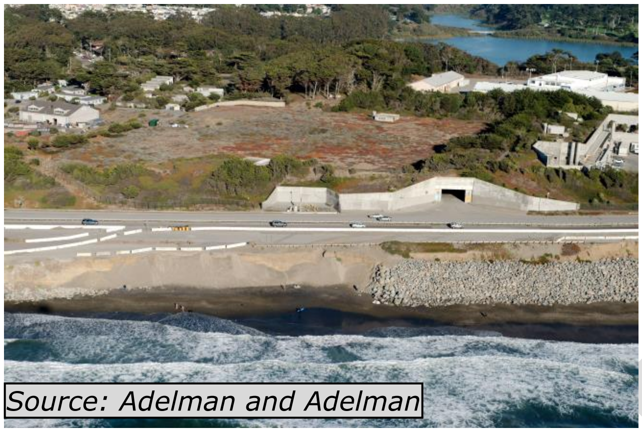
San Francisco Littoral Cell

Coastal Regional Sediment Management Plan

Draft – January 2016



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Prepared for:

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LIST OF TERMS

ABAG	Association of Bay Area Governments
Bar	San Francisco Bar
BCDC	Bay Conservation and Development Commission
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CRSM	Coastal Regional Sediment Management
CSLC	California State Lands Commission
CSP	California State Parks
CSMW	Coastal Sediment Management Workgroup
DBW	Division of Boating and Waterways
GGNRA	Golden Gate National Recreation Area
GFNMS	Gulf of the Farallones National Marine Sanctuary
MBNMS	Monterey Bay National Marine Sanctuary
MOPS	Monitoring and Prediction Station
MP	Master Plan
MSC	Main Ship Channel through the San Francisco Bar
NOAA	National Ocean and Atmosphere Administration
NEPA	National Environmental Policy Act
NMFS	NOAA National Marine Fisheries Service
Plan	Coastal Regional Sediment Management Plan
RWQCB	Regional Water Quality Control Board
SCOUP	Sand Compatibility and Opportunistic Use Program
SFLC	San Francisco Littoral Cell
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey

EXECUTIVE SUMMARY

ES.1 PLAN DESCRIPTION

A Coastal Regional Sediment Management Plan (CRSMP) frames policy and guidance strategies to restore, create, and maintain coastal beaches and other critical areas of sediment deficit; sustain recreation and tourism; enhance public safety and access; restore coastal sandy habitats; and identify cost-effective solutions for restoration of areas of excess sediment. This CRSMP (Plan), which comprises the Pacific shoreline and surroundings of San Francisco, Daly City, and Pacifica (Figure ES–1), focuses on coastal stretches where mitigating existing and expected future coastal erosion and other co-objectives – e.g., ecology, recreation, and protection of property and infrastructure – is or will be crucial for their survival. Conceptually, increased sediment supply contributes to wider beaches and hence mitigates coastal erosion while providing multiple benefits. These benefits potentially include reduced risk of damage to property and development, sustained beaches and their ecology, and maintained and enhanced recreation. There is also a desire to identify regional approaches that are often more effective, less costly, and easier to fund than local efforts.

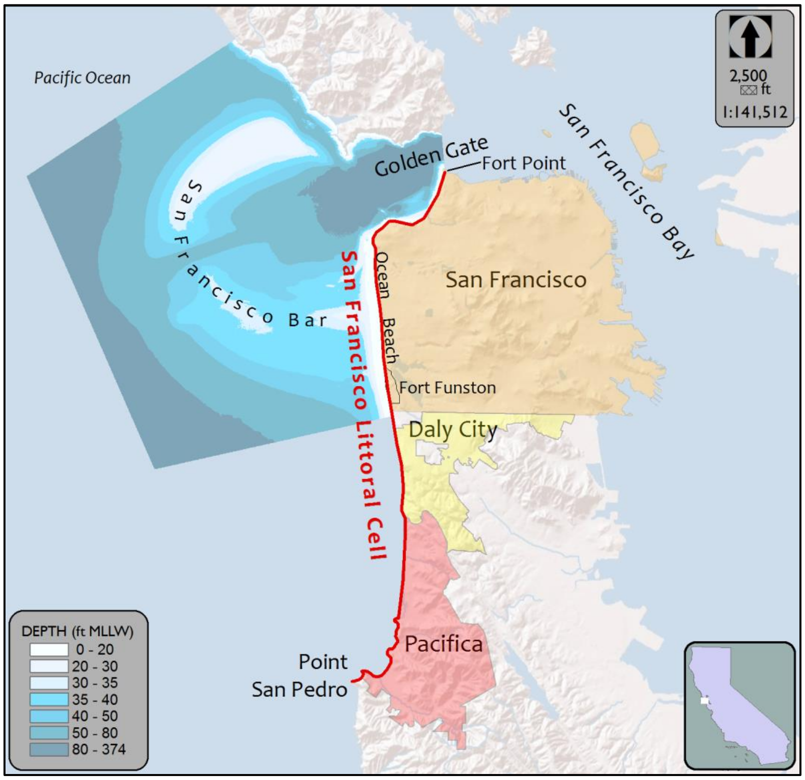


Figure ES–1: San Francisco Littoral Cell (red shoreline)

