construction in 2018.

The project would involve placing sand in Encinitas and Solana Beach through an initial placement of 340,000 and 700,000 cy of sand, respectively. Periodic nourishment would follow, with 220,000 cy of sand placed every 5 years in Encinitas and 290,000 cy of sand placed every 10 years in Solana Beach.

2.2.5 River Transport

The majority of sediment that was historically transported from the San Dieguito River watershed to the ocean is now captured in either the Lake Hodges or Lake Sutherland Reservoirs. These upstream modifications greatly regulate the riverine sediment supply and transport through the San Dieguito River Basin. As a result, significant sediment transport now only occurs following large runoff-generating events, and because these events occur intermittently, actual measured sediment transport data is difficult to obtain (USACE 2016).

A substantial amount of work has been done to understand the river sediment transport through the lagoon. Section 2.2.5.1 discusses the sediment yield or quantity of sediment transported by the river. Section 2.2.5.2 presents results of sediment sampling and discusses the sediment grain size in the lagoon and on the beach.

2.2.5.1 River Sediment Yield

Many studies using varying methods and focuses have been completed to look at the sediment yield of the San Dieguito River. The literature presents values of total sediment yield ranging from 9,200 – 15,000 cubic yards per year (cy/yr) with a sand flux of 3,900 – 15,000 cy/yr. These studies are briefly discussed below and sediment yield quantities are summarized in Table 2-5.

Brownie and Taylor (1981), Stow and Chang (1987), and Slagel and Griggs (2006) looked at the natural and actual sediment yield of multiple Southern California rivers with dams. Brownie and Taylor found a 79% reduction of total sediment delivery to the coast due to the Lake Hodges and Sutherland dams, while Slagel and Griggs estimated a 93% reduction in sand and gravel flux. Stow and Chang also estimated 93% of total watershed sediment yield to be blocked by dams.

USACE 1988 used sediment rating curves to estimate the annual sand yield, while USGS (2007) used rating curves to estimate the suspended sediment load. Warrick and Farnsworth used similar methods to the USGS and found similar results for suspended sediment load. USACE also estimated that 6,500 cy of sand drops out in the lagoon annually, so only 600 cubic yards of sand makes it to the ocean each year.

USACE (2016) used a two-dimensional sediment transport model to assess fluvial sediment delivery to the coastal zone under different flood scenarios (10-, 25-, 50-, and 100-year floods) as well the cumulative sediment delivery over a 100-year period with an assumed storm series. USACE also compared sediment delivery to the Highway 101 bridge during 100-year flood events using a one-dimensional model (results from Chang 2006) and two-dimensional model both before and after completion of the SONGS San Dieguito Lagoon Restoration Project.

Since estimates of the river sediment yield vary from study to study, a high (15,000 cy/yr) and low (3,900 cy/yr) sediment yield were used in the sediment budget (Section 2.5). This captures the range of current sediment yield estimates (i.e. excluding estimates of natural, pre-dam yields).

TABLE 2-5
SAN DIEGUITO RIVER SEDIMENT YIELD ESTIMATES

Source		Natural Sediment Yield (no dams) (cy/yr)	Total Sediment Yield (cy/yr)	Suspended Load (cy/yr)	Bedload (cy/yr)	Sand Yield (cy/yr)	Method/Source
Brownlie and Taylor	1981	64,200[1]	12,500[1]	9,000[1]	3,600[1]	12,500[1]	Sediment rating curves (power function fit) were created based on Lake Hodges sediment accumulation and applied to flows from Lake Hodges. Assumed only bed load is released from Lake Hodges and no suspended fines are released.
Stow and Chang	1987					15,000	Used FLUVIAL numerical modeling, which incorporates initial cross-sections, hydrographs, and Graf's equation to determine magnitude-frequency relationships. Estimated that 93,2% of sediment is blocked by upstream dams
USACE	1988					7,100[2]	Sediment rating curves (power function fit) were created using modeled sediment discharges and USGS 2005.
Everest	2002	131,000[3]					Used basin area, delivery ratio (ratio between upland sediment yield and downstream yield) relationship to determine delivery ratio and then applied the ratio to Taylor 1983 upland delivery estimates.
Slagel and Griggs	2006	58,900[4]	9,200[4]	6,500[4]	2,600[4]	3,900[4]	Sediment rating curves (power function fit) were created for each reach using USGS 2004 and applied to daily discharge from USGS 2005. Sand yield determined by percentage of total sediment.
USGS	2007			2,500[5]			Lowess sediment rating curves (polynomial fit) were created using USGS 2004 and applied to daily discharge from USGS 2005.
Warrick and Farnsworth	2009			2,500[5]	380[6]		Lowess Sediment rating curves (polynomial fit) were created using USGS 2004 and applied to daily discharge from USGS 2005. Bedload determined by percentage of total sediment.
USACE	2016		9,900[7]				Sediment yields derived from AdH model, which was verified against sediment transport observations before, during, and after a 12-year 1993 flood

1. Converted based on 1 ton = 0.82 cy per CDBW and SCC 2002
2. USACE 1988 uses a conversion of 1 ton = 12.1 cf = 0.4481 cy

3. Everest 2002 relies on upland sediment values from Taylor 1983, which use a conversion of 1 ton = 0.9615 m3 = 1.26 cy
4. Slagel and Griggs 2006 uses a conversion of 1 ton = 0.5635 m3 = 0.74 cy for dry sand bulk density
5. Converted using 1 ton = 0.9615 m^3 = 1.26 cy per Taylor 1983 for aggregate sediment
6. Bedload assumed to be 15% of suspended-sediment flux (Warrick and Farnsworth 2009).
7. Annual total sediment delivery calculated by dividing the total 100-year storm series (cumulative sediment delivered over the course of an assumed 100-year period) by 100

Potential Future Projects Affecting Sediment Yield

In 2013, the San Dieguito River Park Joint Powers Authority (JPA) proposed restoration of a 140-acre area (called W19) east of the SCE SONGS restoration. The project aims to establish approximately 60 acres of salt marsh, 15 acres of brackish wetland, and enhance/create 5 acres of riparian zone. The proposal includes grading, berm construction, and two connection points with the San Dieguito River. The draft EIR was released to the public for review in March 2017 with anticipated construction to begin in 2018.

As part of the two-dimensional modeling discussed above, USACE (2016) analyzed how the sediment transport results would change with the W19 Restoration Project. Table 2-6 shows that with the W19 Restoration Project, 75,000 cy would deposit in the lagoon and not make it to the coast over the 100-year storm series. This translates to an average loss of 750 cy/yr or 8% of the current load (as estimated by USACE 2016). Since the W19 Restoration Project has not yet been constructed, these results are not considered in the sediment budget, but implementation of the project could impact the results presented in this plan.

TABLE 2-6
SAND DELIVERY TO BEACH BEFORE AND AFTER W19 RESTORATION

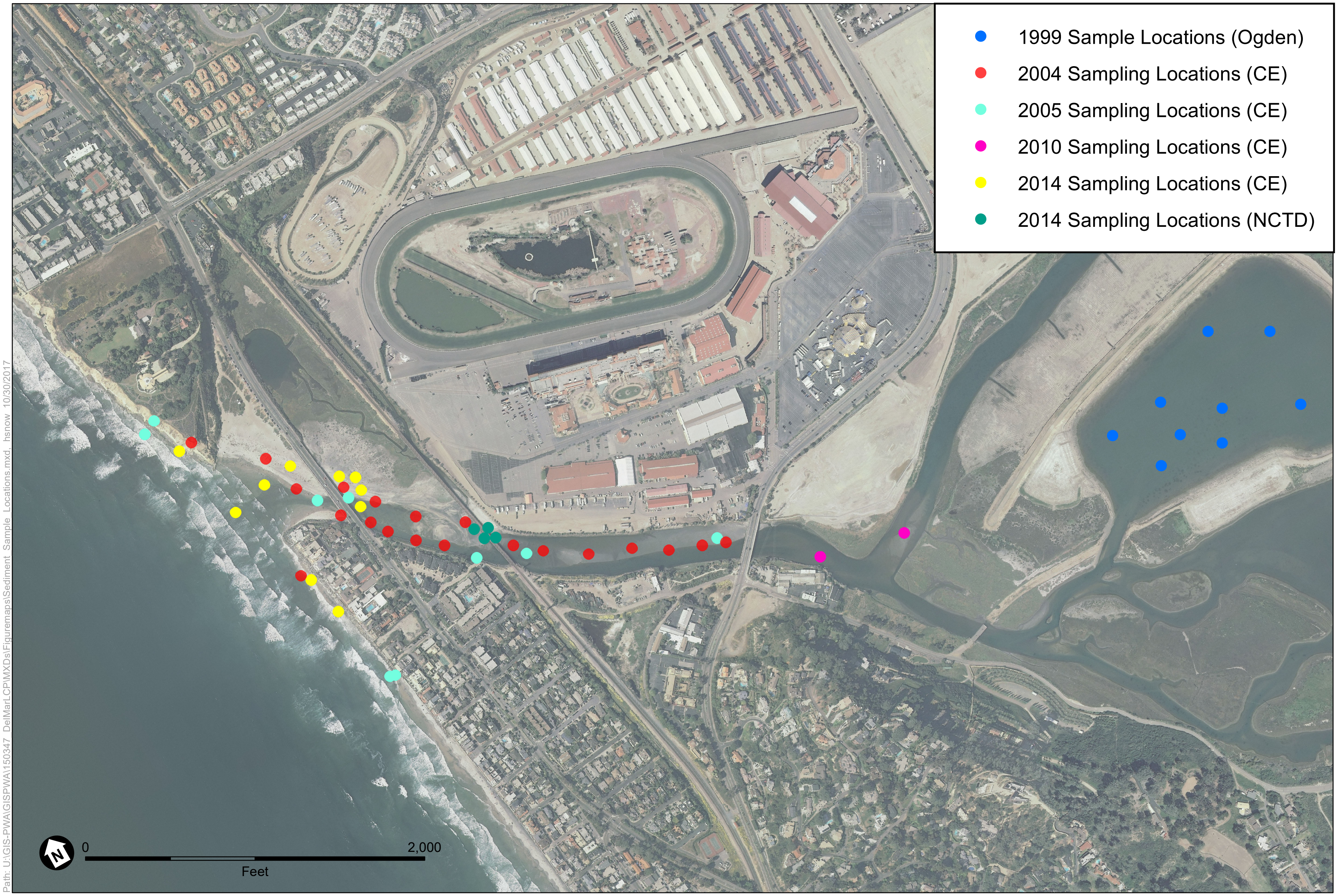
Storm Event	Existing Sediment Delivery (cy)	Delivery Post W19 Restoration	Net Change in Sediment Delivery
10-year	25,000	23,000	-2,000
20-year	142,000	127,000	-15,000
50-year	321,000	312,000	-9,000
100-year	407,000	433,000	+26,000
100-year storm series	990,000	915,000	-75,000

SOURCE: USACE 2016

2.2.5.2 Sediment Size

Sediment samples were collected in the lagoon as part of the SONGS San Dieguito Lagoon Restoration Project in 1999, to inform dredging operations between 2004 and 2014, and as part of the railroad bridge retrofit project in 2014. Data from these sampling events, while not all encompassing, provides insight to the sediment grain size distribution throughout the lagoon. Results from all of the sampling efforts show sediment within the lagoon is very sandy (>80% sand) with sand content increasing toward the mouth of the lagoon.

Ogden (1999) performed the extensive soil analysis within the lagoon. Most of the samples were taken in the vicinity of the future W1 and W4/16 wetland units as shown in Figure 2-4. Table 2-7 provides the grain size distribution for the 10–20-foot-depth samples, which would be the surface material after restoration, at the locations in Figure 2-4. The samples show sandy sediment, with sand percentages ranging from 80–96%, fines ranging from 4-20%, and gravel 0-5% (Figure 2-5).



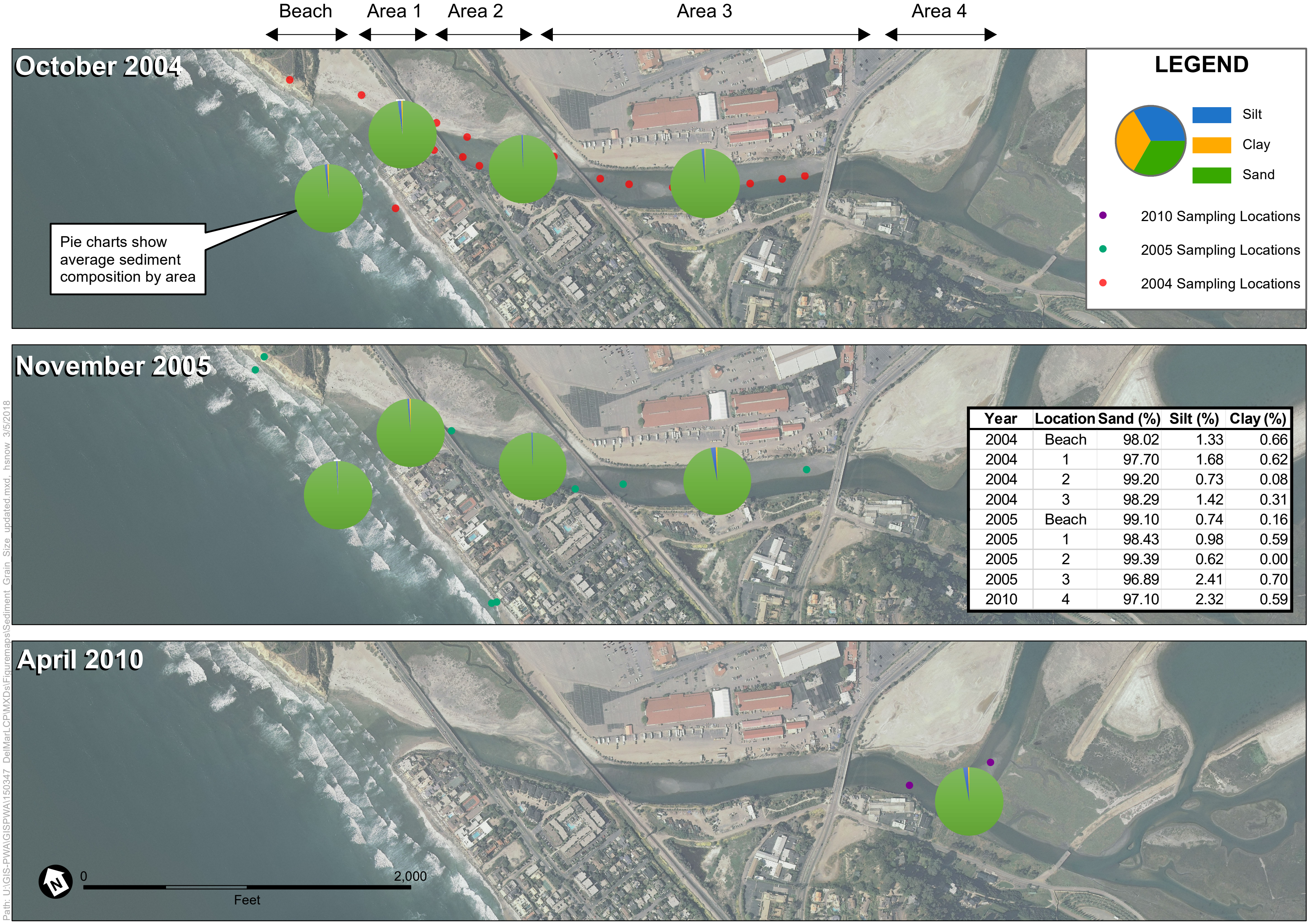
Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\MXDs\Figuremaps\Sediment_Sample_Locations.mxd, hsnow 10/30/2017

SOURCE:Coastal Environments 2010 and 2014, ESRI, County of San Diego

Del Mar LCP

Figure 2-4
Sediment Sampling Locations

ESA



Year	Location	Sand (%)	Silt (%)	Clay (%)
2004	Beach	98.02	1.33	0.66
2004	1	97.70	1.68	0.62
2004	2	99.20	0.73	0.08
2004	3	98.29	1.42	0.31
2005	Beach	99.10	0.74	0.16
2005	1	98.43	0.98	0.59
2005	2	99.39	0.62	0.00
2005	3	96.89	2.41	0.70
2010	4	97.10	2.32	0.59

Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\MXDs\Figuremaps\Sediment_Grain_Size_updated.mxd, hsnow 3/5/2018

SOURCE:Coastal Environments 2010, ESRI, County of San Diego

Del Mar LCP Update . 150347

Figure 2-5

Sediment Grain Size Distribution

ESA

TABLE 2-7
LAGOON GRAIN SIZE DISTRIBUTION

Sample Identification	Depth (ft-BGS)	Soil Type	Percent Gravel (>2mm)	Percent Sand (>0.075 mm)	Percent Fines (<0.075mm)
LG-2	10-12	SP	0	96	4
LG-2	15-17	SM-SP	1	84	15
LG-3	10-12	SP	5	90	5
LG-4	15-17	SP	0	95	5
LG-5	10-12	SM	0	82	18
LG-6	10-12	SP-SM	5	83	12
LG-7	10-12	SP-SM	0	91	9
LG-8	10-12	SM	0	80	20
LG-8	15-17	SP-SM	0	90	10
LG-9	14-16	SP-SM	1	91	8
LG-10	15-17	SP-SM	2	92	6
Average			**1.3**	**88.5**	**10.2**

As part of the lagoon inlet dredging required for mitigation through the SONGS project, Coastal Environments analyzed the grain size distribution of sediment samples taken in 2004, 2005, 2010, and 2014 near the mouth of the lagoon (Figure 2-5). In October 2004, 20 samples were taken at 4 locations along the beach, in the lagoon, and in the river channel. In November 2005, 9 samples were taken within the same general areas and at an additional location along the beach berm. In April 2010, two samples were taken at a new location east of the Jimmy Durante bridge and extending into the north channel. In August 2014, 10 samples were taken along the beach and lagoon inlet as part of the periodic inlet channel excavation and dredging. Sediment sampling was also performed by the North County Transportation District (NTCD) near the mouth of the lagoon prior and during construction of the San Dieguito Railroad Bridge project (Bridge 243.0) in 2014 (Figure 2-4).

The results from Coastal Environments sampling showed that, though the grain size distribution varied slightly across the locations, all sites were overwhelmingly sandy with only a small percentage of fine sediment (Figure 2-5, Table 2-8). The average sand content was approximately 98% while silt and clay comprised just under 2% of the total sediment. Coastal Environment noted that sediment deposited in the inlet channel “has the same physical and chemical characteristics of the littoral sand that constitutes the beach fronting the lagoon” and that sand that migrates into the lagoon has a similar grain size distribution as the beach sediment (2010). The 2014 samples analyzed by NCTD similarly found “poorly graded sands with sand content exceeding 90%” (CCC 2014). The lower sand content of the NCTD samples is likely a function of the sample locations being further into the lagoon and away from the beach compared to the Coastal Environment samples.

