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## The Watershed Institute

Division of Science and
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California State University Monterey Bay
http://watershed.csumb.edu

100 Campus Center, Seaside, CA, 93955-8001
831 582 4452 / 4431


*Central Coast Watershed Studies*

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# A Small-Scale Beach Nourishment Project in Monterey, California

CSUMB Class ENVS660 Fall 2015:


Alex Henson
Daniel Muratore
Amelia Olson
Alex Snyder (US Geological Survey)
Doug Smith Ph.D. (Instructor)

Editor contact details:
dosmith@csumb.edu

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## Executive Summary

This study was conducted as part of a class project by students in the Advanced Watershed Science and Policy (ENVS660) course at California State University at Monterey Bay (CSUMB).

Monterey Bay, California has seen coastal erosion rates between 10–30 cm $yr^{-1}$. Del Monte Townhomes, 0.5 km east of Monterey Harbor, is at risk from coastal erosion. A nourishment project was initiated between the home owners and Monterey Harbor, whereby harbor dredging would be used to nourish the beach adjacent to the townhomes. Cross sections of the beach were surveyed prior to, during, and after two such nourishment events between 2012 and 2015. The first and second nourishment events supplied ~5300 $m^3$ and ~3000 $m^3$ of sediment to the beach adjacent to Del Monte Townhomes, respectively. Analysis of these cross sections indicate that the nourished area lost approximately 5320 $m^3$ between April 2013 and December and September 2015. Control areas located adjacent to the project experienced negligible volume change between 2012 and 2015. While the sand placed into the nourishment berm was gradually diminished, the berm fully protected the Del Monte Townhomes from oceanographic events during the time of the study. As an immediate and short term goal, continued nourishment is prudent. Long term goals should continue to consider structural adaptation and coastal retreat.

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# 1 Introduction

## 1.1 Project Overview

Shoreline position at any point in time is a function of the volume of sea water, volume of ocean basins, and local coastal geometry. Global sea level has risen approximately 120 m since the end of the last glacial maximum approximately 18,000 years ago, resulting in many kilometers of lateral encroachment of the shoreline onto the continental margins (Cooper and Lemckert 2012). The range of coastal impacts of sea level rise (SLR) is dependent on regional morphological and geological differences along the coast. Rising sea level inundates coastal regions and results in the redistribution of the sediments of sandy coasts. SLR increases the susceptibility of coastal regions to storm surges, tsunamis, and extreme astronomic tides. The magnitude and impact of these events will increase as sea level continues to rise (Fitzgerald *et al.* 2008).

SLR affects coastal settlements worldwide. Nearly 25 percent of the world's population lives within 100 m elevation and 100 km distance of the coastline (IPCC 2007). California has over 3,200 km of coast that is susceptible to natural processes including increasing SLR. In 2003 it was estimated that 31 million Californians resided in coastal counties. Sea level on the California coast has risen approximately 20 cm in the twentieth century (Cooper and Lemckert 2012). A 1.4 m rise in sea level would impact approximately 480,000 people; putting them at greater risk of flooding and property loss. Replacing property at risk of coastal flooding under the above scenario would cost $100 billion (year 2000 dollars) (Heberger *et al.* 2009). A wide range of mitigation measures have been used to reduce SLR-related losses. Hard substrate sea walls are most commonly used to armor the coast and corresponding settlements from erosion and flooding, however soft measures such as beach nourishment have also been widely used in recent decades.

Sandy beaches constitute some of the most valuable real estate in the nation (Hapke *et al.* 2006). The broad, sandy beaches of California depend on sea-cliff erosion to contribute sand. Urbanized beaches are often armored by sea walls or rip-rap to protect structures (Dean 1986). When sea walls or rip-rap are used, the supply of sand from erosion is cut off. Coastal erosion is caused by a decrease in sediment supply and change in sea level (Feagin *et al.* 2005). Armoring the coast accelerates the erosion of the local beach sand while it temporarily guards against coastal retreat (Runyan and Griggs 2003).

Monterey Bay is a 48 km long embayment on the coast of central California. The bay is bisected by the Monterey Submarine Canyon, offshore of Moss Landing. The canyon splits the bay into two littoral cells, the Santa Cruz and South Monterey Bay cells. Both cells predominantly transport sediment north to south. The sediment from the Santa Cruz cell is intercepted by the submarine canyon, so all sand moving within the South Monterey Bay cell is locally derived (Dingler and Reiss 2002).