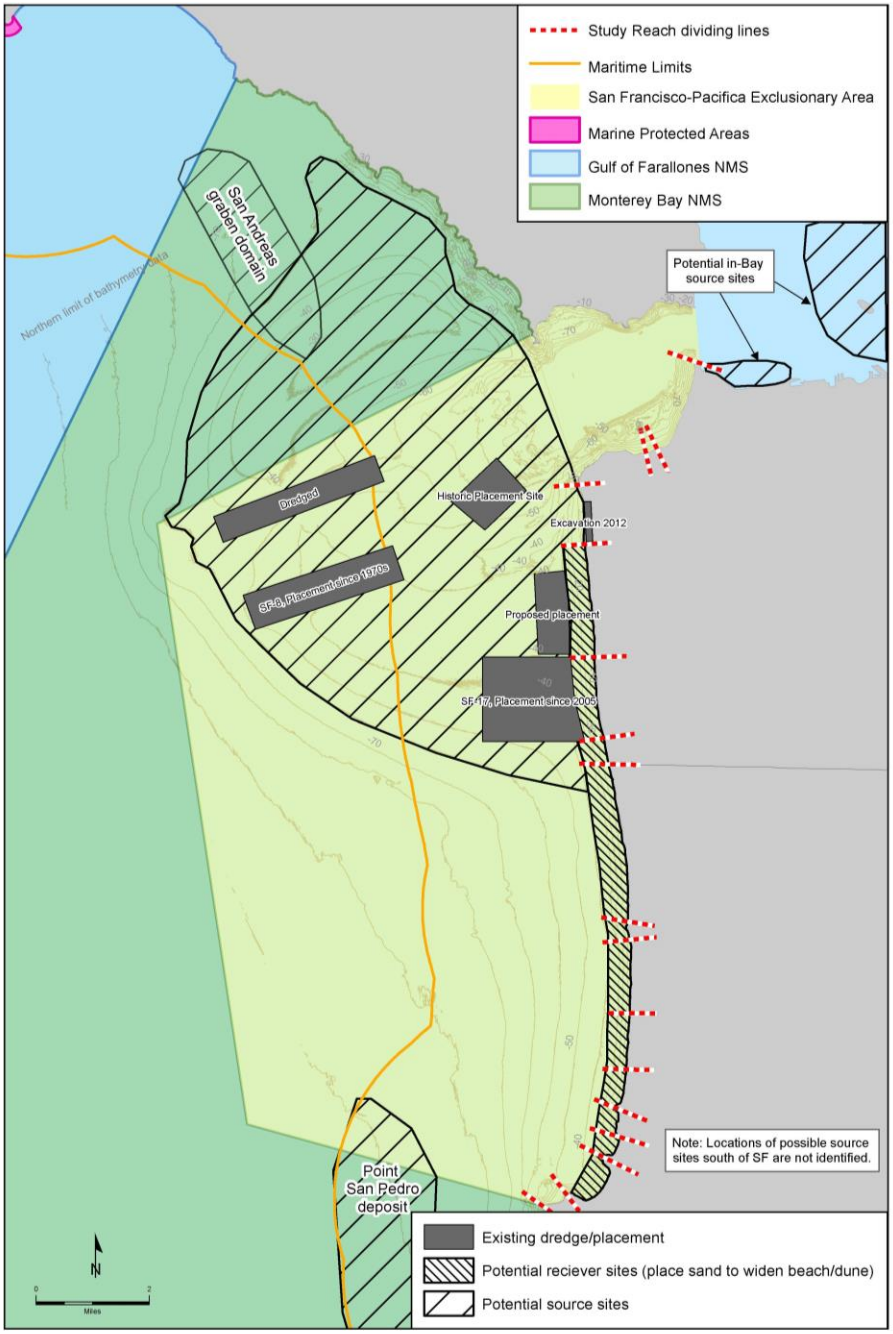
This Plan is one of several being funded by the Coastal Sediment Management Workgroup (CSMW) as part of a Sediment Management Master Plan (SMP) that encompasses the entire California Coast. The CSMW is cochaired by the State of California Natural Resources Agency (CNRA) and US Army Corps of Engineers (USACE). One goal of this Plan is to identify projects that could be considered further for state or federal funding.

The foundation of this Plan is existing information gathered and integrated into a geographical information system (GIS) data base. Available information includes the geology, geography, ecology, development, and property within the SFLC. Using prior studies as much as practical, data analysis identified coastal erosion rates, locations of high coastal erosion, and associated vulnerable assets. Future erosion rates and extents were estimated from historic rates of erosion and the effects of accelerated sea level rise (SLR), consistent with state and federal guidance. Several alternative erosion mitigation measures were evaluated for each stretch of coast (reach) identified as a hazard zone. Beach widths and erosion hazard extents were modeled through the year 2100. Economic analyses assessed the benefits and costs of the erosion mitigation options through the year 2050. The years 2050 and 2100 were selected to be consistent with available sea level rise guidance from the State of California. Early in the Plan-development process, the Association of Bay Area Governments (ABAG) and the ESA conducted Stakeholder Advisory Group and public outreach meetings in San Francisco, Daly City, and Pacifica to provide information to stakeholders and communities, engage them on local coastal hazards and sediment management issues, and identify potential alternatives or other actions that could potentially be included in the Plan.

Public and municipal feedback made it clear that further work was required outside of San Francisco to develop a broadly supported local or regional plan. In response, ABAG and ESA conducted an additional round of municipal workshops and public meetings with Daly City and the City of Pacifica. While there was active engagement by the local governments and citizens, consensus on a specific plan of action was not aspired to. This document therefore provides information that can serve as a foundation for additional development of local and regional plans to mitigate coastal erosion hazards.

ES.2 REGIONAL SETTING AND PROCESSES

The 17-mile shore comprising the Plan (Figure ES-1) is called the San Francisco Littoral Cell (SFLC) because littoral sand transport, driven primarily by waves, extends uninterrupted along its entire length from the Golden Gate southward to Pedro Point. Besides the three afore-mentioned municipalities, the SFLC includes land owned by the National Park Service as part of the Golden Gate National Recreation Area as well as various State and City parks and other government-owned lands and easements. Within San Francisco Bay, another CRSMP is being developed by the San Francisco Bay Conservation and Development Commission (BCDC). There is interconnectedness of sediment transport between the two littoral cells. Because of variations in geography, wave exposure, and development within the SFLC, it was divided into 16 reaches for analysis (Figure ES–2).



Sources: ESA PWA (Figure, Reaches); NOAA (Maritime Limits, NMS); CDFG (Marine Protected Areas); USGS (Bathymetry).

NMS = National Marine Sanctuary

Bathymetry in ft NAVD88 (not shown below 100 ft)

Graben domain and Point San Pedro deposit locations estimated from CSMP (S. Johnson, pers. Comm).

Figure ES–2: Coastal reaches, potential sand sources, and potential receiver sites.

Coastal development invariably changes the local ecology by altering and degrading habitat, often at the expense of protected species of plants and animals. In addition to sandy beaches, coastal habitats in the SFLC include dunes and sandy bluffs, rocky subtidal, outcrops and bluffs, landslide areas, creeks, lagoons, wetland, grassland, and seasonal wetland. Known sensitive species of animals include steelhead, California red-legged frog, San Francisco garter snake, leatherback sea turtle, bank swallow, western snowy plover, and an array of marine mammals. Known sensitive species of plants include beach saltbush, beach wildrye, Pacific wildrye, mock-heather, silvery beach-pea, dune annual forbs (multiple), dune tansy, perennial wetland species (multiple), and scrub forbs (multiple).

Although the shore is considered important to many residents, there are only limited data available to assess beach use. The compiled of list beach amenities and associated economic metrics is based on limited, and in some cases obsolete, data (e.g., Pacifica only started charging for parking at Linda Mar beach in 2014). These data show that the study area is heavily visited, generating at least $60 million annually in spending by residents and tourists. These metrics, which are traditional in nature, do not attempt to assess the values associated with, for example, ecology and housing that are important to these communities.

ES.3 COASTAL EROSION HAZARDS

Shore erosion rates were computed for the study reaches (Figure ES–3)**.** Shore reaches at the northern end of the littoral cell include relatively slowly eroding bluffs (Point Lobos) and receding or stable shores (China Beach and Baker Beach). North Ocean Beach (NOB) has become wider over time because of sand accumulation (accretion). All of the beaches South of Middle Ocean Beach (MOB) show net erosion with narrowing over time. These beaches are eroding between one and two feet per year averaged over the longer term and across each shore reach. Additional information can be found in ESA PWA (2012)[1].