TABLE 2-8
SEDIMENT SAMPLING IN DEL MAR, 2004 – 2010

Sample	Location	Median grain size (mm)	Mean grain size (mm)	% Sand	% Silt	% Clay
October 2004						
1	Beach	0.21	0.21	97.79	1.52	0.69
2	Beach	0.20	0.20	98.24	1.13	0.63
3	Area 1	0.22	0.22	97.33	2.16	0.51
4	Area 1	0.20	0.20	97.75	1.54	0.71
5	Area 1	0.19	0.19	98.03	1.33	0.64
6	Area 2	0.23	0.23	99.39	0.61	0.00
7	Area 2	0.31	0.31	99.54	0.46	0.00
8	Area 2	0.21	0.21	98.97	1.03	0.00
9	Area 2	0.29	0.29	99.71	0.29	0.00
10	Area 2	0.28	0.28	100.00	0.00	0.00
11	Area 2	0.21	0.21	98.90	1.10	0.00
12	Area 2	0.18	0.18	98.10	1.27	0.63
13	Area 2	0.23	0.23	98.95	1.05	0.00
14	Area 3	0.28	0.28	99.51	0.49	0.00
15	Area 3	0.28	0.28	100.00	0.00	0.00
16	Area 3	0.20	0.19	96.01	3.26	0.73
17	Area 3	0.22	0.21	99.43	0.57	0.00
18	Area 3	0.22	0.22	99.59	0.51	0.00
19	Area 3	0.20	0.20	98.16	1.31	0.53
20	Area 3	0.16	0.16	95.32	3.79	0.89
Average		0.23	0.22	98.54	1.17	0.30
November 2005						
1	Beach (Berm)	0.20	0.20	98.38	0.98	0.64
2	Beach (intertidal)	0.23	0.23	99.37	0.63	0.00
3	Beach (Berm)	0.26	0.27	99.13	0.87	0.00
4	Beach (Intertidal)	0.24	0.24	99.53	0.47	0.00
5	Area 1	0.22	0.22	98.43	0.98	0.59
6	Area 2	0.32	0.25	99.49	0.51	0.00
7	Area 2	0.24	0.24	99.28	0.72	0.00
8	Area 3	0.26	0.26	98.56	1.00	0.44
9	Area 3	0.17	0.17	95.22	3.82	0.96
Average		**0.24**	**0.23**	**98.60**	**1.11**	**0.29**
April 2010						
S10	Area 4	0.305	0.32	96.20	3.06	0.74
S11	Area 4	0.32	0.32	98.00	1.57	0.43
Average		0.3125	0.32	97.10	2.32	0.59
August 2014						

1	Area 2	0.24	0.23	93.99	4.63	1.38
2	Area 2	0.21	0.21	96.01	3.04	0.95
3	Area 2	0.26	0.26	97.69	1.71	0.60
4	Area 2	0.23	0.23	96.97	2.23	0.79
5	Area 1	0.22	0.22	97.62	1.71	0.67
6	Area 1	0.93	0.74	99.33	0.46	0.21
7	Area 1	0.31	0.34	97.55	1.86	0.59
8	Beach	0.26	0.26	99.00	0.59	0.41
9	Beach	0.22	0.21	97.05	2.18	0.77
10	Beach	0.23	0.22	97.71	1.63	0.66
Average		**0.31**	**0.29**	**97.29**	**2.00**	

SOURCE: Coastal Environments

2.2.6 Lagoon Mouth Dredging and Bypassing

As discussed in Section 2.2.4.1, SCE is required to dredge the mouth of the San Dieguito Lagoon to maintain an open connection to the ocean. Sediment regularly builds up in the mouth of the lagoon as a result of wave and tidal forcing, creating a flood shoal inside the inlet. As part of the SONGS restoration of San Dieguito Lagoon, a “sand trap” was constructed between the Camino Del Mar bridge and the railroad bridge to capture and temporarily store sand entering the inlet between dredging events. The sand trap consists of a deeper dredged portion of the river channel, which creates a sink for sand to deposit. The trap is intended to limit sand from depositing further upstream in the lagoon, where dredging is more difficult and costly. The restoration also increased tidal flows (tidal prism) in the channel, which has helped to maintain an open lagoon mouth in conjunction with SCE’s program to dredge the lagoon mouth downstream of the railroad bridge.

SCE’s land-based dredging at Del Mar consists of utilizing standard earth-moving equipment to remove accumulated sand from the lagoon mouth and redistribute the sand onto Del Mar beaches. Sand excavation is performed using two-track excavators or back-hoes that remove sand using hydraulic excavating arms. Sand is deposited from the excavator or hoe into a dump truck (typically an off-highway dump truck) and trucked to the appropriate location on the beach. Front-end loaders redistribute and grade sand on the beach to target design elevations.

Table 2-3 (in Section 2.2.4.1) summarizes the timing and quantity of sand that has been removed from the inlet. Section 2.4 provides more detail on the processes impacting the mouth of the lagoon. Section 4 describes anticipated changes to the lagoon mouth dynamics with sea-level rise and presents recommendations for future management actions.

2.2.6.1 Potential Future Projects Affecting Dredging

The proposed Encinitas-Solana Beach Coastal Storm Damage Reduction Project would increase nourishment to the north of San Dieguito Lagoon, which could result in increased sedimentation in the lagoon. USACE (2015) estimated that the project would increase dredging from San Elijo Lagoon by 700 cy/yr and San Dieguito Lagoon by 16,200 cy/yr if implemented.

2.2.6.2 Potential Need for Upstream Dredging

Although the sand trap constructed between the Camino Del Mar bridge and the railroad bridge is intended to capture sand before it migrates further upstream into the lagoon, there is some evidence that sand has been depositing in the San Dieguito River channel between the railroad bridge and Jimmy Durante Boulevard (and possibly areas upstream of Jimmy Durante Boulevard) since the completion of the SONGS restoration project. Sand deposition has been observed in this reach of the river channel (see Figure 2-6) and is expected to occur until the channel cross-section decreases to the point where tidal velocities would scour sand (rather than deposit it) or until river storm flows scour sediment.

The volume of deposited sand in this reach is currently unknown. Coastal Environments (Hany Elwany, pers. comm.) has indicated that they have performed some surveying upstream of the railroad bridge, but that a significant amount of deposition has not been identified. However, apparent channel shoaling has been noted by others (ESA PWA 2012, City of Del Mar 2017).

2.3 Beach Changes

A substantial volume of data has been collected analyzing the dynamics of the beaches in the OLC. SANDAG has been collecting beach cross-sections, or profiles, since 1997, conducting both spring and fall surveys to capture the seasonal variation. Analysis of shoreline changes over time has also been conducted by multiple researchers. Additionally, SANDAG calculates beach volume for each transect.

2.3.1 Beach Profiles

Figure 2-7 presents the SANDAG cross-sections within the study area and Figure 2-8 shows an example of the cross-section data for fall surveys at 25th Street. SANDAG cross-sections extend from defined points the backshore (typically at the base of a seawall or other structure) out to depths of approximately -40 to -60 feet below the average daily lowest tide (mean lower low water or MLLW). Figure 2-8 is zoomed to show the intertidal area (e.g. the beach area exposed at the lowest low tide) to illustrate changes in the walkable beach, although data is available outside of the figure extents.

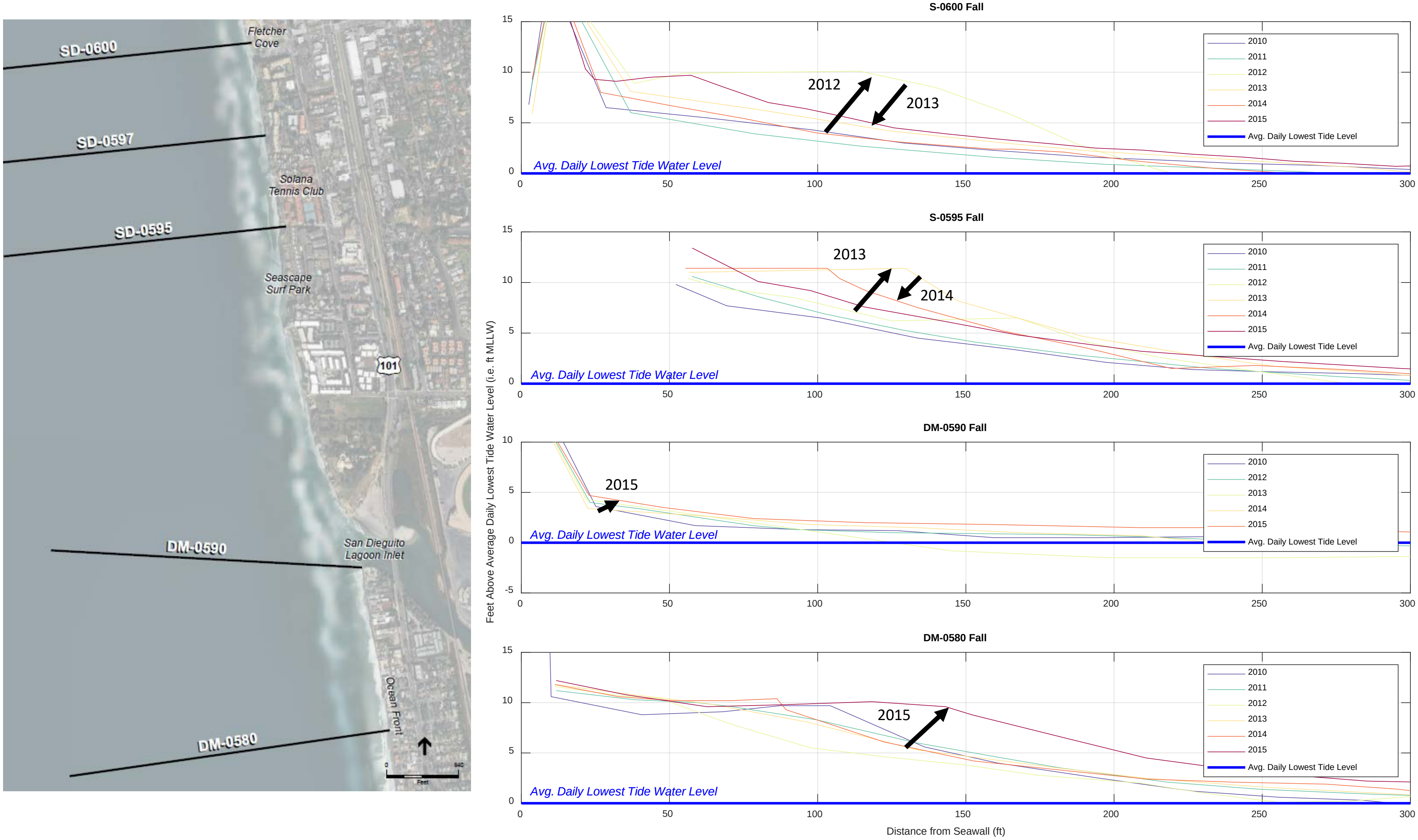
Path: U:\GIS-PWA\GISPWA\150347_DelMarLCP\MXDs\Figuremaps\LagoonDepositionSchematic.mxd, hsnow 3/8/2018

SOURCE: ESRI, County of San Diego

Del Mar LCP

Figure 2-6
Lagoon Deposition

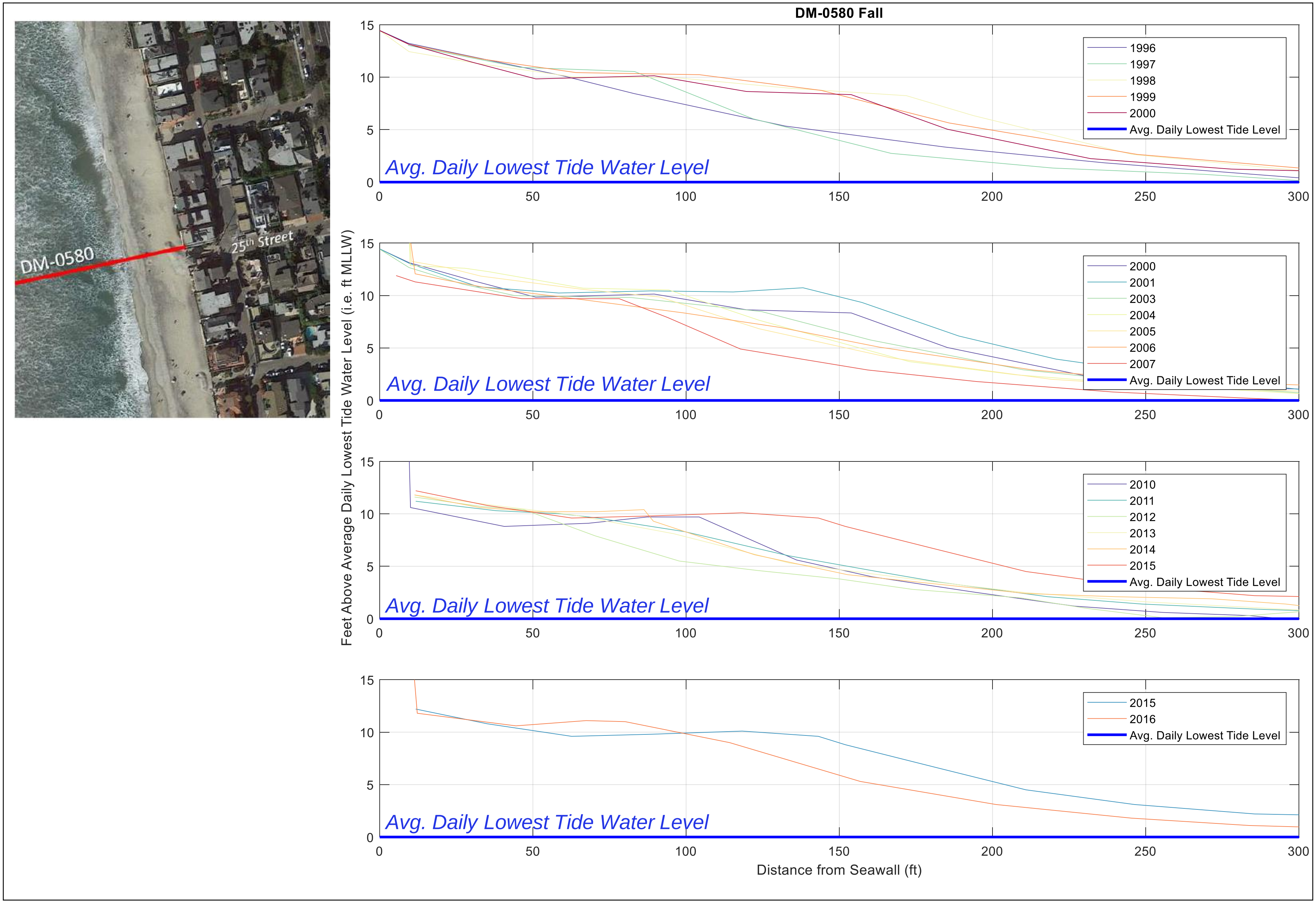
ESA



SOURCE: SANDAG, 2016

Figure 2-7

Transport of Sand Following RBSP II



SOURCE: SANDAG, 2016

Figure 2-8
Example SANDAG Cross-Section

The top plot in Figure 2-8 shows how the U.S. Navy Homeporting project nourishment expanded the fall beach profile at 25th Street in Del Mar after 1997 and how the beach slowly eroded following this. The second plot shows how the 2001 RSBP I sand placement expanded the fall profile initially, but eroded away by the following year. The third plot illustrates how the RSBP II sand placement was more successful at retaining sand and how the nourishment moved south after placement. At 25th Street, cross-section DM-0580 shown in Figure 2-8, the profile increases from 2011 to 2015, which is likely sand from the nourishment in the north transporting to this location. This was confirmed by looking at the cross-sections to the north (Figure 2-9): SD-0600, at Fletcher Beach, shows the sand placement in the 2012 survey with erosion following; SD-0595, near Solana Beach and Tennis Club, shows a slight increase in beach volume in 2012 with a larger increase in 2013 as the sand moved south; and DM-0590, at the south bank of the San Dieguito Lagoon mouth, and DM-0580, at 25th Street, show slight increases in 2012 and 2013 with larger increases in 2014 and 2015.

The bottom plot in Figure 2-8 shows the 2015 and 2016 profiles at 25th Street, which are before and after an El Niño season. During the El Niño, ocean water levels were roughly one foot higher than during a typical year, so data from this time period can be used as a proxy for sea-level rise (see Section 3.1). The profiles illustrate how higher ocean water levels cause erosion of the beach face and move the profile up and inland.

2.3.2 Shoreline Profiles

Other studies have analyzed the trends in shore profiles over time periods preceding the 2002-2011 time period analyzed for this study.

Moffatt and Nichol (1987) reviewed shorelines from maps and aerial photos for 1888-1982 in the vicinity of Del Mar. They found shoreline changes were within the practical uncertainty limits of the study, but that the shoreline generally advanced between 1888 and 1982.

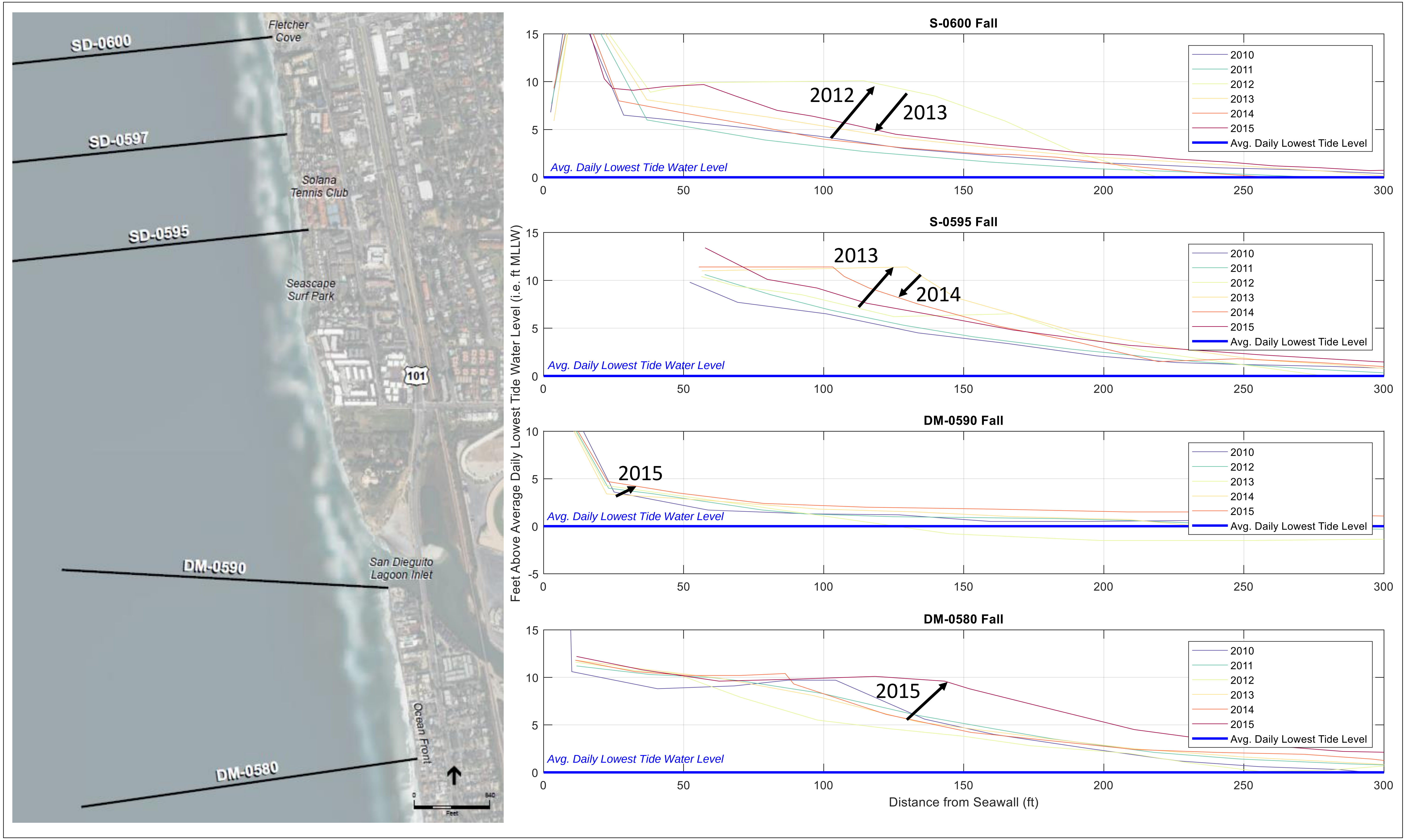
Orme et al. (2011) reviewed aerial photographs from 1946 to 2001 to determine beach widths over time for the OLC. The study found that nourishment had a marked but transient impact on local beaches and that some form of sand retention was required to maintain beach widths after nourishment.

Additionally, beach width measurements have been tracked at DM-0580 (25th Street) since 1978 through a program at Scripps Institute of Oceanography. The data shows a background erosion rate of approximately 2 feet per year for Del Mar, which is consistent with the data from SANDAG. Data from SD-0600 (also collected by Scripps) at Fletcher Beach shows a background erosion rate of roughly 4 feet per year from 1984-2002.

2.3.3 Beach Volumes

For each cross-section, SANDAG calculates the volume of sand at that location. In general, a larger volume of sand indicates a wider beach. Figures 2-10 through 2-13 show the total beach volumes (volumes above and below water) for the Solana Beach and Del Mar cross-sections. In addition to the beach volumes, which were calculated from the cross-sections, nourishment volumes are also displayed.

Figure 2-10 shows the beach volumes in northern Solana Beach. In this area, the beach shows a trend of increasing volume over the time period considered. The sand placements due to lagoon dredging and bypassing is fairly constant over time, but the larger RBSP nourishments in 2001 and 2012 do show up in the beach volume trends. The figure shows a spike for the RBSP I nourishment, and a longer-term increase for the RBSP II nourishment. Relatively small sand placements, such as lagoon bypassing placements, are not obvious in the record because the volume of placed sand may be small relative to measurement noise and alongshore transport of sand. Ludka et al. (2018) found that measured changes in total beach volume following sand placements may vary from the anticipated volume change due to noise and alongshore transport of sand, which moves sand outside of the measurement area.