The coastline of South Monterey Bay is typified by broad sandy beaches that are seasonally dynamic and susceptible to erosion. The sand from these beaches is dependent on sediment supply from coastal erosion, given that Monterey Canyon terminates the large Santa Cruz littoral cell, and the Salinas River does not provide much sand (Thornton *et al.* 2007). Commercial and residential development abuts much of the coastline in South Monterey Bay (Smith *et al.* 2005). Both hard and soft coastal armoring has been used here to reduce the rate of coastal erosion and lessen the impact of SLR on development. Oceanographic events such as El Nino Southern Oscillation (ENSO), especially in conjunction with high tides and large swells have produced significant erosion events in Southern Monterey bay (Quan et al. 2013).

Monterey Bay National Marine Sanctuary (MBNMS) occupies the waters offshore of South Monterey Bay, so special consideration must be given to coastal geomorphic modifications. Efforts to protect commercial and residential developments on the coastline of South Monterey Bay impact the protected wildlife in MBNMS. Approximately 24 km of the MBNMS coastline was armored, as of 1998. (Stamski 2005).

A taskforce was initiated by Congressman Sam Farr in 2004 to develop a proactive, site specific response to coastal erosion that considered a wide range of coastal management options (pers. comm. Doug Smith September 22, 2015). In addition to seawalls, soft technology such as beach nourishment was assessed. The taskforce report suggested that beach nourishment might be feasible near Monterey Harbor, where wave energy is relatively low and dredge material is available as a nourishment source (ESA PWA 2012).

## 1.2 Study Area

The study area for this project is the South Monterey Bay littoral cell on the central coast of California, and the project site is located at the Del Monte Townhomes, formerly known as the La Playa Townhomes (Fig. 1 and Fig. 2). Del Monte Townhomes is located roughly 0.5 km east of Municipal Wharf 2 at the Monterey Harbor, at the end of La Playa Street in Monterey, California. The northwest corner of the Del Monte Townhomes abuts the interface between the incipient dunes and the beach berms, exposing it to wave damage and flooding (PWA 2008; Fig. 3). The adjacent broad sandy beach at Del Monte Townhomes and its intersection with development is typical of South Monterey Bay (Smith *et al.* 2005).


**Figure 1.** The regional site map. Del Monte Townhomes is located in the South Monterey Bay littoral cell, which has the highest mean erosion rate in the state (Hapke *et al.* 2006). Long-term future erosion rates adjacent to the project site are estimated to be ~10–30 cm $yr^{-1}$ (PWA 2008; ESA PWA 2012).

Broad sandy beaches, such as the one located near the Del Monte Townhomes, are typical of the South Monterey Bay littoral cell. According to PWA (2008), the Del Monte Townhomes are high-risk, and threatened by continued dune erosion over the next fifty years. The future predicted erosion rate for the project site is between 10–30 cm $yr^{-1}$, and mitigation efforts are required to prevent property loss (PWA 2008; ESA PWA 2012). Without mitigation, the first losses were predicted to occur approximately in 2028, with 25 % of the at-risk townhomes lost in ten year increments (PWA 2008).


**Figure 2.** The project site map, showing the Del Monte Townhomes property adjacent to the broad sandy beach, located on incipient, actively migrating dunes. This beach is typically gently sloping and wider in summer, but narrower and steeper in the winter (Stamski 2005). The beach nourishment project involved two nourishment events; one in the winter of 2012/2013 to establish a new berm between the townhomes and the beach, and one during the winter of 2013/2014 to supplement the previously constructed berm (pers. comm. Jay Jonekait, August 27, 2015).

**Figure 3.** The northwest corner of Del Monte Townhomes. Small riprap was placed to protect a fence and drain pipe. Photo was taken November 11, 2012, shortly before the nourishment project began.

## 1.3 Management Options

There are three widely used strategies designed to mitigate coastal erosion: beach nourishment, beach armoring, and managed retreat (Landry *et al.* 2003).

Since 1970 beach nourishment has been the most common mitigation technique, accounting for over 80 % of all coastal protection measures (Speybroeck *et al.* 2006). Beach nourishment is the process of adding sand to a shore undergoing erosion in order to maintain the protective or recreational function of the beach (Speybroeck *et al.* 2005). Dredged materials used to alleviate erosion are required to match the sediment of the beach (Greene 2003). Due to this requirement the aesthetic implications of beach nourishment are minimal. Although beach nourishment may be successful in addressing erosion concerns, it doesn't resolve the initial problem of sediment transportation through wave activity, and therefore is typically viewed as a temporary fix (Shipman 2001). Ongoing maintenance of the nourishment site is essential in order for beach nourishment to be considered a viable long-term solution to shoreline erosion. Like most management options, initial costs of beach nourishment are typically high, making the ongoing maintenance costs problematic.