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[1] ESA PWA 2012. Technical Memorandum #1: Preliminary Implementation Options for CRSMP Reaches, 13 pp.

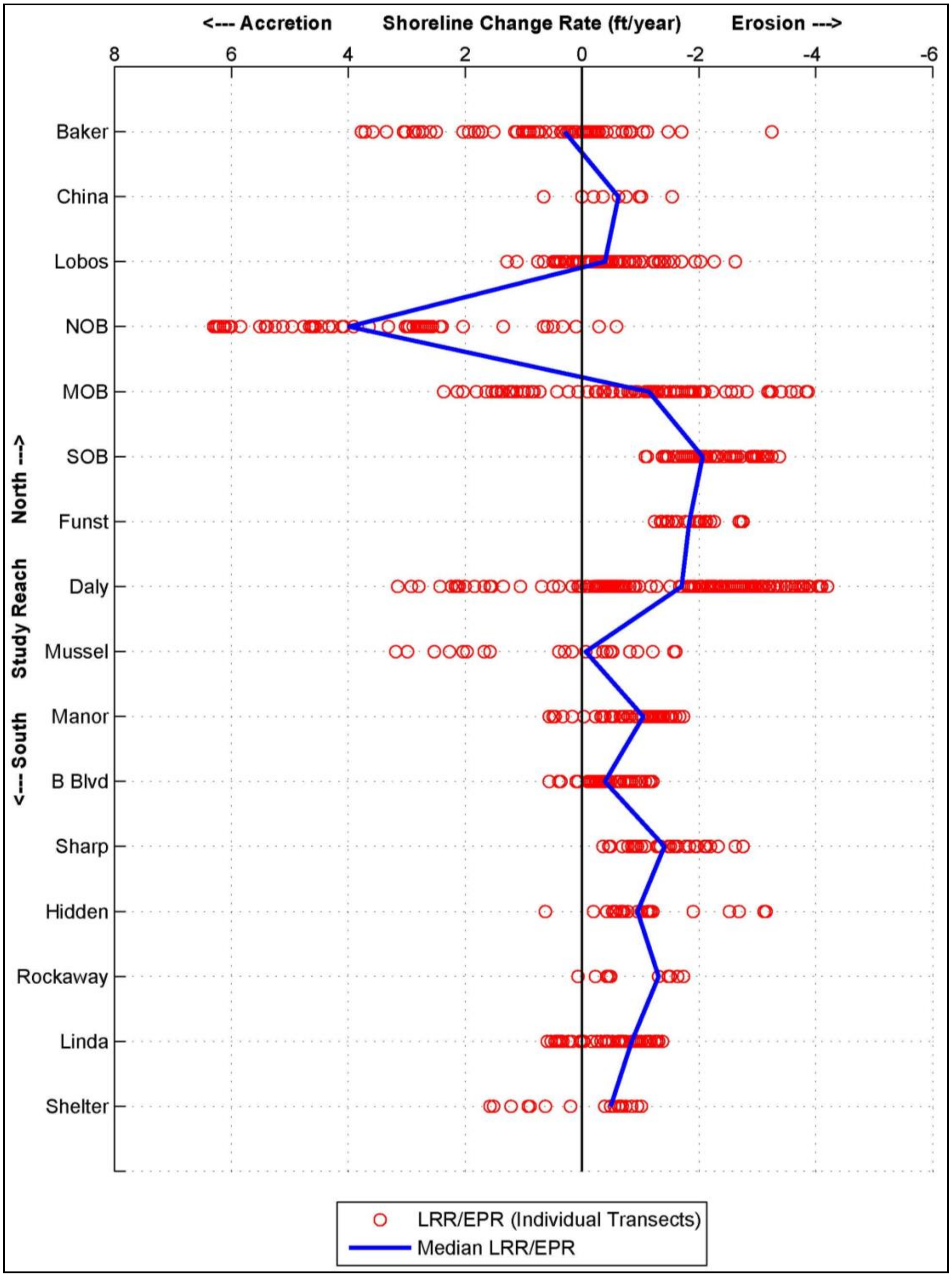

Figure ES–3: Shoreline Change Rates by Reach. Linear Regression Rates (LRR) and End Point Rates (EPR) for cross-shore transects constructed from the Digital Shoreline Analysis System (DSAS).

Sea level rise is expected to exacerbate shoreline retreat by shifting the wave impact zone upward and toward land. Recent State and Federal guidance has resulted in a range of sea level rise projections, with high estimates about 1.5 meters (about 5 feet) by the year 2100. For this study, the high sea level rise curve was used with a rise of 0.5 meters (1.5 feet) by 2050 and 1.5 meters (5.0 feet) by 2100. These values are higher than the subsequently published State projection of 0.3 meters (0.9 feet) and 0.9 meters (3.0 feet), respectively, but within the recommended ranges.

Based on simplified beach-slope geometrics, sea level rise could potentially cause landward shore migration – without a notable decrease in beach width – on the order of 50 to 100 times the vertical change in sea level. For Ocean Beach, this distance was estimated to be about 300 feet for a 5-foot rise (SPUR, 2012)[2]. Within most reaches of the SFLC, the actual landward migration, however, is expected to be impeded by bluffs and backshore armoring, resulting in a reduction of beach width and increase in flood elevation (wave runup) at the backshore.

Approximately one third of the entire SFLC has substantive backshore armoring intended to mitigate coastal erosion. Armored shores, however, were still considered at risk if backshore assets were within zones of projected potential erosion and flooding, and if future beach widths were expected to be limited. Of the 16 shore reaches in the study area, nine are characterized as “Critical Erosion Hotspots” where coastal erosion is expected to damage assets, with significant assets at risk[3]. The ecology of most of the Critical Erosion Hotspots is degraded relative to historic conditions, but some protected species and habitats remain.

ES.4 EROSION MITIGATION ALTERNATIVES

Future conditions at the nine Critical Erosion Hotspots depend on both sea level rise and adaption choices. For example, armoring typically is designed to protect the backshore but does not prevent beach narrowing. This Plan analyzed the potential for sand placement to maintain beaches and mitigate hazards to backshore property and development. Offshore rock reefs were also considered as a means of reducing wave exposure and extending the width and life of sandy beaches. In addition to the sand placement with and without offshore reefs, “bookend” approaches of complete armoring[4] and retreat[5] were also considered. The shore response for each erosion mitigation alternative was then approximately modeled in terms of beach width and potential backshore damages through years 2050 and 2100.