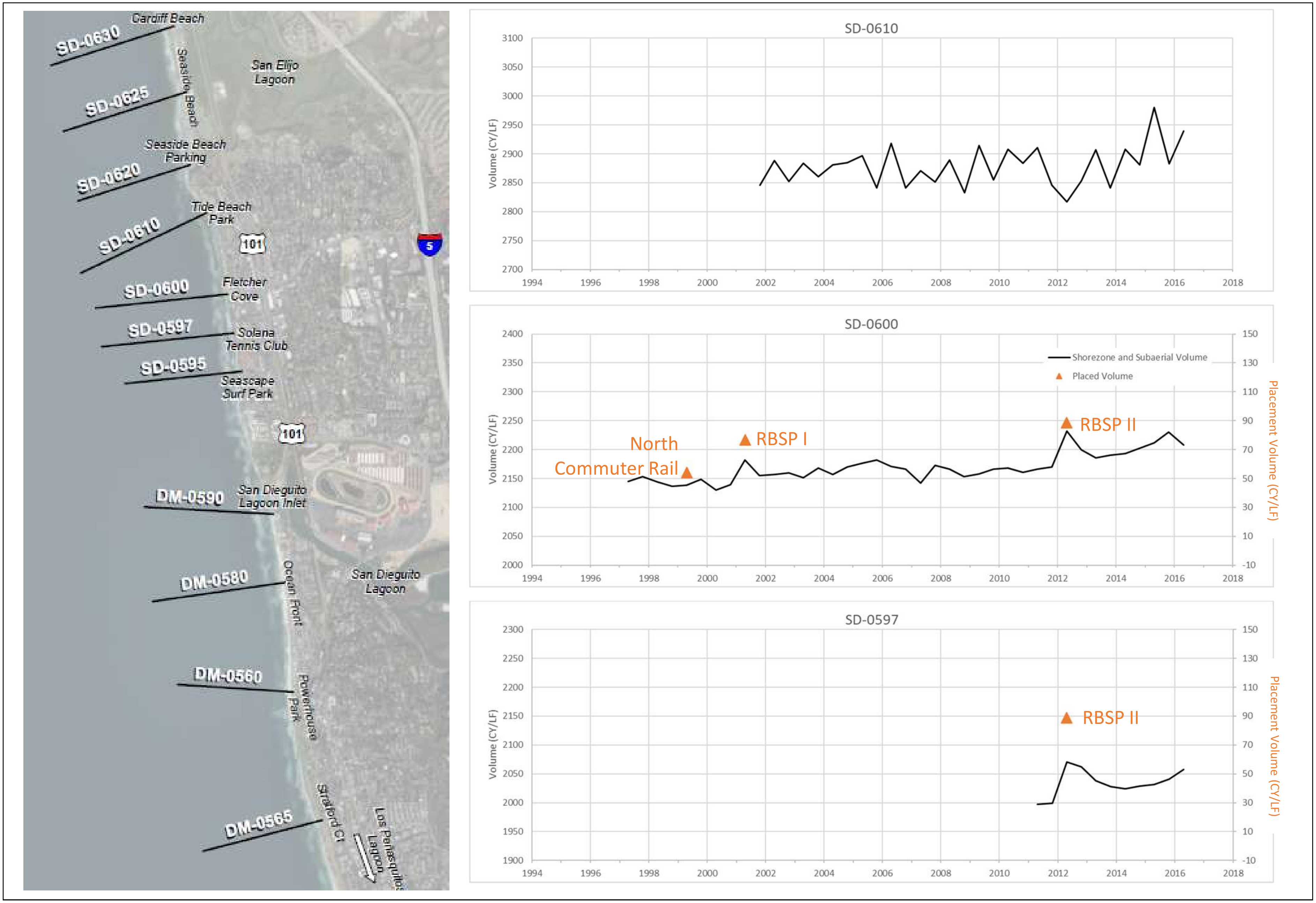
SOURCE: SANDAG, 2016

Figure 2-9

Transport of Sand Following 2011 RBSP II

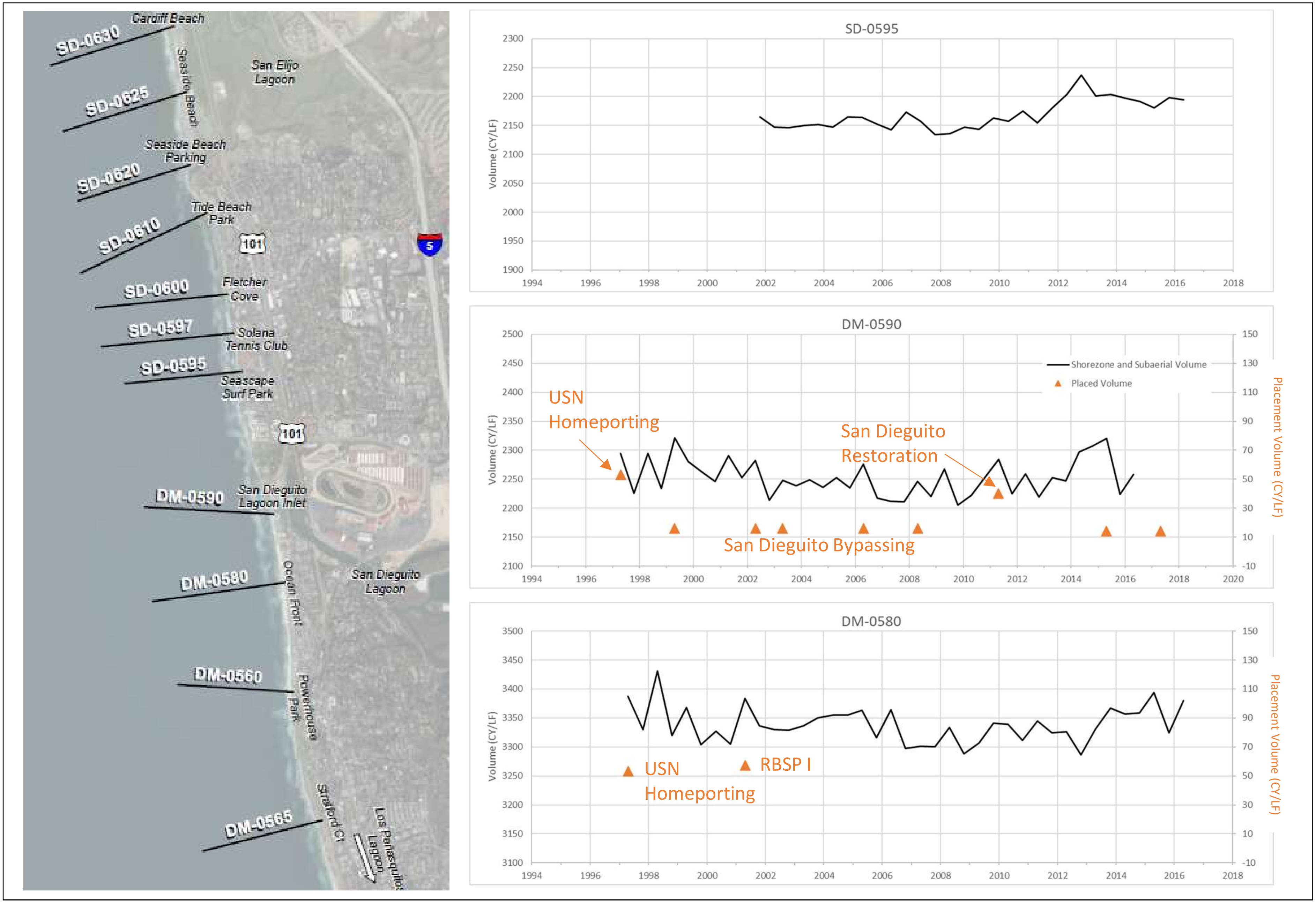
SOURCE: SANDAG, 2016
NOTES: Nourishment placement volumes converted to CY/LF using approximate placement dimensions. Placements plotted in fall of each year though actual placement dates vary (some unknown). Placements plotted on transects at the documented or assumed placement location.

Figure 2-10
North Solana Beach Volume Transects



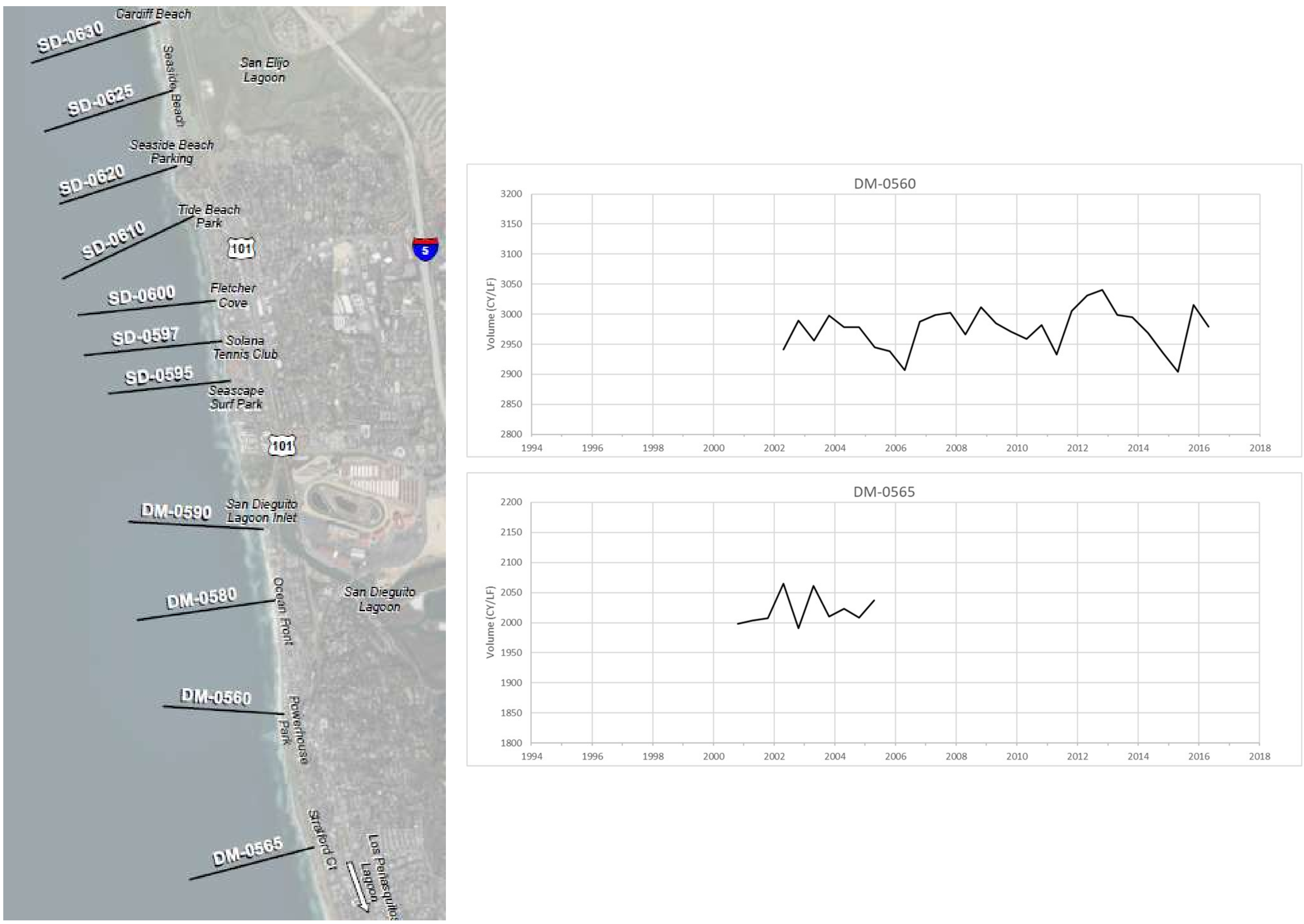
SOURCE: SANDAG, 2016
NOTES: Nourishment placement volumes converted to CY/LF using approximate placement dimensions. Placements plotted in fall of each year though actual placement dates vary (some unknown). Placements plotted on transects at the documented or assumed placement location.

Figure 2-11
South Solana Beach Volume Transects



SOURCE: SANDAG, 2016
NOTES: Nourishment placement volumes converted to CY/LF using approximate placement dimensions. Placements plotted in fall of each year though actual placement dates vary (some unknown). Placements plotted on transects at the documented or assumed placement location.

Figure 2-12
North Del Mar Beach Volume Transects



SOURCE: SANDAG, 2016
NOTES: Nourishment placement volumes converted to CY/LF using approximate placement dimensions. Placements plotted in fall of each year though actual placement dates vary (some unknown). Placements plotted on transects at the documented or assumed placement location.

Figure 2-13
South Del Mar Beach Volume Transects

Figure 2-11 shows similar results. At cross-section SD-0610, at Solana Vista Drive, where no sand was placed during RBSP II in 2012, the beach actually sees a drop in volume, while large increases are seen at the two more southern transects. However, cross-sections SD-0600, at Fletcher Beach, and SD-0597, at Lindamar Drive, see decreases after the RBSP placement, while SD-0610 (Solana Vista Drive) sees an increase, presumably as sand from the more northern placement moves south.

Figure 2-12 shows that Del Mar Beach experiences a different trend from Solana Beach during this time frame. From the beginning of the surveys in 1997 to around 2012, the northern Del Mar transects show a downward trend in beach volume, indicating that the beach is eroding. Even though no sand was placed in Del Mar for RBSP II, Del Mar likely received sand from the north from roughly 2013-2015. Much of this sand was "lost" from the surveyed beach volumes during the 2015 El Niño winter, but some rebound of the beach was seen in 2016. Figure 2-13 shows similar results for cross-section DM-0560, at Powerhouse Park, (DM-0565, at 8th Street only has a few years of data and was discontinued after 2005 due to budgetary constraints).

2.3.4 Beach Change Findings

Using the data collected by SANDAG, the rate of change in beach volume was calculated for each transect between April 2002 (after RBSP I) and April 2012 (before RBSP II) (Table 2-9). The transects were then used to calculate the total beach volume change. The analysis showed that during this time period, Solana Beach was growing by 29,300 cy/yr, which is 7,400 cy more than the average annual dredge amount from San Elijo Lagoon. This indicates that Solana Beach grew, without nourishment, at roughly 7,400 cy/yr.

Del Mar showed a beach volume decrease of 7,900 cy/yr during this time frame. Since the average annual dredge amount from San Dieguito Lagoon during this time was 9,500 cy/yr, this means that Del Mar Beach was decreasing by 17,400 cy/yr without nourishment.

TABLE 2-9
BEACH VOLUME CHANGE RATES BETWEEN 2002 AND 2012

Transect	Rate of Volume Change (cy/yr/ft of shoreline)
SD-0630, Cardiff State Beach	6.8
SD-0625, Seaside Beach	4.0
SD-0620, Seaside Beach parking	-1.1
SD-0610, Solana Vista Drive	1.3
SD-0600, Fletcher Beach	0.6
SD-0597, Lindamar Drive	n/a
SD-0595, Solana Beach and Tennis Club	1.0
DM-0590, South bank of San Dieguito Lagoon mouth	-1.1

DM-0580, 25th Street	-2.2
DM-0560, Powerhouse Park	1.6
DM-0565, 8th Street	-0.7

The results indicate that Solana Beach accreted, greater than the rate of nourishment during this time frame, while Del Mar Beach eroded even with placement of sand dredged from San Dieguito Lagoon. An average of 17,400 cy/yr of sand would have been required to maintain a stable beach.

Another volume estimate can be made using the longer dataset measured at DM-0580 or 25th Street (discussed in Section 2.3.2). Based on the SANDAG profile data, a loss of 1 foot of beach width is equivalent to 1.1 cy per foot of beach width. Using this conversion, the data from DM-0580 showing a beach width loss of 2 ft/yr is roughly equivalent to a loss of 2.2 cy/ft/year. This loss is identical to the rate estimated using the SANDAG data for 2002-2011 at the same transect. Over the length of Del Mar beach, this corresponds to a rate of 34,500 cy/yr. This is on the same order of magnitude as the estimate from the SANDAG profile (7,900 cy/yr) and within the high uncertainty associated with these calculations, including temporal and spatial variability.

Similarly, the data from SD-0600 at Fletcher Cove, shows a loss of 4.4 cy/ft/year, or a loss of 63,700 cy/yr over the time period of 1983-2002. The average annual dredge amount from San Elijo Lagoon during this time was 6,000 cy/yr. The data from 1983-2002 shows Solana Beach would have required up to 69,700 cy/yr to remain stable. These data from previous time periods indicate the variability in trends over time and location.

2.4 Lagoon Mouth Dynamics

2.4.1 Lagoon Mouth Overview

Lagoon mouths are dynamic: summer waves deposit sand in the mouth and raise the bottom of the channel, sometimes closing the mouth and limiting drainage of the lagoon, while winter storms with high river flows erode out the sand in the mouth and allow better drainage of the lagoon. Historically, the San Dieguito Lagoon mouth closed periodically, although it was frequently connected to the ocean (Beller et al 2014).

However, by the 1940s, development and hydromodification had significantly altered the watershed hydrology and the lagoon inlet remained closed most of the time. From 1929 to 1999, Elwany et al. (1998) estimated the inlet was open approximately 34% of the time. Though large storm events can still influence inlet dynamics, the extensive management of flows (e.g. through upstream reservoirs) has reduced the frequency of riverine events capable of breaching the inlet. Consequentially, scour and deposition at the San Dieguito Lagoon is primarily regulated by the tides and littoral transport.

The San Dieguito Lagoon is a flood dominant system; flood tidal velocities (velocities when the tide is rising) exceed ebb velocities (velocities when the tide is falling) and result in net sediment deposition within the inlet (Moffat and Nichol 2016). This net sediment deposition results in a flood shoal within the mouth of the lagoon. Elwany et al. (2003) estimated that the shoal traps less than 3 percent of the gross littoral drift near the mouth. They assumed a gross littoral drift rate of 1,177,200 cy/yr, and estimated 11,800 – 19,600 cy/yr of trapping in the shoal. If velocities increase, more sediment can be moved from the coast into the lagoon. Velocities are driven by tidal prism, which is the amount of water moving in and out of the lagoon with each tidal cycle. A larger tidal prism means more water moving, which means higher velocities, and more potential deposition in the lagoon, if sand is available. Tidal monitoring prior to the SONGS restoration project found that the San Dieguito Lagoon had a diurnal tidal prism volume of approximately 180 to 280 acre-feet.

Data collected by University of California Santa Barbara (UCSB) showed that since the SONGS restoration, tidal prism varies from 80 to 740 acre-feet, depending on the mouth conditions, which is up to a 160 percent increase from pre-restoration conditions. This means the SONGS restoration increased the amount of water moving in and out of the lagoon, therefore, increasing the transport of sediment that could deposit in the flood shoal if sand is available. However, this increase in potential sedimentation is offset by the lagoon dredging required by the project's CCC permit (Section 2.2.4.1). While the dredging ensures that the mouth of the lagoon stays open, it also increases potential sediment transport into the lagoon by increasing the tidal prism and the space available for sediment deposition, creating a cycle of dredging and deposition in the mouth. However, there may not be enough sand available to reach the potential transport rate. Modeling prior to the restoration indicated dredging would be necessary on a biennial basis; however, the inlet has only been dredged only twice in 2015 and 2017, indicating that the system may be sediment-starved. If sand deposits upstream of the railroad bridge (where maintenance has not occurred), this would result in a net loss of sediment to the littoral budget.