Beach armoring is a process which utilizes the installation of a seawall, rip-rap, or other hard surfaces designed to protect sensitive shorelines (Fletcher *et al.* 1997). While armoring is typically an effective means of diffusing wave impact and protecting a deteriorating beach, there are some observed instances of negative impacts. These impacts include offshore profile steepening, increased intensity of local scour, sand transportation to extreme offshore distances, erosion downdrift of the armor, and post storm recovery delays (Dean 1986). Due to these potential ramifications and extreme costs of an armoring project, they are a significantly less common mitigation technique than beach nourishment. Rip-rap constricts the flow of necessary littoral material which broad beaches rely on (Runyan and Griggs 2003). Narrower beaches surrounded by seawalls or littered with rip-rap are typically deemed aesthetically displeasing, which again prompts the use of beach nourishment.

Managed retreat is a strategy favored by many prior to the twentieth century and is currently receiving growing support (Dean 1999). Several coastal geologists believe that erosion is an unavoidable problem which can only be temporarily delayed through human interference (Landry *et al.* 2003). These individuals advocate allowing erosion to occur unimpeded, and recommend disassembling structures at risk from shoreline loss. Shores left undeveloped through managed retreat benefit due to the ability of coastal ecosystems to recolonize (Abel *et al.* 2011). Managed retreat acknowledges that shoreline erosion coupled with SLR is an ongoing problem, and therefore developers should plan to build future structures accordingly.

### 1.4 Current Mitigation Effort

A beach nourishment project was initiated in 2008 (Fig. 4) as part of an effort to identify a beneficial re-use of dredged material, that would serve both the Del Monte Townhomes and the City of Monterey Harbor (pers. comm. Jay Jonekait, August 27, 2015). The project intent was to combine two needs: dredging the Monterey Harbor of excess sediment, and depositing it adjacent to the Del Monte Townhomes as a protective measure against coastal erosion.

California Coastal Commission permit number 3-10-040 (Monterey Harbor Dredging) was filed on December 9th, 2010, and approved in 2011 (CCC 2011). The permit allows the dredging from the Monterey Harbor between Municipal Wharfs 1 and 2, and subsequent deposition at two beach nourishment sites east of the harbor. One of these nourishment sites is adjacent to the Del Monte Townhomes, where local sediment characteristics are appropriately similar to Monterey Harbor sediments (CSUMB 2011). The stipulations of the permit include:

1. a dredging volume not to exceed 7,600 $m^3$ annually,
2. the duration of the permit not to exceed five years,
3. a Sampling Analysis Plan and Sediment Testing is required prior to each annual dredge event, and
4. a Dredge Operations Plan will be submitted prior to each annual dredge event, which includes addressing:
    i. identifying the areas where dredging is prohibited,
    ii. grunion spawning protection plans,
    iii. public access protection plans, and
    iv. maintenance of all dredge equipment (CCC 2011).

Beach nourishment at the Del Monte Townhomes began in the winter of 2012/2013, where approximately 5300 $m^3$ of sediments were dredged from Monterey Harbor and transported in a slurry pipe to the west end of Del Monte Townhomes (pers. comm. Jay Jonekait, August 27, 2015). The sediment slurry was ponded to extract the sand, and the sand was shaped into a longitudinal berm using a small tractor (Fig. 5).

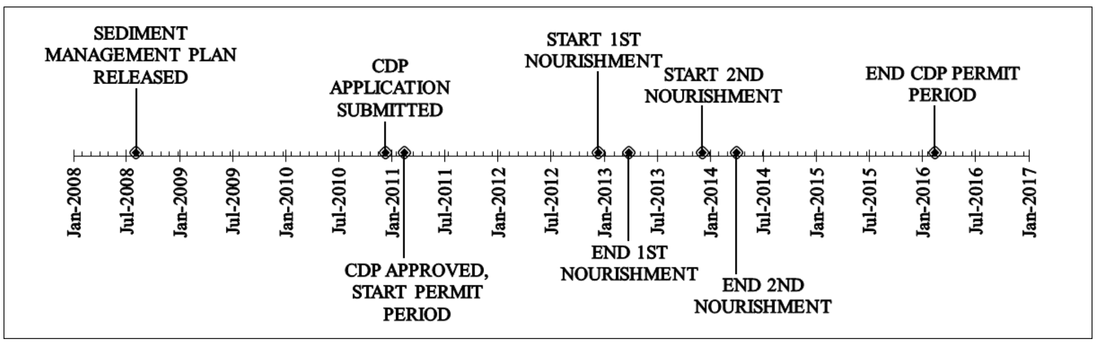


**Figure 4.** Permitting and nourishment event timeline for the Del Monte Townhomes beach nourishment project. A nourishment event did not occur during the 2014/2015 winter. The CDP expires during the 2015/2016 winter. The Monterey Harbor Master has expressed desire to file an extension to allow completion of a 2015/2016 nourishment event (pers. comm. Stephen Scheiblauer, September 8, 2015).