The selected erosion mitigation alternatives are not all-inclusive but do provide a range of choices within the “solution space” formed by no action, soft treatments (e.g. placing sand) and hard treatments (e.g. coastal armoring), as conceptually indicated in Figure ES-4. It should be noted that the sea level rise assumed to occur by 2050, 1.5 feet, is a moderate-to-high estimate within ranges recommended by the State of California by 2050, and at the low end of the estimates by 2100[6].

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[2] SPUR, 2012; San Francisco Planning + Urban Research Association, Ocean Beach Master Plan, with assistance by AECOM, ESA PWA, Nelson\Nygaard, Sherwood Design Engineers and Phil Kink, PhD, May, 2012. http://issuu.com/oceanbeachmasterplan/docs/obmp_document_full/11#

[3] The significance threshold for assets at risk is a judgment call: Qualitatively, extensive private development and municipal infrastructure clustered in a projected erosion hazard zone was considered “significant”.

[4] “Shore erosion control practices using hardened structures that armor and stabilize the shoreline landward of the structure from further erosion.” Source: Shoreline Management Types Definitions, NOAA, Revised October 22, 2007; http://coastalmanagement.noaa.gov/initiatives/definitions.html

[5] “Managed retreat (relocation of structures and utilities)”….a type of Policy and Planning Technique: “Shore erosion control strategies that do not physically alter the shoreline, but instead regulate human uses near or on the shoreline. Often policy and planning techniques are used as a preventative measure to avoid the need for physical shoreline stabilization, or in response to shoreline erosion when physical shoreline stabilization could be costly, ineffective or undesirable.” Source: Shoreline Management Types Definitions, NOAA, Revised October 22, 2007; http://coastalmanagement.noaa.gov/initiatives/definitions.html

[6] The NAS, 2012 report indicates a potential range of 1.0 to 2.0 feet by 2050 and 1.4 to 5.5 feet by 2100 (Table 5).

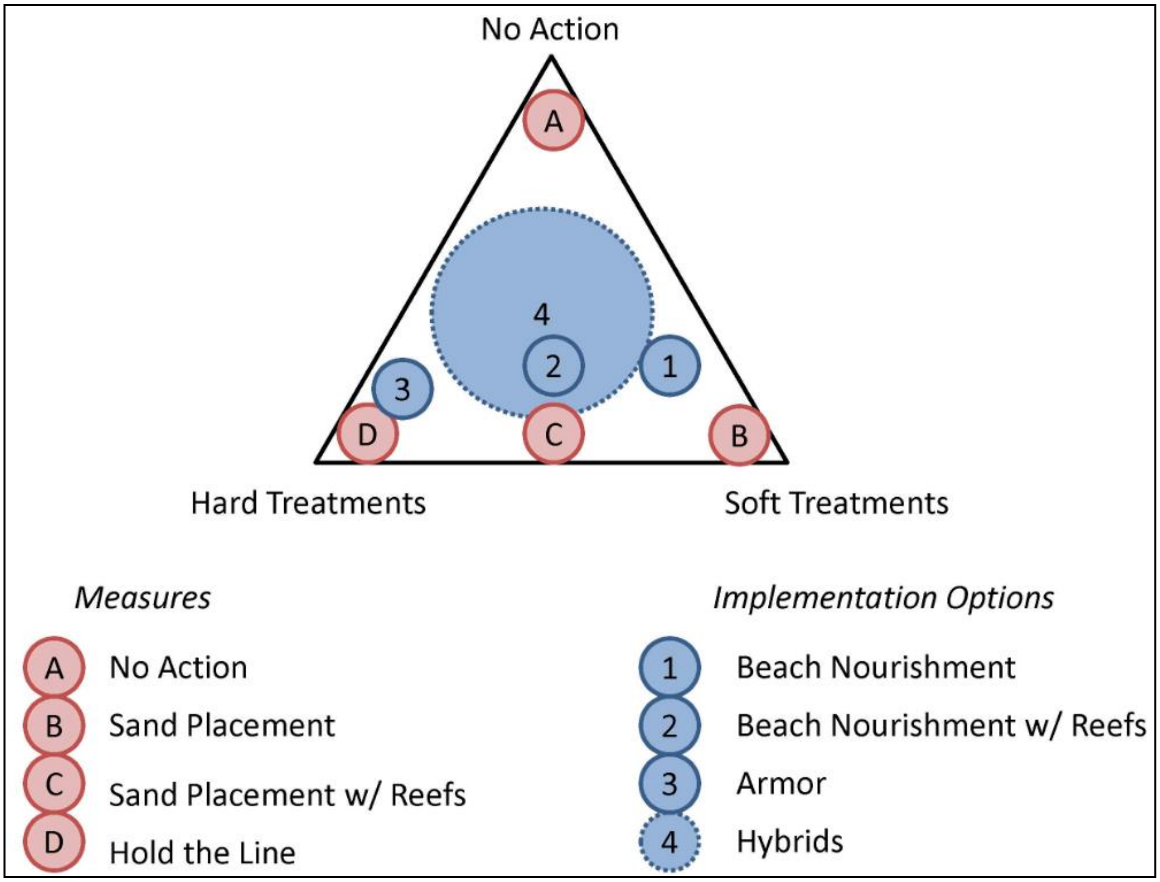

Figure ES–4: Conceptual Solution Space

The Plan's analyses predict that sand placement will result in wider beaches but not provide complete wave dissipation and protection of the backshore. This is partly because of the large volume of sand needed to widen and maintain these beaches. A range of sand placement volumes should be analyzed in future studies to see if larger volumes may be beneficial. The offshore rock reefs provided benefits but were very costly. Further analysis may conclude that lower costs or other structural approaches are more effective in trapping sand. Other sand-retention structures were beyond the scope of this study. Hybrid approaches performed relatively better in many cases, indicating the "all of the above" strategy employed by the Ocean Beach Master Plan (OBMP) may have value for Pacifica and Daly City as well. In all cases, the net economic benefits are computed to be negative or small, while economic activity was positive.

ES.5 ECONOMIC ANALYSIS OF ALTERNATIVES

An economic analysis of the various erosion mitigation scenarios was prepared as part of this Plan. The analysis looked at both costs (e.g., construction, damages) and benefits (e.g., beach recreation, avoidance of storm damages) through the year 2050. The economic analysis of recreation, which is based on estimated beach visits, includes benefits (i.e., what is the value of a beach day) and impacts (i.e., how much money is spent and what tax revenues are generated). Although widely used and accepted, it is not clear whether this model properly assesses the value of Northern California beaches, which have fewer visitors than warmer areas such as Southern California. For example, the dollar valuation of beach ecology is not sufficiently known to incorporate into the economic analysis. This potential to "undervalue" natural resources such as beach ecology is inherent in traditional economic analysis and can be significant (ESA PWA, 2012)[7]. This study does estimate the beach width over time for each scenario, and beach width could be used as an indicator of beach ecology, with very narrow beaches likely having degraded ecological functions. The results of the economic analysis are summarized in terms of Net Economic Benefits (Tables ES-1) and Economic Impact (Table ES-2) for each shore reach and erosion mitigation scenario "option".