2.4.2 Potential Future Projects

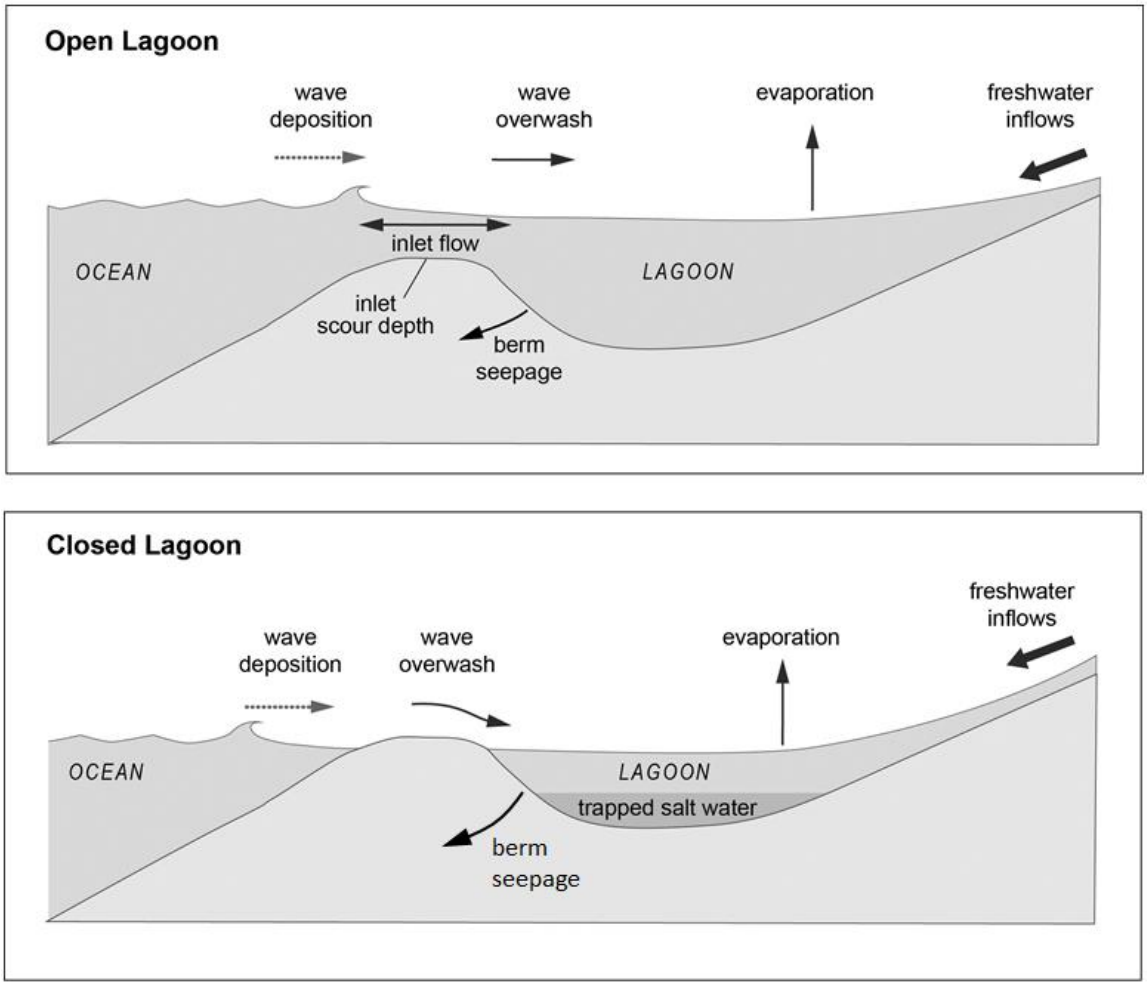
The Encinitas-Solana Beach Coastal Storm Damage Reduction Project, which is slated to add large volumes of sand to the beaches north of San Dieguito Lagoon, analyzed how the project would impact sedimentation in the area lagoons. It was estimated that an additional 16,200 cy/yr would need to be dredged from San Dieguito Lagoon (USACE 2015a). The project would not change the transport rate into the lagoon, but it would provide the sand to be transported and could change the system from sediment-starved to transport-limited.

Additionally, analysis was done for the W19 restoration to evaluate changes in the tidal prism. Modeling indicated that the tidal prism could increase by an additional 30 percent with the W19 restoration (Moffat & Nichol 2015). This would increase the potential sand transport rate into the lagoon, as also noted by Jenkins and Inman (1999).

2.4.3 Inlet Dynamics and Modeling

This section describes the results of a quantified conceptual model (QCM) for San Dieguito Lagoon, which was used to understand the processes that drive mouth morphology and sediment deposition immediately landward of the mouth. The model was also used to assess future changes in these conditions with sea-level rise (see Section 3.2).

The QCM consists of a water balance for the lagoon tied to a sediment balance for the lagoon mouth, beach, and for the flood shoal immediately landward of the mouth (Figure 2-14). It uses time series of coastal and riverine conditions to drive time series of beach-building from waves, resulting mouth conditions (open/closed/perched), and lagoon water levels. It incorporates gauged freshwater inflows to the lagoon and evapotranspiration losses from the surface, and estimates hydrologic terms that complete the water balance, such as flows through the mouth, wave overwash into the lagoon, and seepage from the lagoon to the ocean. This approach has been developed over the last several decades (see Behrens et al. 2015, Battalio et al. 2006), and has been applied by ESA to understand lagoon morphology in a number of coastal lagoon systems in southern California.



Del Mar Sediment Management Plan / D150347.01

SOURCE: Behrens et al. (2015)

Figure 2-14
Conceptual Model of a Typical California Lagoon

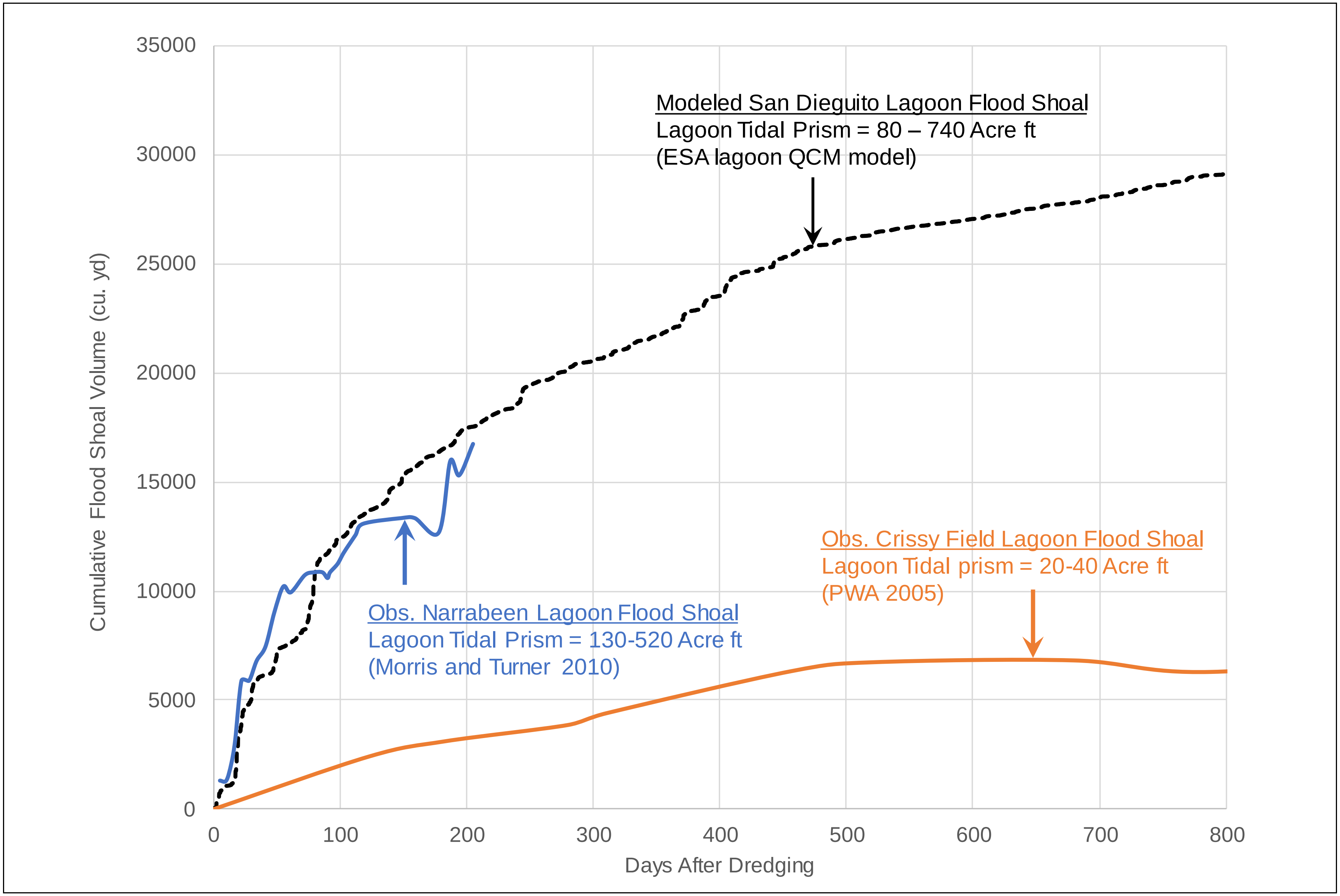
The benefit of this approach is that once a period of several years has been successfully hindcast to match observations, the same period of time can be run with any number of hypothetical sea level rise scenarios or restoration/management alternatives, to understand their direct influence on lagoon conditions over that same period of time. The goal is to find a time period with sufficient data and range of environmental conditions, in order to add confidence in predictions of how the system would behave in the future. The model was used in this case to hindcast observed conditions in San Dieguito Lagoon from 2011 to 2017. The sources of data used to drive the model are summarized in Table 2-10.

TABLE 2-10
DATA SOURCES

Parameter	Source/Location	Measurement Period
Coastal Influences		
Nearshore (10 meter depth) Waves	CDIP Model Output D0638	2000-present
Tide Stage	NOAA La Jolla (#9410230)	1923-present
Beach and Lagoon Mouth		
Mouth Condition (bed depth)	Lagoon water level logger	2011-present
Beach Crest/Profile	Coastal Conservancy Lidar and Coastal Environments surveys	2009-2011, 2016
Dredging/Inlet Maintenance	SCE: See Table 2-3 above	1983-present
Tidal Prism	UC Santa Barbara	2012-2017
Lagoon Hydrology		
Runoff	Watershed scaling from Los Peñasquitos Creek	2011-present
Evapotranspiration	CIMIS #75	1987-present

2.4.3.1 Flood Shoal Dynamics Incorporated in the Model

Sedimentation and growth of the flood shoal immediately landward of the mouth was modeled in the QCM based on observations of the shoal evolution and accounting for the littoral sediment transport rate, the flow rate through the mouth on incoming tides, and on the space available for flood shoal growth (e.g. limits of the channel). The shoal growth was then related to the length of the inlet, based on available aerial images and documentation of mouth maintenance activities (see Table 2-3). As shown in Figure 2-15, studies have shown that flood shoal growth is initially rapid after dredging has made a large depression, or depositional area, available for trapping sediment, and that the growth decays over time as the hole fills in, although short term spurts of growth can follow storm events when longshore sediment transport increases (PWA 2005; Morris and Turner 2010). Flood tide inflow rates were estimated using the QCM for the San Dieguito Lagoon, and nearshore wave conditions were used to estimate a littoral transport rate. It was assumed that mouth maintenance activities (reported in Table 2-3) increased the space available for sand deposition. The effect of flood shoal growth in the model between the maintenance activities in 2011 and 2015 was a continual rise in bed depth of the inlet, which resulted in a measurably smaller tide range in the lagoon by 2015.



SOURCE:

San Dieguito flood shoal: ESA QCM model

Narrabeen Lagoon flood shoal: adapted from Morris and Turner (2010)

Crissy Field flood shoal: adapted from PWA (2005)

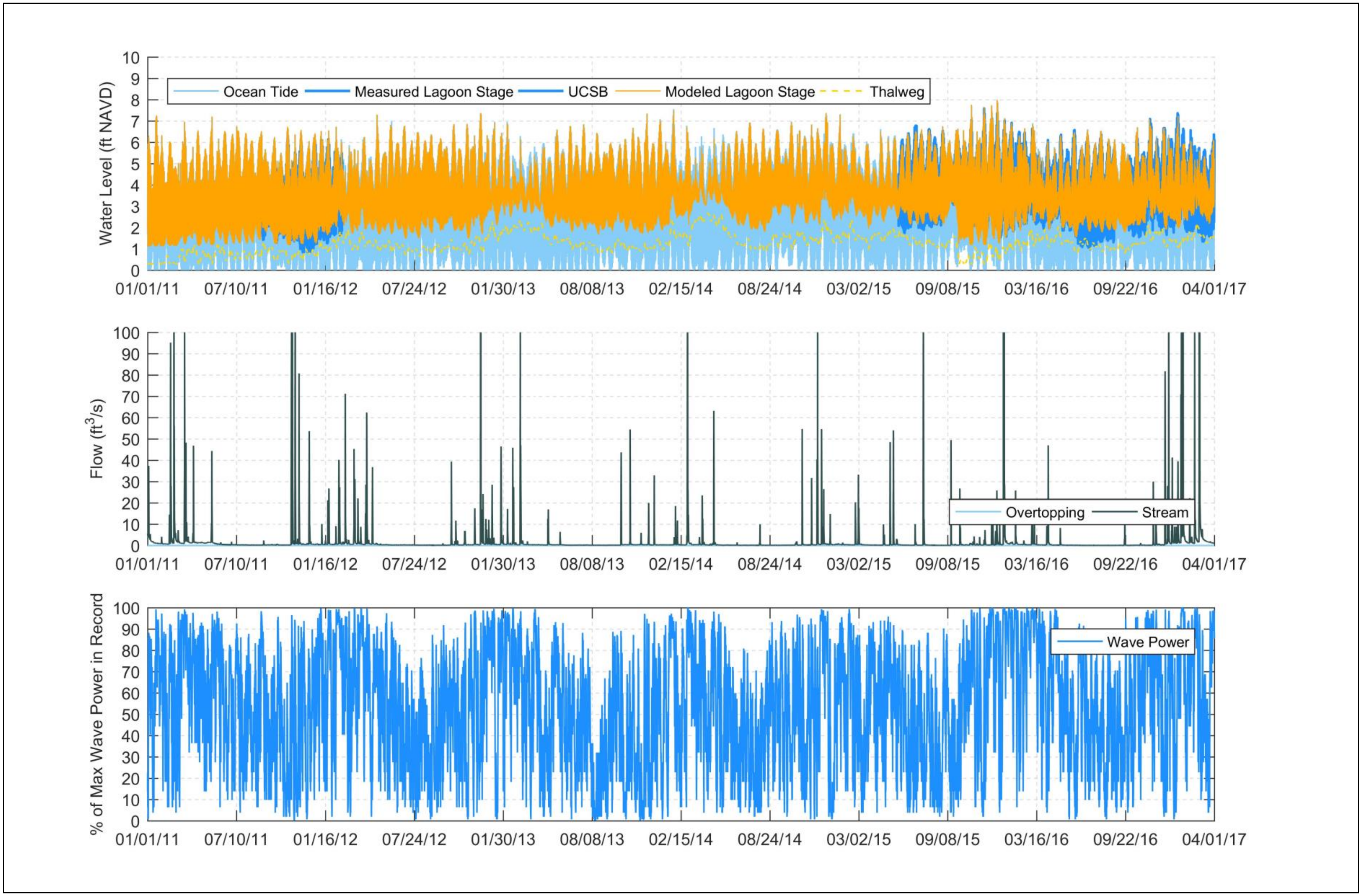
Figure 2-15

Observed flood shoal growth at Crissy Field and Narrabeen Lagoon vs modeled flood shoal growth at San Dieguito after dredging events.

2.4.3.2 QCM Calibration

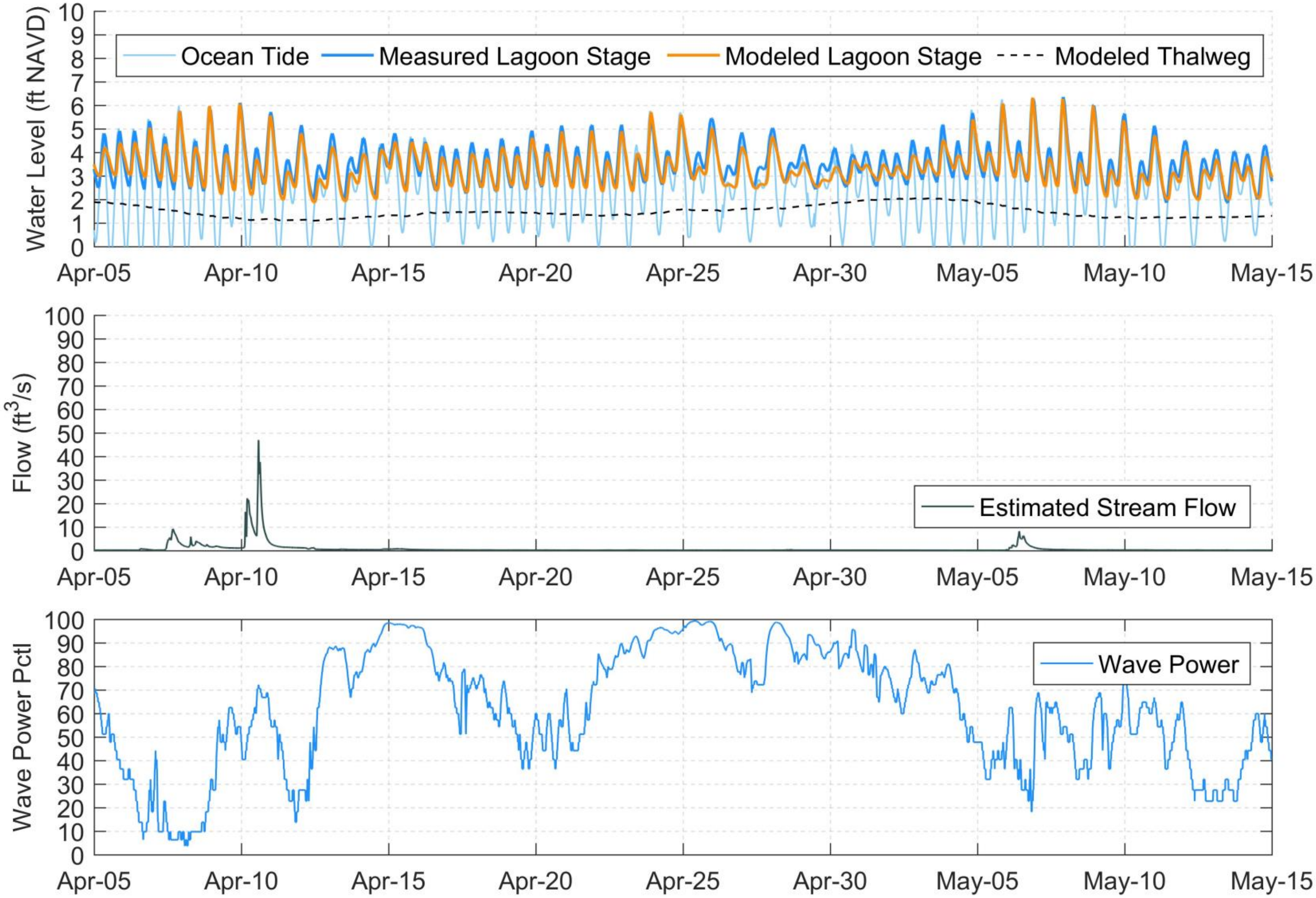
Model accuracy was tested for the hindcast period of 2011 to 2017 by comparing predicted lagoon water levels and tidal prism (the volume of water between the lowest low tide and the highest high tide each day) against observations during this time collected by UCSB as part of the SONGS restoration project monitoring. Available aerial images and surveys of the mouth were used to characterize typical inlet width, depth, and length in the model. Maintenance activities were accounted for by removing the reported dredge volume from the flood shoal in the model when dredging occurred (Table 2-3). Although direct measurements of sedimentation in the mouth were not available, water level observations in the lagoon indirectly reveal sedimentation in the mouth by showing the minimum tide level in the lagoon in a given day. When waves push sediment into the mouth, they raise its bed, which truncates the range of ocean tides that can enter the lagoon. This often means that high tides in the lagoon are similar to nearby ocean tides, while low tides in the lagoon can be several feet higher than oceanic low tides. Although tidal currents and strong freshwater runoff events can remove some of this sediment, without maintenance, the bed can continue to rise until the lagoon closes, and a beach forms at the mouth (Elwany 1998).

Figures 2-16 and 2-17 show how the model compares against the lagoon water level data from 2011 to 2017. The upper panel shows modeled and observed water levels in the lagoon compared against nearby ocean tides, and the predicted thalweg elevation (deepest point) in the mouth. The middle panel shows estimated river flows, and the lower panel shows nearshore estimated wave power, represented as a percentile of 2000-2017 conditions. Figure 2-17 gives a closer illustration of model predictions during 2016 to better show how short-term processes are reproduced. The model reproduces a number of important aspects, such as (1) periods of inlet scour during high watershed runoff and destructive wave conditions (e.g. around April 10) (2) mouth shoaling and reduced tide range in the lagoon during periods of constructive long-period wave conditions (e.g. April 25 to May 3), and (3) re-growth of the flood shoal inside the mouth after dredging activities. The latter manifests in the model as a lengthening of the lagoon mouth, which led to shoaling of the bed (increasing cutoff of oceanic low tides from the lagoon) by 2015. Given the complexity of San Dieguito Lagoon and other similar estuaries, the QCM is best used to reproduce the expected distribution of water levels in the lagoon and long-term changes in morphology of the mouth and flood shoal, rather than exact conditions at a short time-scale.