Another nourishment event occurred during the winter of 2013/2014, where 3000 $m^3$ of sediments were dredged and deposited along the center of the Del Monte Townhomes dune area. Continued protection of the Del Monte Townhomes from coastal erosion is dependent on continued beach nourishment, or adoption of an alternative protection measure.


**Figure 5.** The nourishment berm (B) is shown very soon after completion of the first nourishment event in the winter of 2012/2013. View is eastward, toward the fence shown in Figure 3.

## 1.5 Project Goals

The purpose of this study is to utilize data from current and historic shoreline monitoring to assess the effectiveness of the Del Monte Townhomes beach nourishment project.

# 2 Methods

## 2.1 Field methods

We utilized a combination of historic and current beach profile data to conduct the Del Monte Townhome beach nourishment assessment. The historic dataset was captured in a series of 16 field survey events occurring from December 14, 2012 through November 16, 2013. These field surveys were performed using a combination of Real Time Kinematic Global Positioning System (RTK GPS), ground-based mobile LiDAR, and Autolevel surveys. These surveys were conducted by California State University, Monterey Bay professors, undergraduate, and graduate students. Each survey event captured up to 33 cross sections running perpendicular to berm of the beach, spread out across the nourishment site, and two adjacent control sites, one on each side of the nourishment site (Fig. 6). On September 8, 2015 we re-surveyed a subset of the existing transects using RTK GPS. We then performed an assessment of the beach nourishment effectiveness.

## 2.2 Analysis methods

We spatially and temporally compared cross-sections of the 33 recorded transects. The beach surveys were distributed along the nourishment berm (Fig. 6, section B) and along two control sites adjacent to the berm (Fig. 6, sections A and C). Cross sections spread through these three sections were overlaid in Microsoft Excel (2010) to examine the change in sand in both the nourished area and the control areas. We did not analyze all the cross section positions for all survey dates. The specific locations and dates selected for comparison were chosen based on temporal proximity to nourishment events and relation to local oceanographic events. Once these select dates were plotted, we uploaded images of cross section plots into GNU Image Manipulation Program (GIMP 2014). Using image analysis tools in this program, we were able to determine the change in cross sectional area of the berm and control regions of the study area. We calculated volumetric changes in the berm by multiplying the change in cross sectional area by lateral distance along the berm. The initial volume of sand present immediately after nourishment was determined from surveys that immediately pre-dated and post-dated nourishment. With that volume set as 100 %, we then calculated the cumulative percent change from that initial volume over the remaining time steps. To assess the amount of berm retreat corresponding with sediment loss we created a table of berm locations from each cross section within each survey event. This table was plotted in ArcGIS (ESRI 2013) over a recent satellite image of the Del Monte Beach in order to visualize the berm fluctuation over the temporal span of this nourishment site.