Net Economic Benefits are defined as the avoided costs of erosion damages to property and infrastructure as well as the change in recreational value, which may be positive or negative. Where appropriate, the costs of mitigation (e.g., beach nourishment and shore armoring) have also been incorporated into the analysis. Net Economic Benefits are typically negative on these eroding shores, especially where beaches are already narrow or recreation is not extensive (Table ES-1). Net benefits are estimated to be about -$60 to -$100 million in San Francisco, -$200 to -$380 million in Daly City, and -$170 to -$280 million in Pacifica, in present value (2013 dollars) for the period 2013 through 2050. These large negative values indicate that these areas are at risk to erosion, which is why this Plan focuses on them. Small positive net benefits were computed for the hybrid options at Sharp Park and Linda Mar reaches of Pacifica. Positive values at these locations are attributed to relatively wide beaches and the low cost of the hybrid options.

Economic Impact is defined as the economic revenue generated to the community via expenditures associated with the shore use and associated local tax revenues. Economic activity is positive in all locations with the exception of the Daly City shore where the limited beach use data results in zero economic activity (Table ES-2). Given the limited beach use data, it is possible that actual economic activity associated with beach use is greater or lower. Economic impact is estimated to be $150 to $180 million in San Francisco, $10 to $17 million in Daly City, and $220 to $420 million in Pacifica in present value (2013 dollars) for the period 2013 through 2050. These values are only for the reaches with erosion hazards, and not for all the beaches in the study area. These economic impact estimates exceed the net economic benefits values in San Francisco and Pacifica, but not in Daly City. It is possible, however, that access improvements at the Daly City Reach 3 could increase beach use and provide other benefits sufficient to justify the net benefits of -$15 to -$21 million estimated for this reach.

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[7] ESA PWA, 2012; Evaluation of Erosion Mitigation Measures for Southern Monterey Bay, Prepared for the Monterey Bay Marine Sanctuary and the Southern Monterey Bay Coastal Erosion Working Group, with assistance from Dr. Ed Thornton, Meg Caldwell, J.D., Dr. Philip King, Aaron McGregor, May, 2012. http://montereybay.noaa.gov/new/2012/erosion.pdf

Table ES-1: Summary of Net Economic Benefits by reach ($Millions)*

		Scenario Alternatives					
		(1)	(2)	(3)	(4)		
Reach	No Action[a]	Sand Placement	Sand Placement with Artificial Reefs	Hold the Line[b]	Hybrid[c]	Options in Hybrid	Net Benefit Range
				San Francisco			-$60M to -$130M
China	●						
Pt. Lobos	●						
North Ocean Beach	●						
Middle Ocean Beach		-$27.6[d]			-$15.4	Maintain existing seawall; Allow erosion elsewhere	
South Ocean Beach		-$46.9[d]	-$105.0				
Ft. Funston	●						
Daly City (3 sections, north to south)							-$200M to -$380M
1. Upper	●						
2. Middle		-$296.0	-$359.0		-$189.0	No Action	
3. Lower (Landfill)				-$14.9	-$21.0	Managed Retreat	
Pacifica							-$170M to -$280M
Manor District		-$101.0	-$124.0	-$93.8	-$93.8	Maintain existing armoring at selected locations Place sand and allow erosion elsewhere	
Beach Blvd		-$71.1	-$94.6	-$55.8	-$70.8	Maintain existing armoring at selected locations Place sand and allow erosion elsewhere	
Sharp Park		-$40.1	-$36.5	-$25.7	$2.80	No Action, Allow Erosion	
Hidden Cove	●						
Rockaway Cove		-$17.9			-$10.8	Maintain existing armoring; Allow erosion elsewhere	
Linda Mar		-$1.03			$6.70	No Action, Allow Erosion	
Shelter Cove	●						

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*-- Net Economic Benefits are beach-use recreational benefits, minus costs (erosion damages to property and infrastructure, and the cost to implement erosion mitigation measures such as sand placement), for the period 2013 through 2050, in Present Value 2013 dollars.

a – No Action: Allow natural processes without intervention or Not Analyzed because erosion hazards considered low

b – Hold the Line: Maintain existing shore armor, such as sea walls revetments, and add additional armoring as needed.

c – A mix of two or more measures, such as maintain existing armoring and allow erosion elsewhere, with sand placement. Also included “no action” and “managed retreat” measures.

d – Includes managed retreat and armoring elements, consistent with the OBMP, by others.

Table ES-2: Summary of Economic Impact by reach and Alternative ($Millions)*

	Scenario Alternatives						
		(1)	(2)	(3)	(4)		
Reach	No Action[a]	Sand Placement	Sand Placement with Artificial Reefs	Hold the Line[b]	Hybrid[c]	Options in Hybrid	Impact Range
San Francisco							**$150M to $180M**
China	●						
Pt. Lobos	●						
North Ocean Beach	●						
Middle Ocean Beach		$141.0[d]			$107.0	Maintain existing seawall; Allow erosion elsewhere	
South Ocean Beach		$40.4[d]	$40.8				
Ft. Funston	●						
Daly City (3 sections, north to south)							**$10M to $17M**
1. Upper	●						
2. Middle		$17.3	$17.3		$10.1	No Action	
3. Lower (Landfill)				$0	$0	Managed Retreat	
Pacifica							**$220M to $420M**
Manor District		$10.3	$10.3	$4.18	$10.3	Maintain existing armoring at selected locations Place sand and allow erosion elsewhere	
Beach Blvd		$57.5	$62.8	$18.7	$57.5	Maintain existing armoring at selected locations Place sand and allow erosion elsewhere	
Sharp Park		$55.5	$55.4	$31.6	$22.2	No Action, Allow Erosion	
Hidden Cove	●						
Rockaway Cove		$100.0			$41.2	Maintain existing armoring; Allow erosion elsewhere	
Linda Mar		$194.0			$132.0	No Action, Allow Erosion	
Shelter Cove	●						

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*-- Economic Impact is the sum of economic activity (local purchases) and tax revenues, for the period 2013 through 2050, in Present Value 2013 dollars.
a – No Action: Allow natural processes without intervention or Not Analyzed because erosion hazards considered low
b – Hold the Line: Maintain existing shore armor, such as sea walls revetments, and add additional armoring as needed.
c – A mix of two or more measures, such as maintain existing armoring and allow erosion elsewhere, with sand placement. Also included “no action” and “managed retreat” measures.
d – Includes managed retreat and armoring elements, consistent with the OBMP, by others.