SOURCE: ESA QCM model

Figure 2-16
Time series comparing **(top)** modeled and observed water levels in the lagoon, **(middle)** scaled streamflows, and **(bottom)** nearshore estimated wave power.



SOURCE: ESA QCM model

Figure 2-17
Time series comparing **(top)** modeled and observed water levels in the lagoon, **(middle)** scaled streamflows, and **(bottom)** nearshore estimated wave power.

2.5 Current Conditions Sediment Budget

All of the analyses presented in Sections 2.2 through 2.4 were combined to develop a current conditions sediment budget. Table 2-11 presents the budget.

The sediment budget was developed to understand how the system functions under current conditions. Conditions (e.g., waves) have varied over time and from year to year. For example, during less stormy years, longshore transport would be less, and transport to the north, which is common in the summer, may actually be greater than transport to the south, resulting in net northward transport. Also, significant perturbations have occurred to sand transport and the sediment budget for Del Mar Beach and the OLC. These perturbations include the RBSP I and II beach nourishments in 2001 and 2012, respectively; completion of the San Dieguito Lagoon Restoration in 2011 for SCE's SONGS mitigation program; and SCE's ongoing dredging program for the SONGS San Dieguito Lagoon Restoration, in which sand is intermittently dredged from the lagoon mouth and placed on the North Beach section of Del Mar Beach. Given the significant variations over time and perturbations, the sediment budget was developed for the timeframe from 2002 to 2012, which is the timeframe before the San Dieguito Lagoon Restoration, in between RBSP I and II, and over which Del Mar beach transect data show an erosional trend. This timeframe was chosen to capture a period without the large regional nourishments before the San Dieguito Lagoon Restoration so that background conditions could be assessed. Sand from RBSP I placed in 2001 eroded from the beaches relatively quickly and does not show up clearly in the monitoring data after 2001 and therefore may not have significantly affected the sediment budget for Del Mar beach. Note that observations after RBSP I in 2001 suggest sand placed in Del Mar may have moved north into the lagoon mouth.

A key parameter and uncertainty in the sediment budget is the longshore sand transport rate. This Sediment Management Plan includes a review of available studies on longshore sand transport and a sensitivity analysis for the longshore transport rate for Del Mar Beach (see Section 2.2.1). Previous studies have estimated a wide range in potential transport rates and acknowledged the uncertainties and sensitivity of these estimates. The Sediment Management Plan's sensitivity analysis of Del Mar Beach longshore sand transport rate shows that the transport rate is highly sensitive to wave climate and shoreline angle. Given these uncertainties and sensitivities, longshore transport rates cannot be estimated (hindcast) with a high level of accuracy. As longshore transport has the greatest potential to move sand (and is the largest term) within the sediment budget, the sediment budget also cannot be resolved with a high level of accuracy.

Despite the uncertainties and sensitivities in longshore sediment transport and the sediment budget, the sediment budget does provide a useful tool for understanding the Del Mar Beach sediment processes. The beach change data for Del Mar shows that an average of 7,900 cy/yr was eroded from Del Mar beach from 2002 to 2012. Bluff, gully, and terrace erosion, placement of sand dredged from the San Dieguito Lagoon mouth (prior to restoration), and San Dieguito River sand transport are estimated to have contributed a total of approximately 15,000 to 26,000 cy/yr to Del Mar Beach. Together, these sand sources and beach erosion total approximately 23,000 to 34,000 cy/yr. Approximately 15,700 cy/yr of this sand is estimated to be lost offshore (Section 2.2.2). The balance of sand sources/beach erosion and offshore deposition (approximately 7,000 to 18,000 cy/yr) is assumed to be transported to the south for the purposes of balancing the sediment budget. The net longshore sand transport rate estimates (ranging from approximately 50,000 to 200,000 cy/yr) are larger than these sand sources and losses. A key finding of this sediment budget is that there is a potentially a larger volume of sand moving along the Del Mar shoreline than the volumes of sand that are added or lost locally from Del Mar Beach, particularly given that gross longshore transport rate due to both southern and northern swells is much higher than the net longshore transport rate.

From 2011 to 2018, beach change data show larger amounts of accretion and erosion occurred, depending on the year. After the RBSP II nourishment in 2012 at Solana Beach and other locations (excluding Del Mar), a wave of sand appears to have progressed southward (see discussion in Section 2.3.1) and maintained a stable beach width in Del Mar. However, with the strong El Niño in 2015-2016, much of this sand was lost from the beach.

TABLE 2-11
CURRENT CONDITIONS SEDIMENT BUDGET
(2002 – 2012)

	Solana Beach			San Dieguito Lagoon			Del Mar Beach		
Processes	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**
Longshore transport from the north	50,000 – 194,000		Range from the literature for net transport to the south (into Solana Beach box) (Section 2.2.1)	1,100 – 5,400		Assumes 3% of net longshore transport from Solana Beach goes into the lagoon (note: may have increased post-restoration, see section 2.2.6.2).	35,100 – 174,800		Assumes 97% of net longshore transport from Solana Beach bypasses lagoon and goes to Del Mar Beach
Cross-shore transport		14,500	Lost to offshore (Section 2.2.2)	n/a	n/a			15,700	Lost to offshore (Section 2.2.2)
Bluff, gully, and terrace erosion	8,100		Bluff erosion (no gully/terrace erosion) (Section 2.2.4)	n/a	n/a		5,500		Bluff + gully/terrace erosion (Section 2.2.4)
Beach nourishment/dredging	21,900		Average annual bypassing volume between 2002 and 2012 (Section 2.2.4)		9,500	Average annual bypassing volume between 2002 and 2012 (Section 2.2.6)	9,500		Average annual bypassing volume between 2002 and 2012 (Section 2.2.4)
River transport	n/a	n/a	Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.	3,900 – 15,000		Range from the literature (Section 2.2.5)	0 – 11,600		Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.
Beach storage		29,300	Beach is growing, so acts as a sediment sink, removing sand from the box, so less is available to leave the box to the south. (Section 2.3.3)	n/a	n/a		7,900		Beach is eroding, so acts as a sediment source, providing sand to the box, so more is available to leave the box to the south. (Section 2.3.3)
Longshore transport to the south		36,200 – 180,200	Sum of inputs minus sum of outputs		0 – 10,900	Sum of inputs minus sum of outputs		42,300 – 192,900	Sum of inputs minus sum of outputs

A significant data gap in the sediment budget for 2012 to 2018 is the volume of sand that has deposited in the San Dieguito River channel between the railroad bridge and Jimmy Durante Boulevard (and possibly areas upstream of Jimmy Durante Boulevard) since the completion of the San Dieguito River Lagoon Restoration (Section 2.2.6)

Given the uncertainty in longshore sand transport rates and the sediment budget and that RBSP II, the San Dieguito Lagoon Restoration, and the 2015-2016 El Nino have caused variations and perturbations to sand transport since 2012, it is not possible to develop a conclusive sediment budget for conditions from 2012 to present within the scope of this planning-level analysis for the Sediment Management Plan.

In the near-term future, it is possible that Del Mar Beach could undergo an erosional trend as observed from 2002 to 2012 if beach nourishment does not occur above the amounts of sand supplied by dredging from San Dieguito Lagoon mouth. The erosional trend that was observed following RBSP I in 2001 (after sand placed in RBSP I eroded from Del Mar beach) could reoccur. Sand that was placed in Solana Beach in 2012 for RBSP II and migrated to and widened Del Mar beach was eroded during the 2015-2016 El Niño and may not “return” to Del Mar Beach in the future. Proposed sand placement north of Del Mar (Encinitas and Solana Beach) can be expected to benefit Del Mar temporarily, presuming the sand migrates southward and it is enough to largely remain onshore.

SECTION 3

Future Conditions

3.1 Beach Changes with Sea-Level Rise

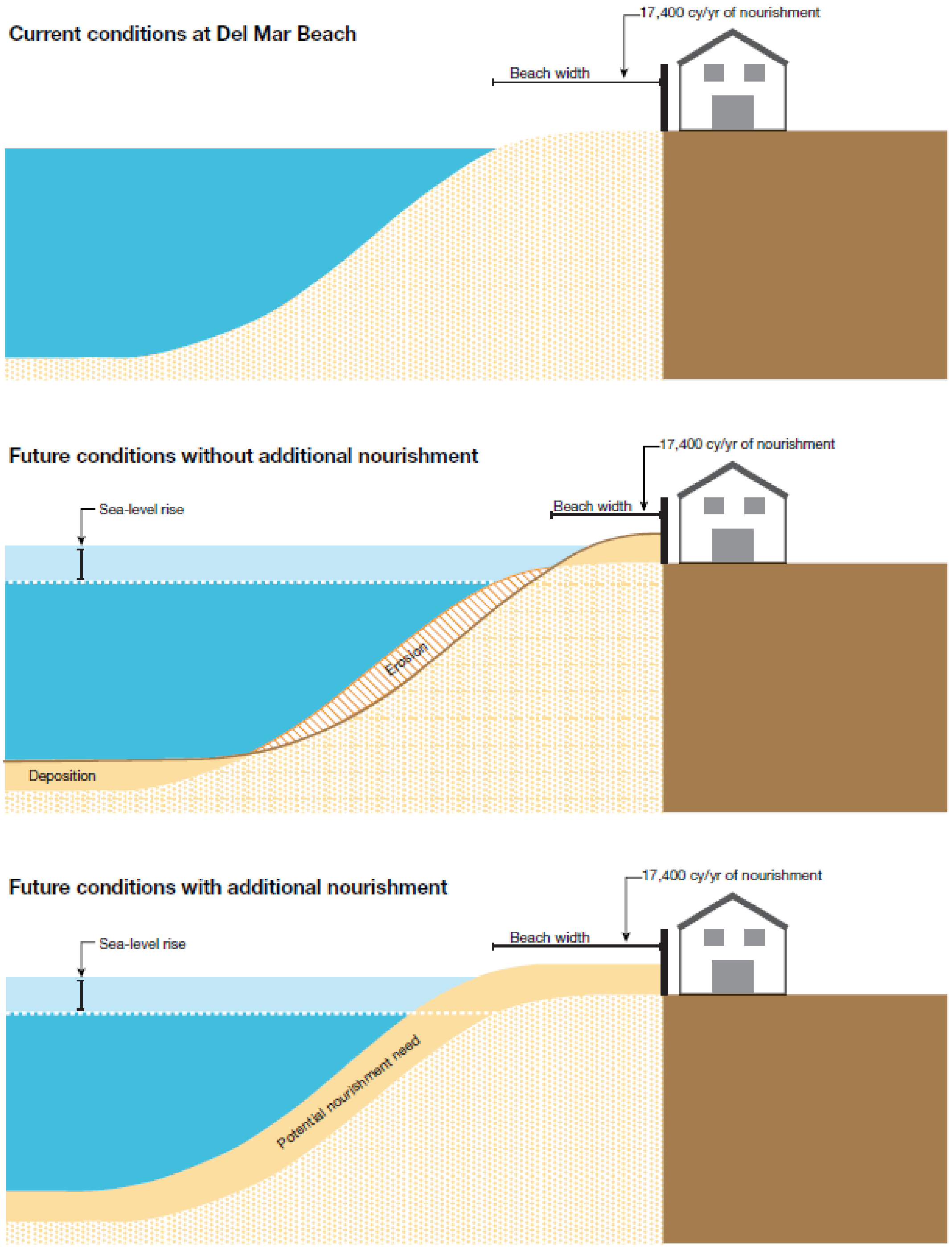
Higher sea levels in the future are expected to cause the shore to migrate, with the shoreline moving landward similar to erosion. Bruun (1962) laid out a simple approach for relating long-term beach retreat with sea-level rise, now referred to as the Bruun rule. The Bruun rule predicts that a shoreline profile will move up and inland with sea-level rise, resulting in deposition at the top of the beach, erosion along the beach face, and deposition along the toe of the profile. If the beach is limited by a seawall or other structure, the beach width will shrink. The bottom panel of Figure 2-8 (in Section 2.3.1) shows the 2015 and 2016 profiles at 25th Street, which are before and after an El Niño season. During the El Niño, ocean water levels were roughly one foot higher than during a typical year, so the 2016 profile is representative of the changes expected with sea-level rise. The 2016 profile illustrates the Bruun rule nicely: the shape of the 2015 profile has moved up and inland.

As discussed in Section 2.3.4, 17,400 cy/yr of sand is needed to maintain the Del Mar Beach under current conditions. With this amount of sand, the beach width will be maintained (top profile in Figure 3-1). Under sea-level rise conditions, if no nourishment is added in addition to this 17,400 cy/yr, the beach will erode according to the Bruun rule (middle profile in Figure 3-1). If enough additional nourishment is added, the entire profile can theoretically be raised with sea-level rise, and the beach width will be maintained (bottom profile in Figure 3-1).

The additional sand required to address sea-level rise was calculated at each SANDAG profile (Section 2.3.1) by multiplying the beach height by the beach slope by the rate of sea-level rise at a given time per Flick and Ewing (2009). Table 3-1 presents the amount of sand needed to raise the beach with sea-level rise. The existing sand demand of 17,400 is in addition to the sand demand to counter sea-level rise (see Section 3.6).

TABLE 3-1
SAND NEEDED TO RAISE THE BEACH PROFILE UNDER FUTURE CONDITIONS

	Sand Volume at 1 ft of Sea-Level Rise (cy/yr)	Sand Volume at 2 ft of Sea-Level Rise (cy/yr)	Sand Volume at 5.5 ft of Sea-Level Rise (cy/yr)
Solana Beach	30,200	42,300	67,900
Del Mar Beach	34,000	50,900	76,400



SOURCE: ESA 2018
NOTE: the 17,400 cy/yr is the estimated existing deficit for Del Mar, and the amount needed to maintain the beach without any sea-level rise. See Table 3-1 for the additional sand volume needed to counter sea-level rise.

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Figure 3-1
Beach Profiles with Sea-Level Rise

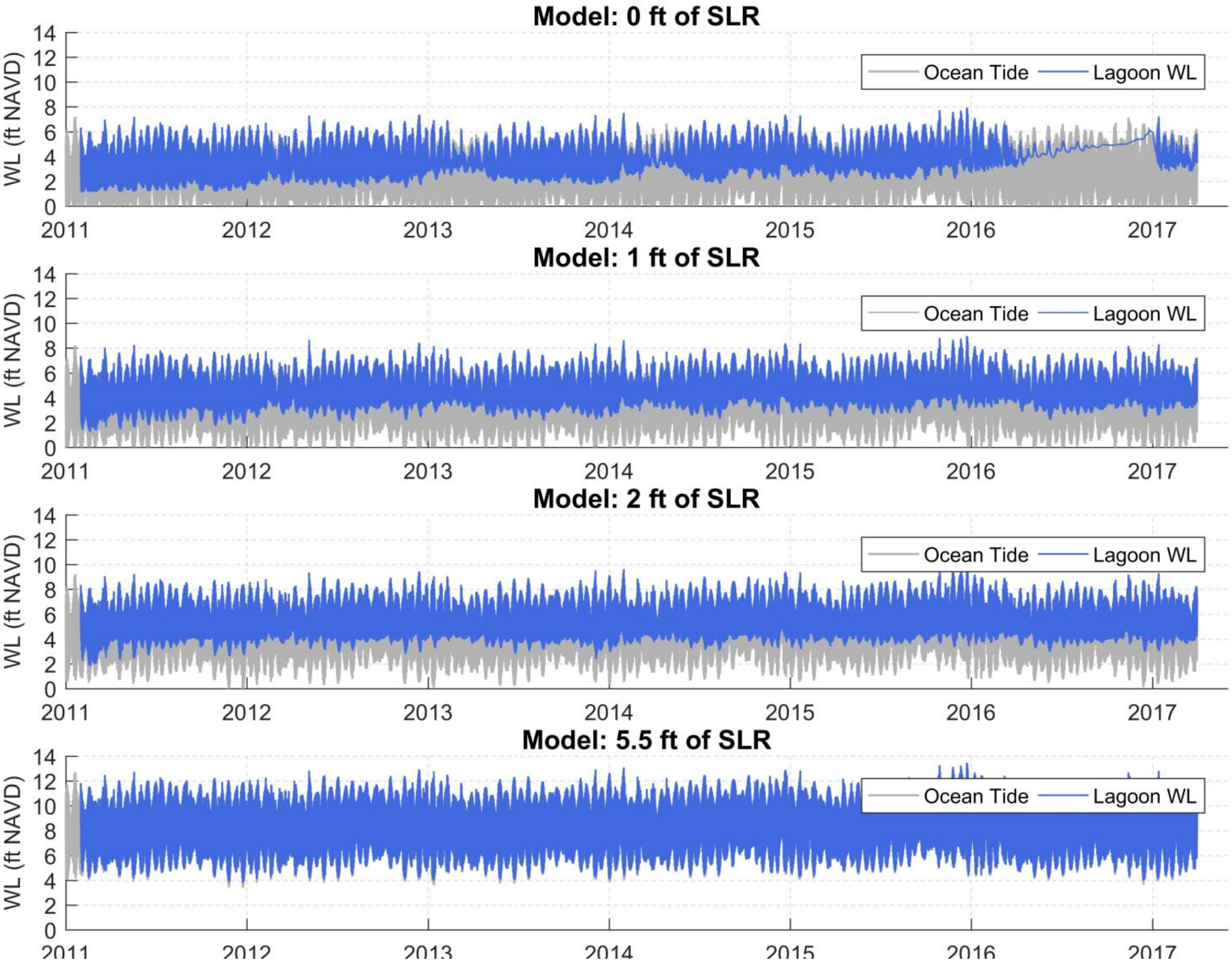
3.2 Changes to Lagoon Mouth Dynamics with Sea-Level Rise

To understand the influence of sea-level rise on mouth dynamics and sedimentation within the lagoon, the QCM was run for the period 2011-2017 again, but with 1, 2, and 5.5 feet of sea-level rise. Figure 3-3 shows the resulting lagoon water levels for each case. For simplicity, it was assumed that channel dredging was not performed. Although this may not be true in the future, it was assumed here to help illustrate the influence of sea-level rise on mouth and lagoon conditions more clearly.

The top panel of Figure 3-3 shows existing conditions, but without channel dredging. As a result of natural wave deposition processes, and growth of the shoal over time, the model results show the lagoon undergoing several periods of truncated tides. Without maintenance, the mouth was predicted to experience closure in 2016, as indicated by a slowly climbing water level in the lagoon. This is an indication that the inlet bed in the model experienced enough deposition that a beach formed in the mouth, and water levels were ponding behind the beach. The winter of 2015-2016 was a strong El Niño year with large waves, which caused the closure of other lagoon mouths, such as the Tijuana Estuary, which had not been closed since 1983. These regional observations along with the model results suggest that dredging of the mouth by SCE in 2015 prevented the mouth from closing in 2016.

With sea-level rise, the tidal prism in the model increases, as more areas are drowned by rising tides propagating into the lagoon. The greater tidal prism increases flows into the lagoon during each tidal cycle, which the model predicts will increase the size of the flood shoal more rapidly. This is consistent with the result of Jenkins and Inman (1999). However, the greater tidal prism also leads to faster currents in the mouth and more erosion, meaning that the model shows that the mouth is better able to maintain a connection with the ocean. For 1 and 2 feet of sea-level rise, the mouth remained open for the entirety of the simulation, but enough deposition still occurred to cut off low tides for most of the simulation. For 5.5 ft of sea-level rise, the greatly increased tidal prism caused enough erosion that lagoon tides were essentially the same as oceanic tides. This is in agreement with tidal velocity modeling completed by Moffatt and Nichol (2016), which concluded that under 5.5 ft of sea-level rise the lagoon would switch to ebb dominant, improving the entrance channel stability.

Estimates of future flood shoal size, and its effect on the morphology of the mouth and thalweg, could be refined as more survey data are collected in the depositional areas immediately upstream of the mouth. While the tidal prism is very likely to increase with sea-level rise, potentially giving rise to faster currents in the mouth, understanding the evolution of the flood shoal will require continued data collection of deposition in this area.



SOURCE:

ESA QCM model

Ocean tide levels obtained from NOAA La Jolla Pier station

Figure 3-2

Predicted San Dieguito Lagoon water levels for 1 to 5.5 feet of SLR.