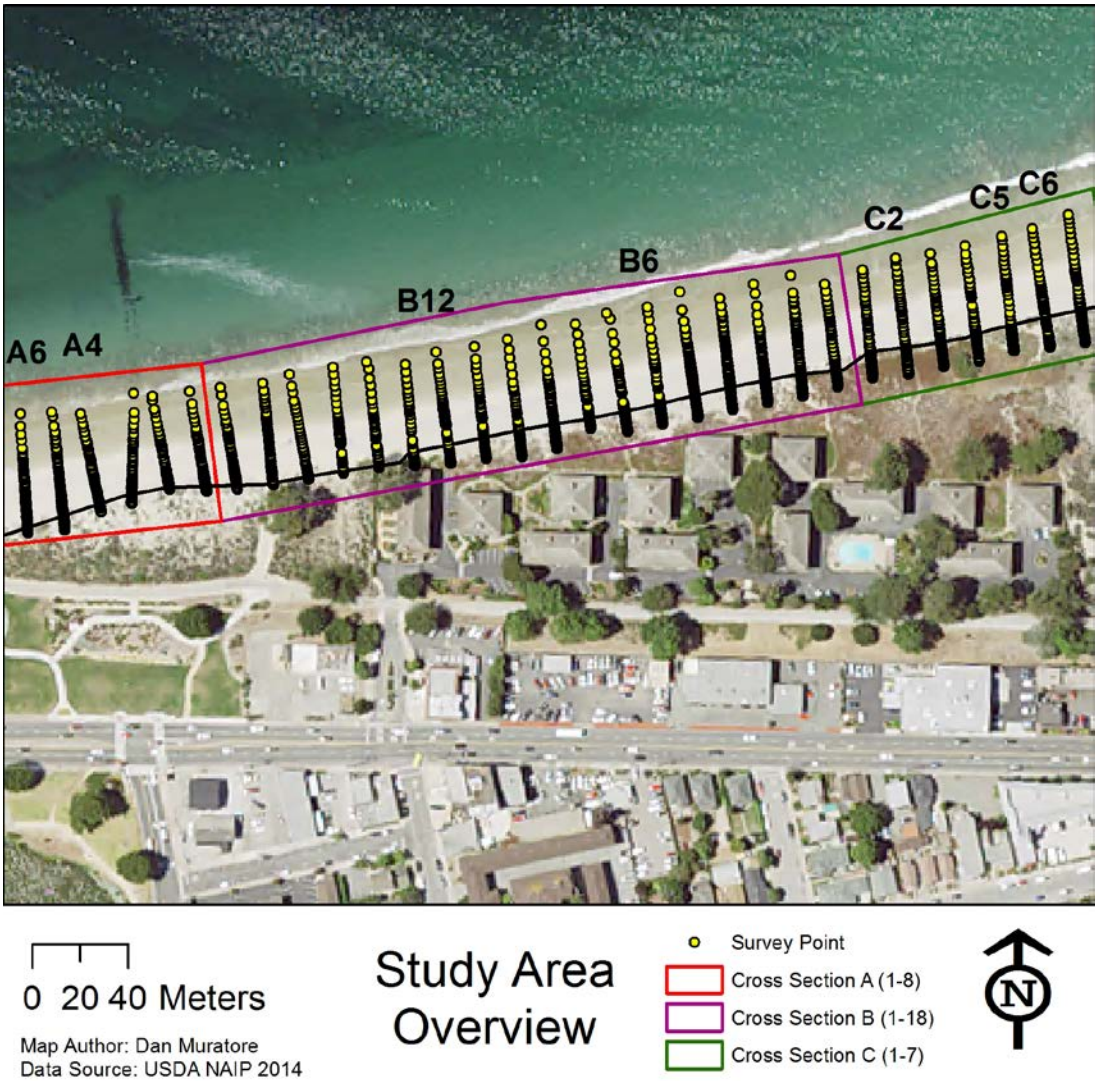


**Figure 6.** Cross section locations. Lines of yellow dots are the locations of repeated cross section measurements over the course of the study. Individual dots are measurement locations. The labeled cross sections were used in the current analysis to evaluate beach nourishment success. Section B represents the nourished area, while sections A and C represent the control areas where no nourishment occurred.

## 3 Results

The nourishment area (Section B) lost a total of roughly 4870 $m^3$ of sand from May 24, 2013 to September 8, 2015 (Fig. 7; Table 1). This volume represents roughly 59 % of the total nourishment volume of 8300 $m^3$ applied over two events (2012/2013 and 2013/2014) (Table 1).

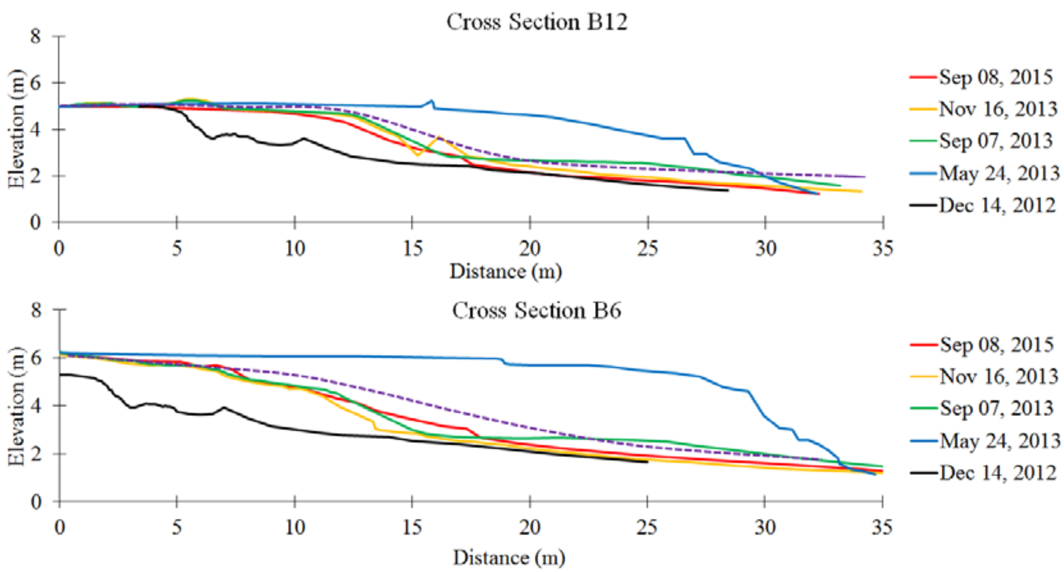


**Figure 7.** The nourished area cross sections B12 and B6, represent the change of Section B. The amount of sediment gained and lost over in this section is well represented by these cross sections. The dashed line indicates an assumed berm location after the second nourishment event, which is unknown.