This analysis does not include all valuations, in particular ecological considerations that may lead to actions to mitigate erosion and sustain beaches. Thus these economic estimates should be considered conservative (low) indicators of the potential for a community to economically or otherwise justify improvements to their shores. Lower rates of sea level rise would delay damages and hence significantly reduce the present value of these costs. These estimates assume that the assets at risk do not change over time. Development and additional infrastructure would increase potential assets at risk. On the other hand, there may be other benefits that are associated with the full range of potential actions not considered in this study.

ES.6 BIOLOGICAL ASSESSMENT OF ALTERNATIVES

Beach enhancement should provide ecological benefits, although the existing protected species and habitats will likely place constraints on coastal construction activities. This biological assessment provides a general indication of impacts and benefits of the array of erosion mitigation measures, but any future project will require a project-specific environmental assessment before approval.

Sand placement can be beneficial by creating and maintaining wider beaches for a period of time, as long as ecologic recovery occurs. Construction activities such as coastal armoring and sand placement generally have an immediate negative impact to ecology during construction, after which habitat recovery generally takes place. Backshore retreat over time can provide space for a beach to migrate in response to sea level rise. Conceptually, a wider beach that is infrequently disturbed by construction activity is considered more likely to have a vibrant ecology. Rock reefs used to enhance sand placement by reducing sand transport away from placement locations would be incrementally beneficial in terms of sustained beach and reduced sand placement frequency.

The footprint for backshore armoring with rock revetments and seawalls tends to reduce beach width. The impact to ocean ecology is negative in terms of the loss of benthic habitat in the structure footprint, although positive effects may be realized in terms of increased rocky habitat. Over time, armoring can result in progressive beach loss by preventing landward migration of the shore. Conceptually, the beach can be “squeezed” between the migrating shoreline and the backshore armor, and “drowned” by rising sea levels. Hence, shore armoring has the potential to directly and progressively degrade beach ecology.

ES.7 GOVERNANCE

Generally, “governance” refers to processes of interaction and decision-making among relevant entities involved in a collective problem or goal. In the context of this Plan, a governance structure will provide a framework for decision-making by local, regional, state, and federal entities on actions and activities relevant to regional sediment management and coastal restoration in or affecting the San Francisco Littoral Cell. The governance structure will also provide opportunities for citizens to provide input and will maintain accountability to the public and transparency in decision-making.

Governance is particularly relevant for CRSMPs because of the regional nature of sediment transport, and consequently the need to manage sediment from a regional perspective. Sediment does not stay within existing jurisdictional boundaries, and therefore a new structure must be identified to ensure efficient coordination and use of funding and staff resources, and to clarity roles and responsibilities regarding regional-level decision-making among municipalities and agencies with coastal jurisdiction. A clear governance structure will support information sharing; collaboration on studies and projects; education, outreach, and engagement of stakeholders and the interested public; sharing of resources and efforts to pursue and secure funding; keeping the SFLC CRSMP updated and relevant, and transparency and accountability around region-wide decision-making.

Effective governance will also help ensure that the potential benefits of the SFLC CRSMP are better realized. These benefits include protecting habitat, buildings and infrastructure, improving and maintaining safety of public access, operating with efficiencies of scale, access to more funding, coordinated stakeholder engagement, and informing other planning efforts (e.g., Local Coastal Programs, Master Plans).

The uniqueness of the physical features, coastal development patterns, and geopolitical structures of the SFLC region requires development of an individualized approach to sediment management that best meets the needs of local jurisdictions and agencies in addressing a diverse and specific set of issues spread throughout the littoral cell. Because of the complexities involved with the SFLC region and the lack of an obvious governance structure model and lead agency, this Plan has identified a range of potential governance options. Additional discussions among local jurisdictions, agencies, and other stakeholders in a collaborative context will be needed to inform an eventual decision by stakeholders on the most appropriate governance structure for the region.

Several options exist for governance of coastal regional sediment management in the SFLC. The options are generally organized from lesser to more intensive approaches relative to effort, complexity, and resources required.

1. Status quo
2. Coordinating Network
3. Existing Jurisdiction(s) as the Lead CRSMP Agency
4. Special District, including Geologic Hazard Assessment District
5. Joint Powers Authority

Preliminary recommendations for a governance structure for the SFLC CRSMP, as well as other analyses in this Section, should be discussed further by relevant local jurisdictions and agencies. These discussions should examine the governance options identified in this Plan, and participants should be invited to assess the different options against how well they achieve the intended purposes of governance and keys to success described above.

Additional recommendations will be informed by comments received during public review of this Plan.

Preliminary recommendations include:

- If there are concerns about resource commitments, creating a Coordinating Network may be a good first step in advancing governance and coordination for sediment management in the SFLC (this would be formalized through a cooperative agreement [MOU or MOA] between relevant local jurisdictions and agencies). The Coordinating Network could be used as a test case to better understand the governance requirements around sediment management in the SFLC and to assess periodically whether a more formal governance structure is needed.
- To the greatest extent possible, governance for the SFLC CRSMP should be closely linked or coordinated with governance of other relevant structures – especially those established to support: 1) the San Mateo County Sea Level Rise Vulnerability Assessment, 2)

implementation of the Ocean Beach Master Plan in San Francisco, and 3) the Bayside CRSMP being led by the San Francisco Bay Conservation and Development Commission.

- Because the cities of Pacifica and Daly City have limited staff and funding resources to support sediment management activities, consider having the Counties of San Mateo and San Francisco (along with relevant federal and state agencies such as GGNRA, as appropriate) serve as eventual lead agencies in a governance structure. The roles and responsibilities of the involved jurisdictions and agencies could be established in the MOU/MOA to account for these resource constraints and make it easier for Pacifica and Daly City to participate.
- A hybrid structure involving a Coordinating Network and a lead agency or agencies may be a good way to address a situation where some local jurisdictions and agencies have more resources and capacity than others, but where all may want to be involved.

ES.8 CONCLUSIONS, DATA GAPS, AND RECOMMENDATIONS

There are significant data gaps that hamper the evaluation of future shore conditions and adaptation planning. In particular, sediment transport in Pacifica and Daly City has not been studied in sufficient detail. Basic unknowns are beach thickness (depth to rock or hardpan), extent of beach-sized sand deposits offshore, and sand transport rates. As an example of a data gap, Figure ES-3 shows the limited information presently available about sand sources directly offshore of sand placement sites identified in Pacifica. Grain sizes of the offshore sand sources, which are a strong indicator of compatibility with existing beaches, are not known except in the vicinity of San Francisco. Also, publically available economic data are limited, which limits understanding of costs and benefits associated with coastal erosion and beaches.