Assuming sufficient sand is available, the model predicts that the channel thalweg elevation will continue to exist at high enough elevations that it will cut off oceanic low tides in the estuary, even for 1-2 feet of sea-level rise. For higher amounts of sea-level rise, although the model predicts scouring of the thalweg, this result is less certain because the flood shoal growth into the lagoon would likely be much greater than at present. As described in Section 4, sand is expected to deposit in the channel bed under future conditions, which could partly limit the growth of the tidal prism and its effect on scouring the mouth. Table 3-2 lists the predicted deposition rates in the flood shoal immediately upstream of the mouth.

TABLE 3-2
PREDICTED ANNUAL-AVERAGE DEPOSITION RATES (CU. YD PER YR) IN THE FLOOD SHOAL

Average rate of sand deposition in flood shoal	1 foot of sea-level rise	2 feet of sea-level rise	5.5 feet of sea-level rise
Dredging every year	21,000	28,700	40,800
Dredging every 2 years[1]	11,800	15,000	20,400

1. Deposition rates are lower for 2-year average because flood shoal growth is fastest in the first year and tapers over time (see PWA 2005, Morris and Turner 2010).

3.3 Changes to Other Sediment Budget Inputs and Outputs with Sea-Level Rise

The following sections present brief discussions of how other processes in the sediment budget could change with sea-level rise.

3.3.1 Longshore Transport

As discussed in Section 2.2.1 and 2.5, longshore transport is highly variable depending on the wave climate and the availability of sediment. With sea-level rise and climate change, longshore transport will likely continue to be variable. Increased storminess could increase transport rates as more frequent large wave events push sand alongshore. However, sea-level rise will cause a sand shortage without substantial nourishment, and the reduction in available sand could reduce transport rates. We anticipate that more sand will remain close to the placement location, essentially countering the effects of sea-level rise, with less sand migrating downshore, and, therefore, resulting in greater erosion away from the sand placement locations. The range of transport rates used in the current conditions sediment budget is also used in the future conditions sediment budget to bookend the variability in rates.

3.3.5 Lagoon Capture

It is possible that more sand is depositing in the San Dieguito Lagoon than is being dredged and placed on the beach, but data are not sufficient to confirm that the deficit has increased post-restoration. It is also possible that future restoration and sea-level rise will increase the rate of sand transport from the beach and into the lagoon, and these amounts have been estimated (see Sections 2.4.2 and 3.2). However, for the purposes of this study, it has been assumed that the increased sand demand associated with the SONGS restoration project, which pulls sand from the beach into the lagoon, will be mitigated by additional sand placement on the beach. Therefore, the calculations of required sand placement provided in Section 3.1 do not include this "mitigation" requirement, and additional sand may be needed.

3.3.2 Cross-Shore Transport

Cross-shore transport, similar to longshore transport, is highly variable and even less studied. With climate change and potentially stormier winters, cross-shore transport may increase, with sand eroded off the beaches during large wave events moving offshore. Some of the sand moving offshore may be captured in the outer surf zone as depths increase with sea-levels. However, little research has been done on cross-shore transport and sea-level rise, so the rates used in the current conditions sediment budget are also used in the future conditions sediment budget.

3.3.3 Bluff/Gully/Terrace Erosion

Bluff erosion is expected to increase with sea-level rise, if beaches seaward of the bluffs are not maintained and higher water levels bring waves closer to the bluff face. However, if the beach is nourished, bluff erosion in the future would continue at the current rates, since the nourished beach would reduce waves reaching the bluffs and causing erosion.

3.3.3.1 Bluff Erosion without Beach Nourishment

ESA (2016) estimated future bluff retreat rates with sea-level rise for Del Mar, assuming no beach nourishment. These rates, combined with data from Young and Ashford (2006), can be used to approximate sand volumes from bluff erosion, assuming no beach nourishment, which would allow the bluffs to erode and replenish the beach naturally. Table 3-2 presents these potential volumes. Sand volumes assume the bluffs are 75% sand per Young and Ashford (2006).

TABLE 3-2
SAND VOLUME FROM BLUFF EROSION WITH NO NOURISHMENT UNDER FUTURE CONDITIONS

	Sand Volume at 1 ft of Sea-Level Rise (cy/yr)	Sand Volume at 2 ft of Sea-Level Rise (cy/yr)	Sand Volume at 5.5 ft of Sea-Level Rise (cy/yr)
Del Mar Bluffs	13,100	19,800	43,400

Without nourishment, the beach profile in front of the bluffs is expected to follow the Bruun rule, and the beach width would be maintained as the bluff erodes back. The additional sand added to the system would likely be transported offshore into the surf zone and to the south to Torrey Pines State Beach.

3.3.3.2 Bluff Erosion with Beach Nourishment

With beach nourishment (the scenario considered for this Sediment Management Plan), bluff erosion in the future is expected to continue at current rates, since the nourished beach would reduce waves reaching the bluffs and causing erosion. The future sediment budget assumes the same rates for bluff erosion as under current conditions.

3.3.3.3 Gully and Terrace Erosion

Gully and terrace erosion may increase in the future as climate change increases the frequency of storm events, which cause rainwater runoff erosion, but this is not well-studied. The rates of gully and terrace erosion under current conditions were also used for the future conditions sediment budget.

3.3.4 River Transport

Similar to gully and terrace erosion, river transport may increase in the future with increased storm events, which cause increased runoff erosion, but since river discharge is managed by upstream reservoirs, future changes are hard to quantify. The range in rates of riverine sediment transport under current conditions was also used for the future conditions sediment budget.

3.4 Future Conditions Sediment Budget

The analysis presented in Section 2.5 was repeated for future conditions using the analyses and assumptions discussed in Sections 3.1 through 3.3. Tables 3-3 through 3-5 present the future conditions sediment budgets for 1, 2, and 5.5 ft of sea-level rise, respectively.

Despite the uncertainties and sensitivities in longshore sediment transport and the sediment budget, as discussed in Section 2.5, the future conditions sediment budgets are a useful tool for understanding the Del Mar Beach sediment processes under sea-level rise conditions. Bluff, gully, and terrace erosion, background rates of sand dredged from the San Dieguito Lagoon mouth (prior to restoration) and placed on the beach, and San Dieguito River sand transport are estimated to contribute a total of approximately 15,000 to 26,000 cy/yr to Del Mar Beach in the future. Approximately 15,700 cy/yr of this sand is estimated to be lost offshore (Section 2.2.2). Assuming the net longshore sand transport rates remain the same, the balance of sand sources and offshore deposition can be used to estimate the amount of nourishment needed to balance the sediment budget. The sediment budgets show that 34,000 – 35,600 cy/yr could be needed with 1 ft of sea-level rise, 50,900 – 53,200 cy/yr with 2 ft of sea-level rise, and 76,400 – 80,200 cy/yr with 5.5 ft of sea-level rise.

TABLE 3-3
FUTURE CONDITIONS SEDIMENT BUDGET WITH 1 FOOT OF SEA-LEVEL RISE[1]

	Solana Beach			San Dieguito Lagoon			Del Mar Beach		
Processes	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**
Longshore transport from the north	50,000 – 194,000		Assumes no change from current conditions.	1,100 – 5,400		Assumes no change from current conditions.	35,100 – 174,800		Assumes no change from current conditions.
Cross-shore transport		14,500	Assumes no change from current conditions.	n/a	n/a			15,700	Assumes no change from current conditions.
Bluff, gully, and terrace erosion	8,100		Assumes no change because beach is maintained.	n/a	n/a		5,500		Assumes no change because beach is maintained.
Background beach nourishment/dredging	0		Rate of nourishment required to maintain beach under current conditions.		9,500	Assumes no change from current conditions (background dredging rate).	17,400		Rate of nourishment required to maintain beach under current conditions.
River transport	n/a	n/a	Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.	3,900 – 15,000		Assumes no change from current conditions.	0 – 9,300		Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.
Beach/shoal storage with sea-level rise		30,200	Additional sand needed to keep up with sea-level rise. (Section 3.1)		1,600	Additional sand accumulating in mouth based on results of the QCM. (Section 3.2)		34,000	Additional sand needed to keep up with sea-level rise. (Section 3.1)
Longshore transport to the south		36,200 – 180,200	Assumes no change from current conditions.		0 – 9,300	Sum of inputs minus sum of outputs		42,300 – 192,900	Assumes no change from current conditions.
Nourishment required to maintain beach	22,800		Sum of outputs minus inputs to balance budget (and maintain beach).	n/a	n/a		34,000 – 35,600		Sum of outputs minus inputs to balance budget (and maintain beach).

1. Assumes 1 foot of sea-level rise by 2030 for analyses where a time frame is required

TABLE 3-4
FUTURE CONDITIONS SEDIMENT BUDGET WITH 2 FOOT OF SEA-LEVEL RISE[1]

	Solana Beach			San Dieguito Lagoon			Del Mar Beach		
Processes	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**	**Input (cy/yr)**	**Output (cy/yr)**	**Notes**
Longshore transport from the north	50,000 – 194,000		Assumes no change from current conditions.	1,100 – 5,400		Assumes no change from current conditions.	35,100 – 174,800		Assumes no change from current conditions.
Cross-shore transport		14,500	Assumes no change from current conditions.	n/a	n/a			15,700	Assumes no change from current conditions.
Bluff, gully, and terrace erosion	8,100		Assumes no change because beach is maintained.	n/a	n/a		5,500		Assumes no change because beach is maintained.
Background beach nourishment/dredging	0		Rate of nourishment required to maintain beach under current conditions.		9,500	Assumes no change from current conditions (background dredging rate).	17,400		Rate of nourishment required to maintain beach under current conditions.
River transport	n/a	n/a	Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.	3,900 – 15,000		Assumes no change from current conditions.	0 – 8,600		Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.
Beach/shoal storage with sea-level rise		42,300	Additional sand needed to keep up with sea-level rise. (Section 3.1)		2,300	Additional sand accumulating in mouth based on results of the QCM. (Section 3.2)		50,900	Additional sand needed to keep up with sea-level rise. (Section 3.1)
Longshore transport to the south		36,200 – 180,200	Assumes no change from current conditions.		0 – 8,600	Sum of inputs minus sum of outputs		42,300 – 192,900	Assumes no change from current conditions.
Nourishment required to maintain beach	34,900		Sum of outputs minus inputs to balance budget (and maintain beach).	n/a	n/a		50,900 – 53,200		Sum of outputs minus inputs to balance budget (and maintain beach).

1. Assumes 2 feet of sea-level rise by 2050 for analyses where a time frame is required

TABLE 3-5
FUTURE CONDITIONS SEDIMENT BUDGET WITH 5.5 FOOT OF SEA-LEVEL RISE[1]

	Solana Beach			San Dieguito Lagoon			Del Mar Beach		
Processes	Input (cy/yr)	Output (cy/yr)	Notes	Input (cy/yr)	Output (cy/yr)	Notes	Input (cy/yr)	Output (cy/yr)	Notes
Longshore transport from the north	50,000 – 194,000		Assumes no change from current conditions.	1,100 – 5,400		Assumes no change from current conditions.	35,100 – 174,800		Assumes no change from current conditions.
Cross-shore transport		14,500	Assumes no change from current conditions.	n/a	n/a			15,700	Assumes no change from current conditions.
Bluff, gully, and terrace erosion	8,100		Assumes no change because beach is maintained.	n/a	n/a		5,500		Assumes no change because beach is maintained.
Background beach nourishment/dredging	0		Rate of nourishment required to maintain beach under current conditions.		9,500	Assumes no change from current conditions (background dredging rate).	17,400		Rate of nourishment required to maintain beach under current conditions.
River transport	n/a	n/a	Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.	3,900 – 15,000		Assumes no change from current conditions.	0 – 7,100		Assumes net longshore transport to the south moves river sediment down to Del Mar Beach box.
Beach/shoal storage with sea-level rise		67,900	Additional sand needed to keep up with sea-level rise. (Section 3.1)		3,800	Additional sand accumulating in mouth based on results of the QCM. (Section 3.2)		76,400	Additional sand needed to keep up with sea-level rise. (Section 3.1)
Longshore transport to the south		36,200 – 180,200	Assumes no change from current conditions.		0 – 7,100	Sum of inputs minus sum of outputs		42,300 – 192,900	Assumes no change from current conditions.
Nourishment required to maintain beach	60,500		Sum of outputs minus inputs to balance budget (and maintain beach).	n/a	n/a		76,400 – 80,200		Sum of outputs minus inputs to balance budget (and maintain beach).

1. Assumes 5.5 feet of sea-level rise by 2100 for analyses where a time frame is required

SECTION 4

Channel Dredging Adaptation Measure Assessment

4.1 Existing Channel Deposition Processes and Uncertainties

The San Dieguito Lagoon channel upstream of the railroad bridge, which has not been dredged since the completion of the San Dieguito Lagoon in 2011, may be acting as a sand sink. Prior to completion of the lagoon restoration in 2011, the channel had likely reached an equilibrium condition in which erosion and deposition of sand by tidal flows were balanced (when the mouth was open).

The restoration changed this equilibrium by dredging and enlarging the channel from the ocean to just upstream of Jimmy Durante Blvd. In 2011, 40,000 cy of sand was dredged from the channel between the ocean and the railroad bridge, which was placed on the beach. Up to 26,000 cy of sand may have been dredged from the channel upstream of the railroad bridge and was placed on bird nesting sites created in the eastern portion of the lagoon as part of the restoration (Coastal Environments 2010 and 2011).

The lagoon restoration also changed equilibrium conditions by increasing tidal prism (volume of water exchanged with the tides) and flows in the channel. The new subtidal and intertidal basins (e.g., W1 and W4/16, respectively) increased the volume of the lagoon, which, along with channel dredging, increased the tidal prism. Additionally, restoration of W19 could further increase the tidal prism by an additional 30 percent with the W19 restoration (Moffat & Nichol 2015). Increasing tidal prism also has the potential to transport and deposit sand farther upstream into the lagoon.

If the channel was dredged to be larger than the equilibrium channel size, then tidal flows may have transported and deposited sand in the channel upstream of the railroad bridge. Jenkins and Inman (1999) predicted that the restoration would draw sand into the lagoon. Coastal Environments (Hany Elwany, pers. comm.) has indicated that they have performed some surveying upstream of the railroad bridge, but that a significant amount of deposition has not been identified. However, apparent channel shoaling has been noted by others (ESA PWA 2012, City of Del Mar 2017). Channel survey data upstream of the railroad bridge should be obtained and assessed and/or channel surveys should be performed to confirm whether deposition has occurred in the channel and the channel has been a sand sink. The lack of channel survey data is a data gap that will need to be filled to more fully assess both the sediment budget and the need for and effectiveness of channel dredging.

If sand has been depositing in the channel upstream of the railroad bridge, then channel deposition starting after the completion of the lagoon restoration in 2011 is likely to have been a sand sink for the Del Mar beach. While sand was dredged from the lagoon in 2015 and 2017, the dredging did not extend upstream of the railroad bridge and therefore did not include any sand deposited farther up the channel.

4.2 Future Channel Deposition with Sea-level Rise

With future projected sea-level rise, the lagoon tidal prism is expected to increase and the lagoon mouth may stay open without needing to be dredged (see Section 3.5). Intertidal wetland areas within the lagoon will become increasing subtidal with sea-level rise (see the Habitat Migration assessment, ESA 2018). The volume of tidal flows (tidal prism) will therefore increase. Channel dredging to keep the mouth open may no longer be necessary with 1 ft of sea-level rise or more. However, as sea-level rises and the lagoon tide range moves up vertically, more sand is expected to move into the lagoon and deposit. The QCM analysis performed for this Sediment Management Plan indicates that increased channel deposition may occur with up to approximately 2 ft of sea-level rise. This analysis and the results could be refined and confirmed using additional channel cross-section survey data, which were not made available for the Sediment Management Plan as discussed above. Sand deposition in the channel may also affect river flood levels as assessed in the City of Del Mar Coastal Hazards, Vulnerability, and Risk Assessment (ESA 2016).

4.3 Channel Dredging Assessment and Recommendations

4.3.1 Monitoring of Channel Deposition

Given the data gaps discussed above, it is recommended that the City pursue channel survey monitoring data to inform a refined assessment of past and future channel deposition and river flood risks.

A first step would entail review of available survey data and diagnosis of the rates and volumes of beach sand accumulation in the restored lagoon. Second, once deposition is confirmed, a monitoring plan could be developed to track the sand deposition. Third, the lagoon mouth dredging could be refined or other actions could be taken, if appropriate, to mitigate any identified sand losses, such as increased beach nourishment at Del Mar. The monitoring and mitigation assessment is also pertinent to the planned W19 restoration project.

Review of existing data, development of a monitoring plan, and refinement to the channel dredging program should be conducted in coordination with the SCE SONGS monitoring program and researchers. SCE is already collecting data within the lagoon (some of which has been summarized in this report) and continued coordination will be key to developing a successful plan.

4.3.2 Evaluation of San Dieguito River Flood Risks

Channel deposition monitoring data obtained and/or collected per above should be assessed and used to analyze San Dieguito River flood risks. Channel cross-section survey data should be assessed to further understand channel deposition processes. The QCM model developed for this Sediment Management Plan (see Section 2.4.3.2) could be used to further analyze and predict future changes in sand deposition based on these monitoring data.

River flood modeling could also be performed using these monitoring data to further analyze and assess river flood risks. A river flood model is available from Chang (2014), which is based on 2012 channel survey data collected by Moffat & Nichol after channel dredging was completed for the lagoon restoration. Chang’s model was obtained for the Coastal Hazards, Vulnerability, and Risk Assessment and is available for future use. The Chang model could be used to establish 2012 baseline conditions for river flooding. Channel survey data collected per the above section could be incorporated into the model to analyze flooding for the current and future condition of the channel. Using the model, the increase in flood risk due to channel deposition could be quantified and compared to the baseline conditions to inform the need for adaptation to reduce flood risks. The Adaptation Plan identifies a guiding principle to limit the risk of extreme coastal and river flooding and damage to less than approximately a 5% chance of occurring in a given year. Flood modeling for surveyed channel conditions could therefore be performed over time to assess, for example, when the 1%-annual-chance-of-occurrence river flood event for baseline conditions becomes a 5%-chance-of-occurrence event due to channel deposition.

4.3.3 Assessment and Recommendations

4.3.3.1 Near-term

The current lagoon mouth dredging performed by SCE has contributed to keeping the mouth of the lagoon open as well as supplying sand back to the Del Mar beach. Channel deposition and river flood risk could be monitored and evaluated as described in the sections above. If monitoring and flood risk evaluations were to determine that flood risks have increased over baseline conditions due to sea-level rise and channel deposition, then the channel upstream of the railroad bridge could be dredged to reduce flood risks. SCE has a plan and permits to dredge upstream of the railroad bridge, but has limited dredging to the lagoon mouth downstream of the railroad bridge presumably due to observations of less deposition in the channel upstream of the bridge and/or the increased complexity and cost of dredging the channel upstream of the railroad bridge.

It may be possible to reduce the amount of sand deposition upstream of the railroad bridge by increasing the frequency of dredging downstream of the railroad bridge at the lagoon mouth. Based on published literature and conceptual models of lagoon flood shoal growth, flood shoal deposition first occurs in the mouth of the lagoon. When a flood shoal is formed at the mouth of the lagoon, a defined channel is formed in which tidal velocities are higher and can transport sand farther up into the lagoon. In this way, sand deposition and flood shoal growth progresses upstream. Thus, if mouth dredging frequency is increased such that a defined channel is not permitted to form as frequently, it is possible that less sand could be transported upstream of the bridge. Since completion of the lagoon restoration project in 2011, the mouth has been dredged in 2015 and 2017. Aerial photographs between 2011 and 2015 show that the flood shoal and a defined channel formed, which may have contributed to transporting sand upstream of the railroad bridge. Mouth dredging may need to occur annually or multiple times per year to reduce the amount of sand that may be depositing upstream of the railroad bridge.

4.3.3.2 Future Conditions with Sea-level Rise

With up to about 2 ft of future projected sea-level rise, the potential for deposition in the channel may increase as tide levels move up vertically and create a sink for sand in the bottom of the channel. This would increase channel bed elevations and river flood risks. Deposited sand could be dredged from the channel to maintain a baseline channel bed elevation and acceptable level of flood risk; however, sand could potentially re-deposit in the channel within several years. Increasing the frequency of dredging at the mouth to reduce channel deposition upstream of the railroad bridge as discussed in the section above may not be effective with sea-level rise. If channel deposition and the increase in bed elevations upstream of the railroad bridge cannot be maintained within an acceptable level of flood risk with sea-level rise, frequent dredging of the channel upstream of the railroad bridge could be required. Given the apparent complexities and costs of dredging upstream of the railroad bridge, frequent dredging of the entire length of the river channel from the ocean to upstream of Jimmy Durante Boulevard may not be feasible. In this case, other adaptation measures would be required to reduce the river flood risk with sea-level rise and channel deposition, such as constructing levees around the perimeter of the river lagoon as identified in the Adaptation Plan.