The control areas of Del Monte beach (Sections A and C), did not exhibit major erosion or deposition from December 7, 2012 to September 8, 2015 (Fig. 8 and Fig. 9). Both areas were minimally impacted by the initial nourishment, shown in the increase in sand from the pre-nourishment survey on December 7, 2012 to the post-nourishment survey on May 24, 2013. The cross sections closer to the nourishment area were influenced more by the nourishment events than those farther away.

Cross sections from control area A were analyzed to quantify sediment loss over time. Two cross sections were selected to represent control area A. A total of 205 $m^3$ of sand was lost from May 24, 2013 to September 8, 2015 (Fig. 8; Table 1).

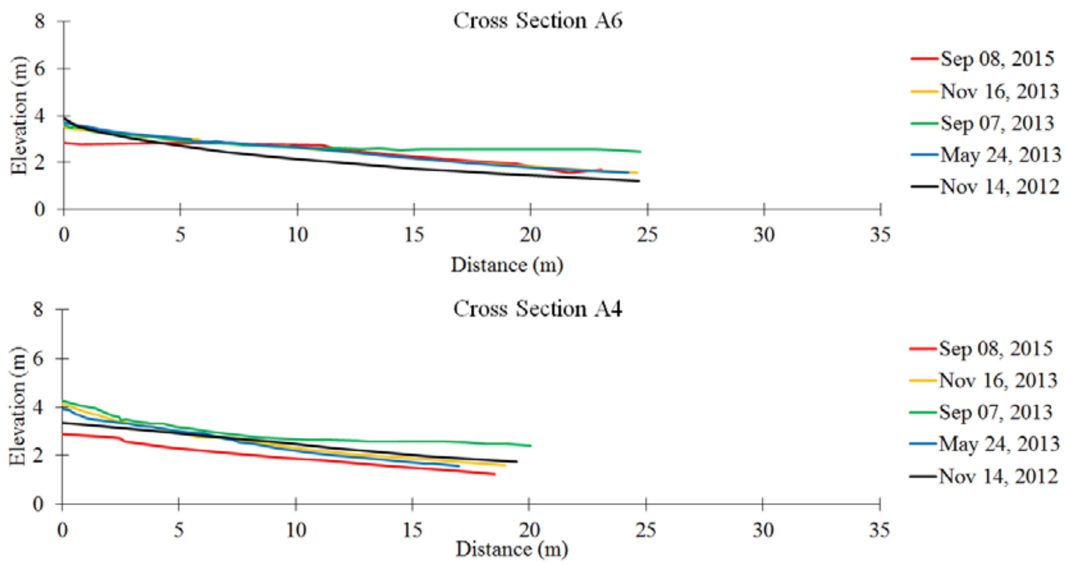


**Figure 8.** Control area A cross sections 4 and 6. Little change in sediment volume over time, with minimal impact associated with the nourishment events.

Likewise, cross sections from control area C were also analyzed to quantify sediment loss or gain over time. Three cross sections were selected to represent control area C. Control area C gained a total of roughly 640 $m^3$ of beach sediment from May 24, 2013 to September 8, 2015 (Fig. 9; Table 1). Most of this sediment appears to be in the toe of the berm, and the berm scarp fluctuated minimally.