With the exception of Ocean Beach where the OBMP is under development and implementation, there are a range of views, and no clear consensus, on what a desirable adaptation strategy would consist of. These communities face tough choices that will affect built assets, property, ecology, and recreation. Regardless of the actions taken, the projected costs are estimated to be on the order of multiple hundreds of millions of dollars in each community over the next 50 to 100 years (Table ES-1). We therefore recommend continued work toward a better understanding of coastal processes, economic and social considerations, and development of adaptation strategies. This will require effective public engagement and governance. Additional funding and guidance from the state and federal governments will be extremely helpful if not required. In addition, this study finds significant economic activity associated with the local beaches, also on the order of $100 million in San Francisco and Pacifica, and on the order of $10 million in Daly City, in terms of present value for the study time period of 2013 to 2050 (Table ES-2).

The City and County of San Francisco, which has partnered with the National Park Service, is farther along with a comprehensive adaptation strategy – the OBMP – that includes a range of actions (e.g., sand placement, managed retreat, highway realignment, armoring). Daly City and Pacifica have not yet developed comprehensive adaptation strategies. Therefore, we recommend additional funding for focused studies in those cities.

ES.9 FUNDING CREDIT AND DISCLAIMERS

The USACE provided funding for ESA PWA, and ABAG was funded by Department of Boating and Waterways (DBW: now a Division within State Parks) as part of the CSMW's efforts to complete a SMP for the entire California Coast. The study leaders (ESA and ABAG) have utilized the funding to develop findings and recommendations that are in accord with local issues and needs, and CSMW has participated in an advisory and oversight role to help maintain consistency with similar projects elsewhere in coastal California.

Recommendations are presented in this report for consideration by government agencies, organizations, and committees involved in the management and protection of coastal resources in the study area as well as to inform the local citizenry of the state of their coast. This document was prepared with significant input from CSMW members but does not necessarily represent the official position of any CSMW member agency.

This CRSM Plan does not preclude the study and implementation of other erosion control alternatives – e.g., perched beaches, groins, dynamic revetments, breakwaters, submerged breakwaters, headland enhancement, – nor does ABAG or other Joint Powers Agreement Authority presently have any jurisdiction over these intervention measures.

CHAPTER 1. INTRODUCTION

The Pacific coastline of San Francisco and northern San Mateo Counties – the SFLC (Figure 1) – experiences periodic severe coastal erosion from terrestrial and marine processes, placing shoreline ecosystems and 150 years of coastal development at risk. Because an integrated approach to ameliorate future erosion is critical to maximizing the use of limited funds, a CRSMP (Plan) will greatly benefit the coastal communities of the SFLC – San Francisco, Daly City, and Pacifica – by:

- Developing a suite of solutions to beach erosion affecting infrastructure, recreation, public safety, public coastal access, and habitat
- Evaluating effects of sea level rise
- Building partnerships between local and regional bodies to develop regional management of sediment resources and establish a process to address beach erosion

Furthermore, acceptance of the CRSMP will facilitate the completion of the statewide sediment management strategy of the CSMW.

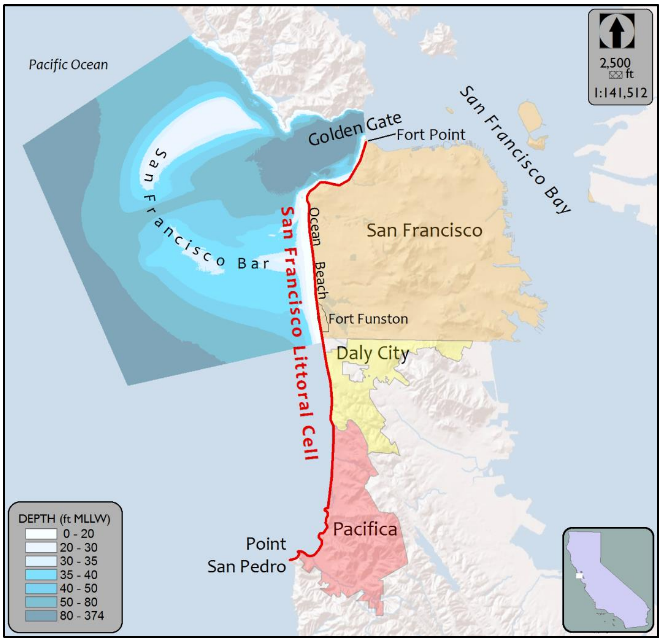


Figure 1: San Francisco Littoral Cell – the deepest point is at the Golden Gate (~370 ft).

Separately, those cities have addressed coastal erosion through different and disconnected strategies. State and federal landowners in the region have historically pursued disparate approaches. The development of the OBMP in San Francisco in 2012 unified many entities behind a shared vision among local, state, and federal stakeholders. The CRSMP expands on the process used in the OBMP by engaging with many of the same groups and adding the cities to the south.

Along the California Coast, beaches undergo seasonal cycles. Generally, they are the widest and highest in elevation in the summertime and the narrowest and lowest in elevation in the winter. Coastal longshore currents tend to transport sand downdrift but also to import new sand from updrift. Imbalances can cause beach width changes; winter spring conditions typically move sand offshore while summer and fall conditions move it onshore, contributing to the seasonality of the beach widths. Shores therefore tend to migrate, and landward migration of the shoreline, herein called "recession", signifies erosion of the beach face. Consequently, the backshore narrows and often disappears, leaving coastal dunes and bluffs at risk, especially under changing sediment supply conditions. Over time, receding shores threaten, and eventually damage coastal infrastructure. When critical infrastructure and coastal development sit atop a coastal bluff or extend into the beach, recession can place both humans and ecosystems at risk. Sea level rise will increase the speed of shore recession. In the SFLC, tectonics also plays a significant role in causing erosion though landslides, earthquakes, uplift, and oversteepening of bluffs. As a result of these processes, much of the backshore along the SFLC coastline is eroding, and erosion is expected to continue. Armoring has been constructed along many stretches of SFLC coast, preventing or slowing erosion of the back beach. Those structures result in a narrowing of the beach as well as passive erosion adjacent to the hardened surface. Therefore, shoreline management is potentially beneficial along the SFLC shoreline to slow further degradation of sandy beach habitat from hard structures, limit bluff failure, and minimize the loss of life and public and private property throughout the region.

Substantial amounts of sand were added to the Ocean Beach shore in the period from 1900 to 1930 from sand dunes and since the 1970s from nearshore placement of sand dredged from the navigation channel through the San Francisco Bar (Battalio, et al, 1996; Battalio, 2014). Conversely, disruption of sand movement to the region's beaches has occurred over that same time period because of the

- Proliferation of hard structures (e.g., seawalls) that prevent bluff sand from being deposited on the beach,
- Implementation of flood control and other infrastructure throughout the coastal watersheds that reduces supply of sand from rivers,
- Construction of Highway 1 in the 1930s and other coastal roads in the such as the Great Highway along Ocean Beach in the early 1900s, and
- Dense urbanization in the coastal zone.