SECTION 5

Beach Nourishment Plan

Beach nourishment is an adaptation strategy that provides protection against coastal storm erosion while maintaining the natural condition, beach habitat, and processes (such as the ability of the beach to erode in response to winter storms and build up sand in response to summer wave conditions). Beach nourishment can be accomplished by placing a sediment-water slurry directly on the beach and/or mechanical placement of sediment with construction equipment (Figure 5-1). Sand can be obtained from inland sources (e.g., sand trapped in dam reservoirs, construction projects) and can be dredged from offshore.

Del Mar Sediment Management Plan / D150347.01

SOURCE: SANDAG

Figure 5-1
Beach Sediment Placement in Carlsbad

Despite its benefits, beach nourishment could potentially have some negative effects that may need to be mitigated, including effects to beach ecology, changes to surf conditions, impacts from mining sand sources, and increased deposition of sand in the mouths of San Dieguito Lagoon and Los Peñasquitos Lagoon. These impacts should be evaluated further and considered in future planning. Additionally, development of a sand budget is inherently complex with a high level of uncertainty and any nourishment plan should be flexible to account for variations. Current estimates should be updated as more research becomes available and detailed monitoring should be used to improve understanding and nourishment methods.

The following section presents recommendations for using sand nourishment as an adaptation strategy.

5.1 Sand Placement and Retention Strategies

Different strategies for sand placement and retention will likely be more effective in the near-term, when rates of sea-level rise are still low, than in the long-term, when sea levels are increasing more rapidly. The following sections discuss these two time frames.

5.1.1 Near-term

In the near-term, rates of sea-level rise will be closer to current conditions, and strategies used today can still be effective. As discussed in Section 2, Del Mar beach needs approximately 17,400 cy/yr of sand to remain stable. This is more than what is currently dredged from San Dieguito Lagoon and placed on the beach, so additional sand is needed. This sand could come from increased dredging of the lagoon, opportunistic nourishment[1], or regional sand placement.

It is important to note that the near-term is also the best time to start planning for the future. The following sections provide recommendations on optimizing current sand management.

5.1.1.1 Location

Sand placement is assumed to be needed for the entire Del Mar Beach in order to meet the Adaptation Plan guiding principle of maintaining a walkable beach and continuous horizontal beach access through Del Mar. However, placement of sand typically provides a temporary benefit until the sand erodes and migrates away from the placement area. It is therefore important to consider the fate of the sand and implications of deposition in other areas. Placing dredged sand differently may better maintain the beach.

As discussed in Section 2.4, some of the sand that is dredged from the San Dieguito Lagoon mouth and placed on Del Mar Beach is likely being transported back into the mouth due to southern swells and northward longshore sand transport. The effectiveness of placing dredged sand could potentially be improved by evaluating swell forecasts and strategically placing sand based on forecasted longshore sand transport. For example, if/when southern swells are forecast, sand could be placed farther to the south end of Del Mar Beach. This approach has the potential

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[1] Opportunistic nourishment refers to sand made available from other actions such as development and beneficially reused for beach enhancement http://www.dbw.ca.gov/csmw/scoup.aspx

to keep more of placed sand on the beach, rather than setting it up to be transported back into the lagoon.

5.1.1.2 Frequency

SCE's current dredging practice relies on monitoring data to determine when the mouth of the lagoon needs to be dredged to maintain an open connection with the ocean. Dredging of the mouth has only occurred twice since the SONGS restoration project was completed in 2011. However, the CCC permit for the project allows dredging as frequently as every 8 months, so the dredging frequency could be increased to better maintain the width of Del Mar beach. It is recommended that the City pursue coordination with SCE to consider increasing beach nourishment from lagoon dredging.

5.1.1.3 Monitoring

Monitoring plays an important role in identifying the need for re-nourishments. Monitoring is typically focused on the annual maximum and minimum beach width. At any time, beach nourishment may be required in response to erosion from a major storm event.

SANDAG currently monitors four beach transects in Del Mar (see Section 2.3.1). These data should be analyzed regularly to evaluate beach trends and to identify the need for re-nourishment.

5.1.1.4 Near-Term Future Projects

Restoration of San Elijo Lagoon, which includes placement of 300,000 cy of sand on Cardiff State Beach and at Fletcher Cove, began in early 2018. Depending on the final grain size distribution of the placed sand and on wave conditions, it is possible that Del Mar Beach will receive some of this nourishment as it is transported south by longshore currents. Additionally, dredging of the Batiquitos Lagoon is expected in 2018-2019, and would contribute additional sand to northern Encinitias. These two projects are expected to provide sufficient beach nourishment for Encinitas and Solana Beach over the next five years (Kathy Weldon, City of Encinitas, pers. comm.).

The Encinitas-Solana Beach Coastal Storm Damage Reduction Project (discussed in Section 2.2.4.4), which proposes to place over 700,000 cy of sand on Solana Beach initially, with re-nourishment of 290,000 cy every 10 years would also be likely to contribute sand to Del Mar Beach. However, funding is not currently available for this project, and, with the lagoon restoration projects discussed above, is not likely needed in the next five years (Kathy Weldon, City of Encinitas, pers. comm).

5.1.2 Long-term

In the long-term, the rate of sea-level rise is projected to accelerate, and strategies used today will not be as effective without additional actions. The existing San Dieguito Lagoon mouth dredging and beach nourishment program performed by SCE for the SONGS restoration project will not be sufficient to maintain Del Mar Beach in a walkable condition in the future. Increased sea-level rise will result in higher nourishment needs throughout the region.

For Del Mar, it is estimated that 34,000 – 35,600 cy/yr could be needed to maintain current beach widths with 1 ft of sea-level rise, 50,900 – 53,200 cy/yr with 2 ft of sea-level rise, and 76,400 – 80,200 cy/yr with 5.5 ft of sea-level rise. However, annual nourishment is not necessarily ideal or feasible. Nourishment frequency depends on multiple factors (e.g. wave/storm conditions, planning, funding). There was an 11-year interval between SANDAG RBSP I and II, likely due to the time needed to monitor effectiveness, to secure funding, and to plan, design, and implement the subsequent phase. Assuming an average nourishment frequency of every 11 years to match the current frequency of the RBSP, Del Mar alone could require nourishment volumes comparable to the entire current RBSP placement in the OLC (Tables 5-1 and 5-2). It is important to note that these estimates assume that beaches to the north and south of Del Mar would implement similar scales of beach nourishment or that sand retention structures would be installed in Del Mar to retain sand. If regional nourishment does not occur, greater volumes of sand would likely be needed to maintain Del Mar beach, since sand would disperse to other, less-nourished beaches in the area. Based on rates developed by Flick and Ewing (2009), the total sand volume need for the entire OLC is approximately 2.2 million cy/yr, or 22 million cy/yr over 10 years around the middle of the century. Since this is an average for the middle of the century, the beginning of the century would require less sand and the end of the century would require more. This mid-century volume is more than thirty times greater than the potential scale of Del Mar Beach during the same time frame and greater than documented sources of sand in the region. Sand retention structures such as offshore reefs could be implemented to capture and retain sand in Del Mar; however, beach nourishment was not analyzed in conjunction with sand retention structures for the Sediment Management Plan.

Table 5-2 also presents the estimated potential costs for future Del Mar beach nourishment. As discussed above, these Del Mar beach nourishment and cost estimates assume that beaches to the north and south of Del Mar would implement similar scales of beach nourishment. If comparable nourishment does not occur to the north and south, greater volumes of sand and/or sand retention structures would be required to maintain Del Mar Beach, which could significantly increase costs. The costs do not include sand retention structures. The development of the cost estimates is discussed in detail in Section 6.

TABLE 5-1
CURRENT RBSP NOURISHMENT

	RBSP I 2001 (cy)	RBSP II 2012 (cy)	Average ~Every 11 Years (cy)
Del Mar	183,000	-	n/a
Solana Beach	146,000	142,000	144,000
Cardiff Beach	101,000	89,000	95,000
Total in OLC	1,833,000	1,082,000	1,457,500
Total for SANDAG RBSP	2,104,000	1,532,000	1,818,000

TABLE 5-2
FUTURE DEL MAR NOURISHMENT NEEDS AND COSTS ASSUMING COMPARABLE NOURISHMENT ELSEWHERE IN THE OCEANSIDE LITTORAL CELL AND/OR SAND RETENTION STRUCTURES

	Current	Under 1 ft of Sea-Level Rise	Under 2 ft of Sea-Level Rise	Under 5.5 ft of Sea-Level Rise
Nourishment needed every 11 years	191,400	374,000 – 391,600	559,900 – 585,200	840,400 – 882,200
Unit Costs	$30/cy	$25/cy	$25/cy	$25/cy
Total Costs every 11 years	$5,742,000	$9,350,000 – $9,790,000	$13,997,500 – $14,630,000	$21,010,000 - $22,055,000

While beach nourishment is likely to be feasible for lower amounts of sea-level rise, the feasibility of larger scale beach nourishment with sea-level rise of about 3 to 5 ft at Del Mar is uncertain, primarily due to uncertainties in the regional demand and availability for sand sources (Section 5.2). Additionally, the existing sea walls and revetments would likely need to be raised in conjunction with beach nourishment to maintain the existing level of flood management for North Beach. In other words, with a given amount of sea-level rise, beach nourishment could be used to raise the beach profile by an amount comparable to sea-level rise and the sea walls and revetments would also likely need to be raised by a comparable amount.

The following sections discuss recommendations on future sand management to address these needs.

5.1.2.1 Regional Planning

To be able to satisfy the large amount of sand needed to maintain the beach with sea-level rise, it is recommended that Del Mar begins planning for larger scale beach nourishment. This includes regional coordination (e.g., participating in potential future SANDAG RBSP programs, continued participation in the San Diego Regional Climate Collaborative).

The City of Del Mar’s participation in regional beach nourishment programs such as potential future phases of the SANDAG RBSP will benefit the City. Planning, designing, permitting, and implementing beach nourishment at a regional scale is likely to be more cost effective than a City-lead program. Sand placed directly on the Del Mar beach has the potential to better maintain a walkable beach, rather than relying on sand transport from up-coast nourishment.

The nourishment volumes presented in Table 5-2 assume regional nourishment is being implemented on a similar scale, so that all of the beaches in the OLC are maintained. As discussed above, if regional nourishment does not occur, greater volumes of sand would likely be needed to maintain Del Mar beach, since sand would disperse to other, less-nourished beaches in the area.

5.1.2.2 Sand Retention Structures

As discussed in Section 2.5, a key finding of the current sediment budget is that there is potentially a larger volume of sand moving along the Del Mar shoreline than the volumes of sand that are added or lost locally from Del Mar Beach. Sand retention structures could potentially capture sand being transported along the coast and used to maintain the beach and increase the effectiveness of beach nourishment.

Artificial reefs are underwater, offshore reef structures constructed of rock or other materials. While there is not enough experience with successful reef installation to ensure that reef implementation will provide the intended benefits, offshore reefs have the potential to provide a multi-benefit solution that could potentially provide benefits to marine ecology and surfing resources in addition to retaining sand. Offshore reefs may be an effective sand retention strategy for Del Mar beach because a reef could potentially capture sand transported by both north and south swells, which both drive significant sand transport along the Del Mar shoreline. In comparison, groins may not be as beneficial given their potential impact and the fact that they are more effective when sand transport is more dominant in one direction.

It is recommended that the City begin to explore offshore reefs as a sand retention strategy. While hard structures are not the preferred plan for Del Mar, additional research is needed to better understand reef performance and impacts for possible future use. Any sand retention structures that could be used in the future would require further planning and are likely to have impacts that would require mitigation, consistent with the Adaptation Plan. For example, it would be important to consider how coastal sand transport dynamics may change if Del Mar were to implement structures, such as reefs, to capture and retain sediment. Since sand retention structures influence the amount of available sediment for transport, the City would need to coordinate with neighboring cities and other jurisdictions that may be affected by hard structures.

5.2 Sand Sources

To date, offshore sand sources and opportunistic nourishment projects have been used to nourish the beaches in the OLC beyond lagoon bypassing. While offshore sand sources are available and opportunistic nourishment projects are likely to continue in the future, it is uncertain whether the sand available would meet the regional demand with higher amounts of sea-level rise. Considering Lake Hodges Reservoir as a potential sand source is recommended as well.

5.2.1 Offshore

External sources of sand are expected to be required to nourish and maintain Del Mar Beach. Offshore sources of sand have been identified, mined, and placed to nourish beaches in San Diego County through the SANDAG RBSP. Previous nourishment efforts by SANDAG have identified a productive borrow site with appropriate beach material located approximately 2,500 feet offshore of Del Mar (borrow site SO-5). Sand placed during the RBSP II in 2012 was excavated from three offshore borrow areas, two within the OLC (SO-5 and SO-6), and one in the Mission Beach Cell (MB-1). The location of the two OLC borrow sites are shown in Figure 5-2. As part of the RBSP II EIR, Moffat & Nichol identified the dredge volume available at each of the three borrow locations (Table 5-3). Additional sites are also available in the OLC.

TABLE 5-3: APPROXIMATE VOLUMES FROM OFFSHORE BORROW SITES

	SO-5	SO-6	MB-1
Approximate Volume Available for Dredging (cy)	700,000	1,900,000	1,600,000
Maximum surface area to be dredged (acres)	44	124	107
Water Depth (ft, MLLW)	-42 to -56	-34 to -49	-60 to -74

Notes: Assumes entire footprint dredged 10 feet; more sand would be available if dredging extends deeper

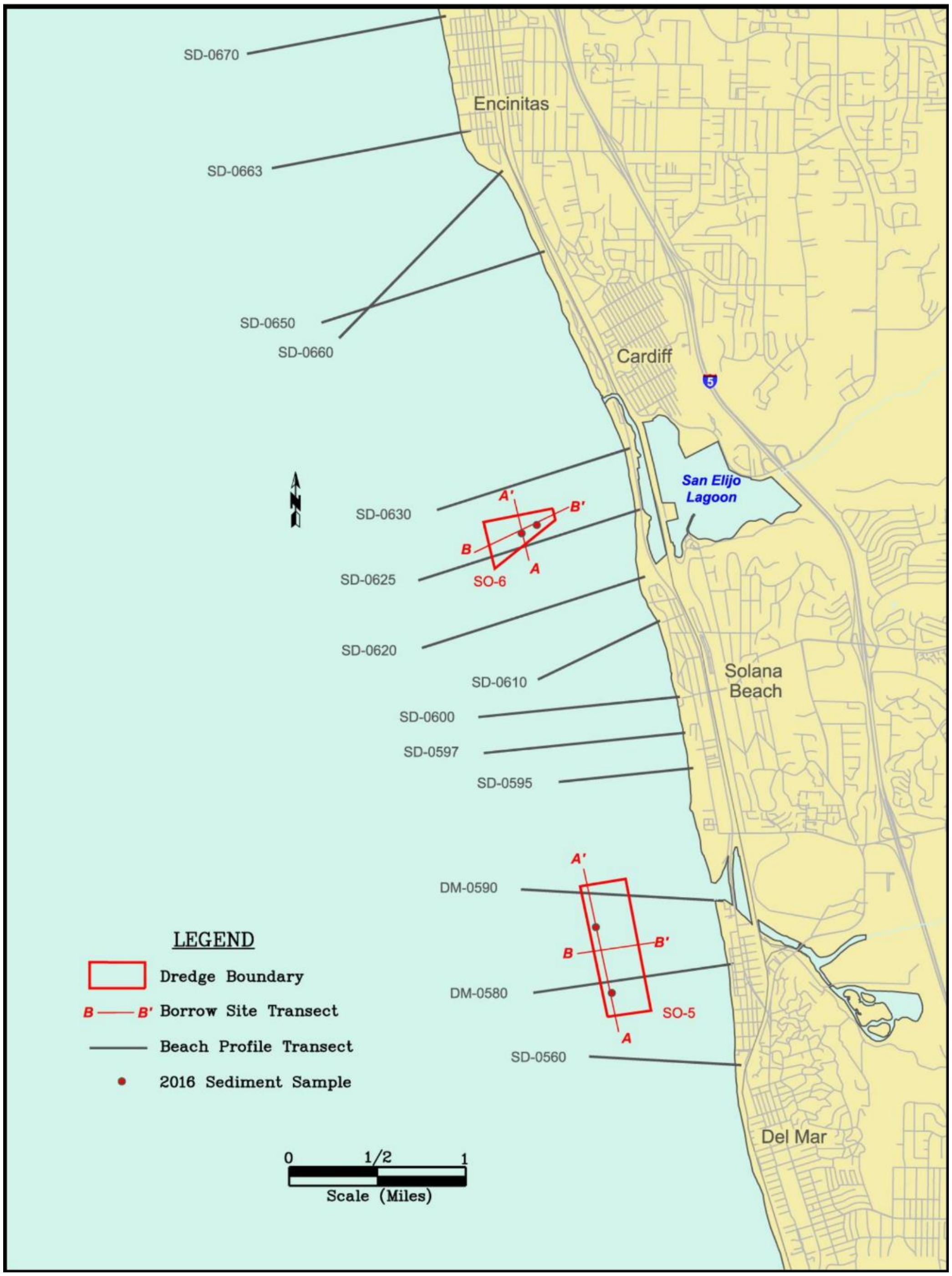
These three sites offer a total of at least 4.2 million cy of sand. The RBSP placements ranged from 1.1 – 1.8 million cy, so these offshore borrow sites could possibly only provide approximately 3 more regional placements before being depleted. Sources of sand off the coast of San Diego have not been comprehensively explored or assessed. Additional offshore sources may be available but have not been studied.

The City of Del Mar could pursue beach nourishment using offshore sources through regional beach nourishment programs or possibly through a City-lead program.

5.2.2 Opportunistic Nourishment

In addition to offshore sand mining for nourishment, the City could also establish a Sand Compatibility and Opportunistic Use Program (SCOUP) to opportunistically accept beach-compatible sand from other sources for small beach nourishment projects (less than 150,000 cy) (California Division of Boating and Waterways, http://dbw.parks.ca.gov/?page_id=29355). If beach-sized material becomes available via construction or other activity, the City will consider whether the material could be beneficially re-used on the Del Mar beach.

Though the proposed W-19 restoration project will excavate approximately 1.2 million cy of material, the geotechnical investigation performed as part of the EIR found the material unsuitable for either beach nourishment or surf zone disposal.



Del Mar Sediment Management Plan / D150347.01

SOURCE: SANDAG

Figure 5-2
RBSP II Borrow Sites in the OLC

5.2.3 Lake Hodges Reservoir

It is also possible that sand trapped in the Lake Hodges Reservoir could be dredged, transported, and placed in Del Mar. As discussed in Section 2.2.5, much of the historic sediment yield from the San Dieguito River is trapped within the Lake Hodges Reservoir. Slagel and Griggs (2006) estimated that 4,096,500 cy of sand has accumulated behind the dam at Lake Hodges based on hydrology calculations, with an additional 400,200 cy of sand behind the dam at Sutherland Reservoir. The sand within Lake Hodges could possibly provide roughly an additional three regional sand placements, based on the previous RSBP efforts, or roughly enough sand for Del Mar through 2100. The actual volume of sand available in Lake Hodges Reservoir would need to be confirmed.

Though the City may consider this option as a future sand source, there are no current plans to dredge Lake Hodges. Consequentially, there is little to no information available on sediment quality or costs associated with dredging and transportation of dredged material. Additional analysis of the feasibility of transporting sand from the reservoir to the beach would need to be considered in future planning.

SECTION 6

Planning-Level Cost Estimates

6.1 Presentation

The opinion of probable construction costs for various beach nourishment scenarios at Del Mar elaborated upon in this section is considered a Rough Order of Magnitude (ROM) estimate, and has an anticipated accuracy range of +50%/-30%. Further design and planning efforts are needed to reduce uncertainties and improve the accuracy of the figures incorporated in the cost estimate. Key assumptions used to develop the unit cost estimates are discussed below.

6.2 Disclaimer

In providing opinions of probable construction costs, ESA has no control over the actual costs at the time of construction. The actual cost of construction may be impacted by external economic factors and market forces which include the availability of construction equipment and crews, fuel costs, and fluctuation of supply prices at the time the work is bid.