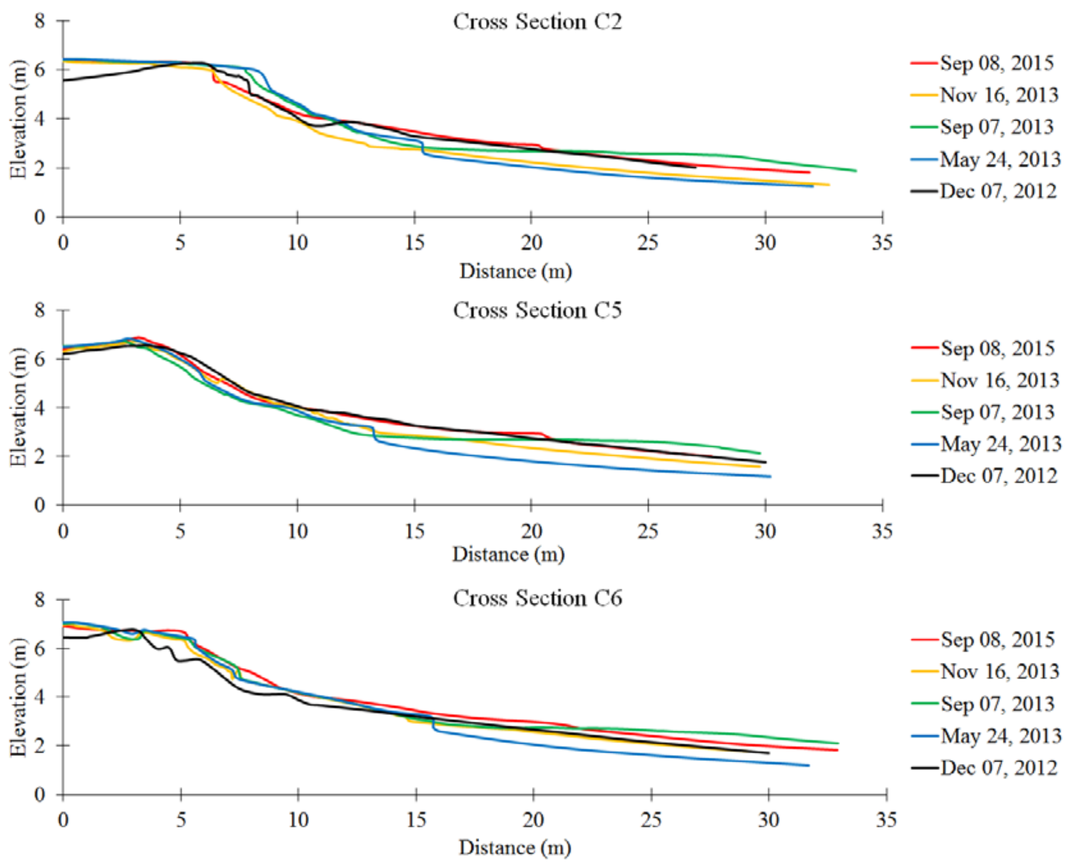


**Figure 9.** Control area C, cross sections 2, 5, and 6 showing very little change in sediment volume over time. Larger change can be seen nearer the nourished area, which may be associated with overlap of nourishment

**Table 1.** Depicts the amount of sediment change from cross section surveys. The May 24, 2013 values reflect the difference in volume of beach sediment between the pre-nourished surveys and the first post-nourished surveys. Section A and C are negative because no sediments were added, and natural erosion occurred between these two surveys. Section B is large positive values because of the nourishment. The volumes of sediment gained and lost between May 24, 2013 and September 8, 2015 are the summation of all values for each cross section after the initial post-nourishment survey (May 24, 2013) values. "Length" is the lateral shoreline length that each cross section represented. Berm Volume change ($m^3$) = Cross Section Area change ($m^2$) × Length (m).

| Cross Section | Length (m) | May 24, 2013. ($m^3$) | Sep 7, 2013 ($m^3$) | Nov 16, 2013 ($m^3$) | Sep 8, 2015 ($m^3$) |
|---|---|---|---|---|---|
| A4 | 60 | +50 | +200 | −180 | −215 |
| A6 | 60 | +130 | +160 | −130 | −40 |
| B6 | 135 | +4460 | −2910 | −540 | +250 |
| B12 | 135 | +2230 | −1190 | −270 | −210 |
| C2 | 58 | −280 | +400 | −640 | +560 |
| C5 | 20 | −280 | +170 | −30 | +100 |
| C6 | 11 | −20 | +60 | −40 | +60 |

We assessed the timing between significant oceanographic events and changes in the berm (Fig. 10). Northwest swells tend to be directed towards the Southern Monterey Bay beaches due the shape of the mouth of the bay. Swells larger than 1.5 m, registered at buoy 46042, were annotated in reference to the surveys. These swells tend to happen in the winter during heavy storms, and in the spring. King tides typically occur exclusively in the winter months.

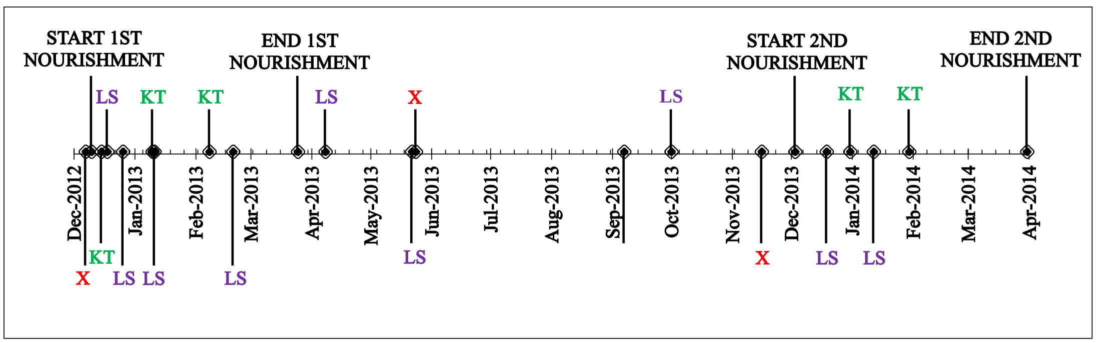


**Figure 10.** Nourishment events during the winter of 2012/2013 and the winter of 2013/2014 in the context of large swells, king tides, and surveys. LS denotes northwest swells greater than 1.5 m registered at buoy 46042 near Monterey, CA, X denotes survey dates, and KT denotes king tide dates (NOAA 2015; LAWK 2013; Papendick *et al.* 2013).

## 4 Discussion

Both control areas exhibited very little change over time. The relative percentages of change differ from the nourishment area, and the total volume of sand loss is much less. The control area location and relatively small amount of erosion do not pose a threat to the townhomes.

The nourishment area displayed a uniform shape and initial response to nourishment. Over time, erosion volume and rates differed across section B. The general trend is similar; a large decrease from the first nourishment to the first post nourishment survey and a slowing erosion rate until the last survey in 2015. Most of the sand elevation remains above the pre-nourishment level with the exception of B14. This cross section is adjacent to the outer wall protecting the Townhomes.

Despite the gradual loss of sand from the berm, the nourishment project fully protected the townhomes during the study period. Additionally dune vegetation has become increasingly present across the berm, which may help stabilize sediment and prolong the life of the nourishment project. The current dominant vegetation is sea rocket (Cakile maritima). C. maritima is a non-native annual species adapted to colonize close to the shoreline, where there is a lack of competition from other vegetation. Further establishing dune vegetation in all areas of the berm, especially near B14 where erosion was highest might extend the lifespan of the nourishment project. This cross section is located at the far west corner of the Del Monte Townhomes property, making it the closest to the shoreline and at the highest risk from incoming tides.

Typically the initial costs of beach nourishments are prohibitively high. However, in the case of the Del Monte townhomes, one cost was paid for by homeowners; the cost of approximately 600 m of 20 cm diameter pipe for transporting the sediment slurry to the townhomes. Additionally, harbor function requires routine dredging. This makes nourishment feasible in this area.

Major oceanographic events, defined as swells greater than 1.5 m, were noted in Figure 4 (NOAA 2015). It is difficult to decipher the impact these had on nourishment. Considering there were few swells between the first nourishment event and the September 8, 2015 survey, their impact was likely minimal. Large storms did occur in December 2012 and January 2013 during the first nourishment event; however, their impacts were likely muted by the addition of dredged sediments. King tides occurred during both the winter of 2012/2013 and 2013/2014. Further analysis with increased time steps of cross sections could shed light on the relationship between these king tides and the associated erosion.

Wave energy recorded at the buoy is greatly diminished through diffraction as the swells reach the north-facing beach at the study site, yet significant erosion occurred during the study. Two other erosion mechanisms were observed. The berm was degraded by people walking on the berm slope,

**Figure 11**. Significant berm erosion, indicated by tall erosional scarp, occurred during the king tide of 12/21/2014. The extent of erosion is indicated by the exposed black dredge slurry pipe, which had been buried under the berm.

and periodic high tide events caused significant retreat, even when large swells were not present (Fig. 11).

The nourishment events have been successful in slowing the inland progression of coastal erosion. Soft armoring techniques such as beach nourishment will continue to allow the supply of sediment to travel along the Southern Monterey Littoral Cell. Hard armament of the coast would exacerbate the erosion. It is recommended that beach nourishment continue. Vegetation should be added to the nourishment strategy.

However, with increasing SLR, nourishment may not always be as successful. Nourishment, while presently successful can only be thought of as a temporary solution. Future studies should identify areas of planned retreat.

# 5 Conclusion

Long term coastal erosion in the South Monterey Bay littoral cell will continue to threaten coastal development as SLR continues and severe storms impact the area. Beach nourishment is an appropriate immediate and short term action (ESA PWA 2012). However, long term actions should be kept in mind when creating regional planning goals since the sand in the harbor is a finite resource, and fills slower than the adjacent coastal erosion takes place. Prudent long term actions include structural adaptation and retreat (ESA PWA 2012).

Beach nourishment is admittedly Sisyphean in nature; however, since this sediment must be removed from Monterey Harbor for proper function, it is only logical that it would be used for nourishment to mitigate coastal erosion effects on the Del Monte Townhomes.

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