ESA makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs. ESA recommend that the estimate be updated in concert with the preparation of construction documents and consider restrictions and requirements which may arise as part of approvals and as required by permits yet to be finalized.

6.3 Summary of Opinion of Probable Construction Costs

A summary of the Opinion of Probable Construction Costs is given below. Soft costs, such as engineering, design, environmental compliance, permitting, dredging and placement site geotechnical investigations, sediment physical and engineering properties testing, etc. were not included in the estimate. For very large dredging projects, the relative costs of these activities is anticipated to be small. A breakdown of the anticipated unit costs is summarized in Table 1. These cost items are elaborated in the sections that follow.

TABLE 6-1
SUMMARY OF ANTICIPATED UNIT COSTS OF SAND PLACEMENT FOR VARIOUS SCENARIOS

Cost Scenario	Unit Cost
Best-Case	$19/cy
Most-Likely Case	$25/cy

Worst-Case	$30/cy

6.4 Factors Affecting Unit Prices

6.4.1 Market Conditions

The time of the year that the project is advertised or constructed often affects prices and, if this has changed for the project, the unit prices for the contract items may need revision. The costs presented in this estimates are valid for 2018 (present-day dollars). All costs presented in this estimate were adjusted to reflect cost trends applicable in the Del Mar, CA region and vicinity (nearest urban area: San Diego, CA). Market conditions can affect bid prices significantly.

6.4.2 Geographic Location

Costs can be impacted by several factors related to the location of the work: mobilization and demobilization distances, disposal areas, exposure to wind and waves, and local constraints (such as regulations and permits) that may be placed on the various types of dredge operations.

6.4.3 Quantities of Work (Economies of Scale)

Smaller quantities of work usually carry a higher unit cost compared to larger volumes. That is because mobilization, transport of materials, overhead, and other costs are distributed over a smaller base. Additionally, production rates can be negatively affected by smaller volumes, which in turn increases unit costs. Indirect costs become a lower percentage of the total cost on large quantity projects than on small quantity projects.

6.4.4 Traffic and Accessibility

The ease of accessibility to the work will affect the cost to do the work. In this particular case, it is assumed that contractors will be granted access to the project area via 29th Street or below Highway 101 (may require construction of a temporary haul road). Nonetheless, it is anticipated that production will be impacted by the lack of easy access to the work area; this could increase the level of risk perceived by the contractor, and will likely translate into higher bids.

6.4.5 Seasonality

The season during which the work is conducted can slow production. Winter work can lead to exposure to wind and waves. Summer months may also lead to strong swell waves which may limit production rates.

6.4.6 Timing

The timing of bidding is an important factor affecting prices. CALTRANS guidelines suggest that “the time of the year that the project is advertised and constructed affects the unit cost for items of work. Contractors are usually more readily available for work early in the spring and will therefore bid conservatively at that time. Later in the spring and during the summer, many contractors have ongoing projects that keep them busy; therefore, they tend to bid higher or not at all." Evaluating the impact of timing on overall costs of construction is difficult. These uncertainties are generally captured in the design contingency, as well as in the market-premium contingency.

6.5 Description of Activities

6.5.1 Land-based Dredging

As part of continued maintenance the SONGS restoration project completed in 2011, the lagoon inlet is periodically mechanically dredged from shore by SCE to maintain adequate tidal flushing (Section 2.2.4.1). Re-use of dredged material from the inlet has previously been placed on Del Mar beaches to the north and south of the inlet. Past dredge volumes have been relatively small (typically 14,000 to 16,000 cy) when compared to previous regional nourishment efforts, such as SANDAG RBSP I and II.

Land-based dredging at Del Mar consists of utilizing standard earth-moving equipment to remove accumulated sand from the San Dieguito Lagoon inlet and redistribute the sand onto Del Mar beaches. Sand excavation is performed using two-track excavators or back-hoes that remove sand using hydraulic excavating arms. Sand is deposited from the excavator or hoe into a dump truck (typically an off-highway dump truck) and trucked to the appropriate location on the beach. Front-end loaders redistribute and grade sand on the beach to target design elevations.

Land-based dredging can be cost-effective for relatively small projects as land-based costs are largely linear (i.e. increase with the volume of dredging). Mobilization and demobilization represent a smaller fraction of overall project costs when compared to offshore dredging projects. Furthermore, land-based dredging can provide beach sand quickly (short project duration) often with readily-available equipment.

6.5.2 Offshore Sand-Mining

Offshore sand mining involves dredging deep-water sand from an offshore borrow site, transportation of the sand to a placement beach, and distribution of the sand on the beach. Previous nourishment efforts by SANDAG have identified a productive borrow site with appropriate beach material located approximately 2,500 feet offshore of Del Mar (borrow site SO-5, Figure 6-1). The following sections discuss possible dredge methodologies which could be implemented to remove material from SO-5 and place it along the Del Mar Beach. These sections focus on the dredging and transport aspects of the sand-mining operation, with the assumption that on-beach grading will be similar to that described for land-based dredging. Dredging methods impact the overall unit cost associated with the nourishment project.

6.5.2.1 Trailing Suction Hopper Dredge

Based on previous projects involving offshore sand mining and beach placement (i.e., SANDAG RBSP I and II), the most likely scenario for sand nourishment at Del Mar involves the use of a trailing suction hopper dredge with a stationary floating platform pump to transport sediment to and distribute along the beach.

Trailing suction hopper dredges (hopper dredges) are hydraulic dredge systems onboard an ocean-going vessel. One to three suction arms equipped with hydraulic pumps extend from the hull of the ship to the seafloor. The suction arms transport a slurry of sediment and water to ship, where the material is stored temporarily in a hopper within the ship's hull. When the hopper is full, the ship travels to an offload destination where a pump-out system deposits dredged material either directly into a pipeline or onto a barge. Hopper dredges can typically dredge material at depths between 10 to 140 feet (USACE 2015b).

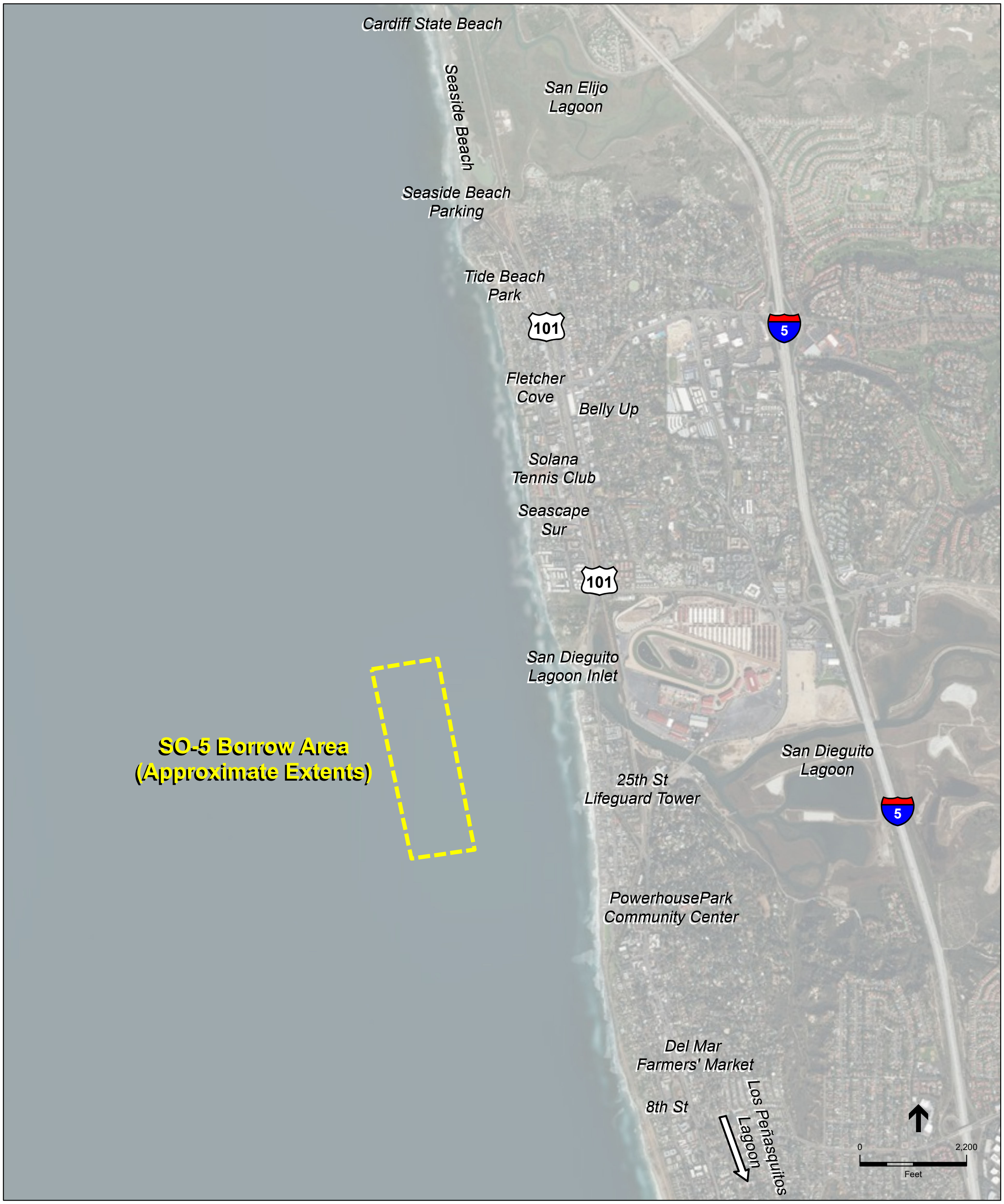
Key Benefits

- Hopper dredges are the only dredge systems that can operate in rough seas. Some hopper dredges can operate in up to 12 ft of swell (USACE 2015b).
- Hopper dredge systems are highly maneuverable and are self-propelled (typically do not need tug assistance).
- These systems excel at dredging loose, unconsolidated materials (i.e., sand).

Limitations

- Hopper dredges cannot operate continuously and must periodically unload the sediment stored in the onboard hopper.
- The deep draft of hopper dredge vessels limits access to shallow water areas (less than 10 feet deep) (USACE 2015b).

Trailing suction hopper dredges have been used successfully in the past to remove material from the SO-5 borrow site, located immediately offshore of Del Mar.



SOURCE: USGS

Del Mar LCP Update. 150347

Figure 6-1

SO-5 Borrow Area

6.5.2.2 Mechanical Bucket Dredge

The mechanical bucket dredge uses a bucket system to excavate and lift material from the seafloor onto an adjacent scow barge. Various bucket types systems exist, with a common type being the clamshell or grab bucket. In this system, a two-part bucket, suspended from a barge-mounted crane, is opened and lowered to the seafloor where it impacts and closes around bottom material. The closed bucket is lifted by the crane to the surface where it opens and empties dredged material onto an adjacent scow barge. The scow barge then is moved to the placement location, where the sand can be pumped into a pipeline for distribution.

Key Benefits

- Bucket dredge systems can operate continuously as long as a scow barge is available to receive dredged material. This typically requires multiple scow barges.
- Bucket systems can dredge most types of material, including unconsolidated sediment, consolidated sediment, and some stone and crushed rock materials.

Limitations

- Bucket systems can generate a plume of suspended sediments, particularly in areas with high sediment fines content. Sediment plumes can travel and may negatively impact nearby biological resources such as kelp beds and seagrass beds.
- Production rates are low relative to hydraulic dredge systems such as a hopper dredge.
- Bucket dredge systems are not self-propelled and require tug assistance to move an appreciable distance (although they are able to perform moderate repositioning).
- Bucket systems are typically limited to 100 ft of depth (USACE 2015b).

Since a hopper dredge was used for the SANDAG projects, it is unlikely that a bucket dredge system is competitive for Del Mar.

6.5.2.3 Cutterhead Suction Dredge

The hydraulic pipeline cutterhead dredge, or cutterhead suction dredge (CSD), is a commonly used dredging vessel and is generally efficient and versatile for many situations. A cutter arm and suction pipe extend below the dredging vessel to suction slurries of dredged material into a discharge pipeline. The CSD has the capability of pumping dredged material long distances to upland placement areas. Cutterhead dredges are documented to be able to reach depths of up to 50 ft (USACE 2015b).

In cutterhead dredging, the pipeline transport distances usually range up to about 3 miles. For commercial land reclamation or fill operations, transport distances are generally longer, with pipeline lengths reaching as far as 22 miles, for which the use of multiple booster pumps is necessary.

Key Benefits

- Cutterhead dredges are able to achieve production rates typically ranging from 500-1,000 cy per day.
- The cutterhead operates on an almost continuous dredging cycle, resulting in maximum economy and efficiency.
- Cutterhead dredges are used on both new work and maintenance projects and are capable of excavating most types of material and pumping it through pipelines for long distances to upland placement sites.
- The use of a pipeline alleviates the need for constructing a mooring dock capable of handling several scow barges typically used with bucket dredges, which would be otherwise necessary in the absence of a conveyance pipeline. The hydraulic outlet is typically moved or often a pipeline is placed with multiple discharge ports (sometimes referred to as a “diffuser” or “manifold”), facilitating sand placement along the beach with less mechanical grading.

Limitations

- High sea states can break discharge pipelines, causing either possible damage to nearby structures resulting from runaway pontoons/pipe or navigation hazards resulting from sunken pontoons/pipe. High seas can also make the act of adding or removing discharge pipelines more dangerous to dredge personnel. According to USACE guidelines, the maximum wave height for safe operations of cutterhead dredges is 3 ft.
- The pipeline from the cutterhead dredge can cause navigation problems in small, busy waterways and harbors. The dredge itself can also be a hazard to navigation due to its immobility operating on spuds.

The wave exposure at Del Mar may be too large (i.e. wave heights are often greater than three feet) to continuously dredge. Given that the SANDAG beach nourishment projects were accomplished with a hopper dredge, it is likely that the cutterhead dredge and pipeline system is not as effective for Del Mar.

6.6 Historical Rates

Previous assessments of unit costs have been performed. A summary of historical unit costs per cy is given below as a function of when the estimate was either formulated, or published. Note that in some cases, assumptions of what these unit costs include could not be fully documented. The numbers reported in the following paragraphs thus represent ROM unit costs for the dredging and placement of sand in Southern California, and should be used accordingly.

6.6.1 SANDAG RBSP I and II

SANDAG’s RBSP I consisted of a large-scale regional beach nourishment effort in 2001. From the beginning of April to the end of September, 2.1 million cy of beach sand was placed on twelve receiver beaches between Oceanside and Imperial Beach. Sand was obtained from six offshore borrow sites located in approximately 30 to 50 feet of water using a trailing suction hopper dredge. Sand was piped from the dredge to the receiver beach and was graded using standard construction equipment. The total budget for RBSP I was $14.2 M, resulting in a nominal unit cost of approximately $7/cy of sand. Adjusting this unit cost to 2018 dollars using a 4% escalation rate results in a 2018 unit cost of approximately $13/cy.

In 2012, SANDAG implemented RBSP II, and placed 1.5 million cy of sand on eight of the previous receiver beaches. Four previous receiver sites, including the City of Del Mar, opted not to participate in RBSP II. Three previous offshore borrow sites (SO-5, SO-6, and MB-1) were utilized for RBSP II. Dredging was conducted by Great Lakes Dredge and Dock Company using the trailing suction hopper dredge Liberty Island, which has a capacity of 6,500 cy. As with the RBSP I, sand was piped from the dredge to shore and graded using standard construction equipment. The base bid for RBSP II from the Great Lakes Dredge and Dock Company was $22.8 million, resulting in an approximate nominal unit cost of $15/cy of sand. Adjusting this unit cost to 2018 dollars using a 4% escalation rate results in a 2018 overall unit cost of approximately $19/cy. ESA separated the fractional cost associated with the placement at Solana Beach, located just north of Del Mar, which used dredged material from offshore borrow site SO-5. The adjusted unit cost for the Solana Beach placement only was estimated to be $13/cy in 2012 dollars and $17/cy in 2018 dollars.

6.6.2 Flick & Ewing (2009)

Flick & Ewing (2009) provide estimates of sand nourishment volumes needed to maintain existing beaches as sea-level rises in Southern California. Sand volume estimates were obtained using the Bruun Rule (Bruun 1962) for 20 to 150 cm of sea-level rise. The paper provides a cost estimate of nourishing beaches with 1.9 million cubic meters of sand per year using a nominal unit cost of $10 per cubic meter (totaling $19 million per year). Adjusting this rate to a cost per CY in 2018 dollars results in $11/cy. Flick & Ewing do not include a source or further information on the nominal unit cost of $10 per cubic meter. While the Flick & Ewing paper provides a useful rough-order-of-magnitude unit cost estimate, the level of documentation is insufficient to establish that this unit cost is directly applicable to the project.

6.6.3 The Water Institute (2015)

The Water Institute of the Gulf prepared a report in 2015 (Water Institute 2015) on the cost of various dredging projects carried out for restoration purposes in coastal Louisiana. Costs were highly varied depending on the type of restoration projects conducted and the source of the sand. Overall unit cost estimates for coastal marsh creation projects averaged $38/cy when adjusting for 2018 dollars and after adjusting by a location factor of 30% for California. Additional costs included in this unit estimate may not reflect actual project needs at Del Mar (i.e., creation of marsh and dune habitat features). Furthermore, most dredging performed in Louisiana entails different equipment than that likely to be implemented in the vicinity of Del Mar.

The Water Institute also provided unit cost estimates for beneficial (opportunistic) use projects ($8/cy in 2018 dollars, location-adjusted) and provided an example offshore borrow source project costs ($12/cy). The beneficial use project rates are not relevant for the Del Mar project as there is not a sufficient volume of available opportunistic sand. The offshore borrow source unit cost is more relevant and is similar to the adjusted RBSP I unit cost.

6.7 Assumptions

Table 6-2 provides a range of unit costs for dredging and placing beach sand at Del Mar. The estimates provided in Table 6-2 were obtained using a variety of methods, including historical process and unit cost of labor and equipment from standard sources. Recommendation for unit prices in Table 6-2 are shown for representative volumes in cy. All unit prices are quoted in 2018.

This ROM cost estimate is predicated upon limited information related to the type of material to dredge and place on the beach. While ESA endeavored to develop reasonable methodologies for disposal, based on historical projects, the basis for the cost estimate is subject to uncertainties which are anticipated to be reduced as design progresses further.

ESA recommends the following unit prices for planning purposes:

Best-Case Scenario:

- $19/CY
- Assumes the right conditions are met, including massive economies of scale (a 1-2+ million CY project), with optimistic conditions
- Not recommended for planning purposes

Most-Likely Scenario for dredge volumes above 200,000 cubic yards

- $25/CY
- Assumes good economies of scale are captured with reasonable assumptions, reasonable market conditions
- Recommended for planning purposes

Worst-Case Scenario

- $30/CY
- Assumes minimal economies of scale (e.g. small job), difficult market conditions, conservative assumptions
- Recommended for capturing upper bounds

Note that a large fraction of the cost is associated with mobilization and demobilization of the dredging equipment, whereas the incremental cost to dredge and place the sand is relatively low. The mobilization costs include the dredge itself, but also the site-specific pipeline and land-based equipment and associated costs. Consequently, the unit cost (dollars per cubic yard of sand placed on the beach) decreases with increased volume of sand placed. Therefore, it will be more economical for Del Mar to cooperate with regional projects such as SANDAG or to place at least 200,000 cy per dredge event. Placing less than 100,000 cy would increase the unit cost to $30 per cy or higher (see “Worst-Case Scenario”).

It is recommended that cost contingencies be carried to account for market conditions and future prices. For example, it is possible that costs will increase in the future as demand for the limited sand and construction capacity increases.

TABLE 6-2
SUMMARY OF ANTICIPATED UNIT COSTS OF SAND PLACEMENT FOR VARIOUS SCENARIOS

Category	Method	10,000 CY	150,000 CY	500,000 CY	1M+ CY	Source
Offshore	Hopper Dredge and Pipeline	NA	NA	NA	**$19**	RBSP II - General/overall
Offshore	Hopper Dredge and Pipeline	NA	**$17**	NA	NA	RBSP II - Solana Beach Fraction. Captures economies of scale which may not be reflected in a more localized project
Offshore	Clamshell & Conveyance Pipeline	NA	**$24**	NA	NA	RSMeans (location adjusted)
Land-side	Mechanical excavation on land (inlet)	**$25**	NA	NA	NA	RSMeans (location adjusted)

NA = not applicable

SECTION 7

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