Data are needed to quantify how much sand is required to maintain viable beaches for recreation and bluff protection. In that regard, there are abundant data for the San Francisco coast and nearshore, but a paucity of data for the Daly City-Pacifica coast and nearshore. For example, there are many studies of erosion troubles along Ocean Beach but few for the coast further south despite visible examples of erosion at residential complexes in Pacifica and below entire neighborhoods in Daly City.

The littoral cell is a sandy reach of the coast that contains its own sediment sources and sinks (Table 1) and is isolated sedimentologically from adjacent coastal reaches. Isolation is typically caused by protruding headlands, submarine canyons, inlets, and some river mouths that limit littoral sediment from one cell to pass into the next. Over the long term, if more sand enters the cell than leaves it, beaches accrete; if less enters, they erode. In California, littoral cells were first described by Inman and Frautschy (1965) for portions of southern California and expanded to the entire state by Habel and Armstrong (1977). Human actions can change the amount of sediment entering a littoral cell by altering delivery by rivers and coastal bluffs through dams or coastal armor (Figure 2). Sand transport can also be affected by structures that interrupt natural pathways in the nearshore environment, and degrade ecology and recreation. An alternative to the existing sediment management approach is to actively address erosion-prone locations from a system-level, or regional, perspective. The two most important elements of a regional approach include reconnecting natural sand pathways from upland sources and coastal bluffs to the beach and moving dredged sand trapped by harbors and coastal structures to locations in need (Figure 3). Through these changes, more sustainable processes can be restored to a littoral cell that has been heavily affected by human activity. This Plan is a comprehensive guidance document that presents coastal regional sediment management in an expeditious, cost-effective, and resource-protective manner for the SFLC.

Table 1: Primary littoral cell sand sources and sinks (Patsch and Griggs, 2007)

SAND SOURCES	SAND SINKS	BALANCE
Longshore Transport in	Longshore Transport out	Accretion
River Inputs	Offshore Transport	Erosion
Sea Cliff or Bluff Erosion	Dune Growth	Equilibrium
Gully Erosion	Sand Mining	
Onshore Transport	Submarine Canyons	
Dune Erosion		
Beach Nourishment		

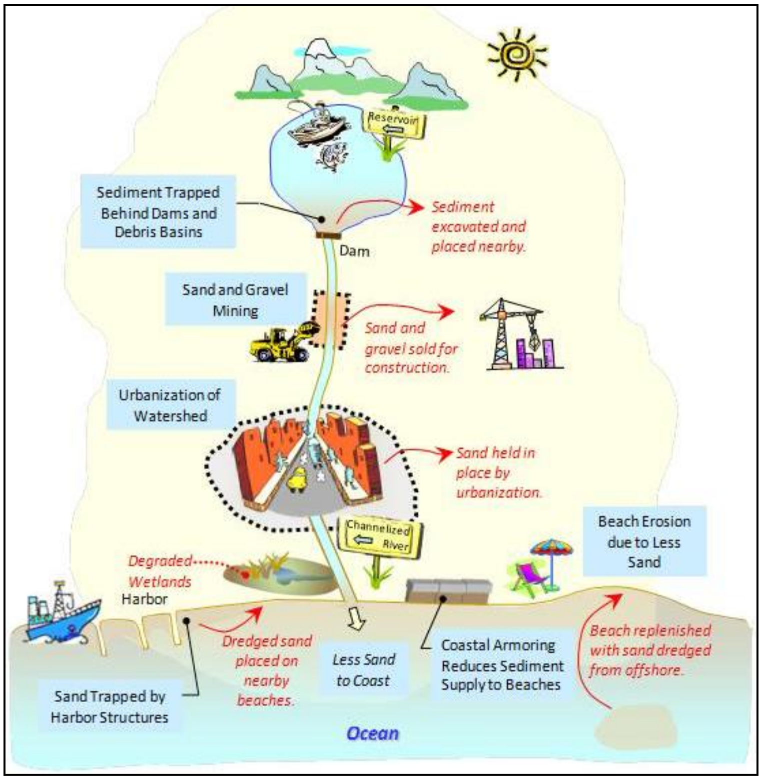


Figure 2: Existing Sediment Management

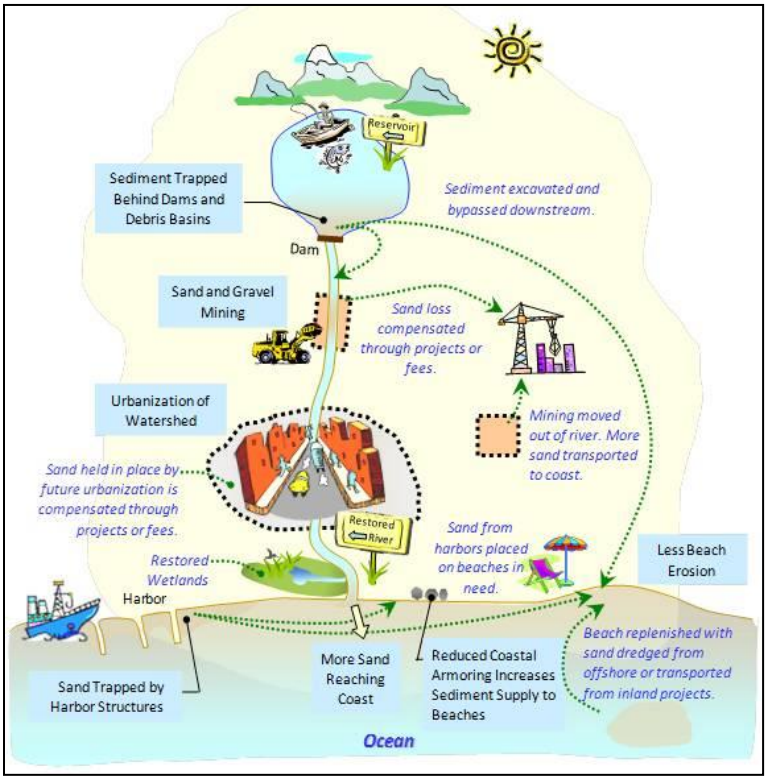


Figure 3: Desirable Sediment Management

1.1 BACKGROUND

1.1.1 Coastal Processes Summary

The SFLC coastal zone is especially dynamic because of complex interactions of the semi-diurnal tidal pulses into and out of San Francisco Bay and waves generated both in the open Pacific Ocean (long-period swell) and locally (wind waves). Those forces are responsible for sediment transport, the resultant patterns of beach accretion and erosion, and periodic bluff retreat. Evidence of these interactions is seen along the shores of Ocean Beach as well as the northern shoreline of San Francisco inside the Golden Gate. South of San Francisco, wave-driven processes increasingly dominate over tidal currents, although recent research by Barnard et al (2013) and by others indicates at least a sedimentological connection between the Bay and the beach sands at the south end of the littoral cell.

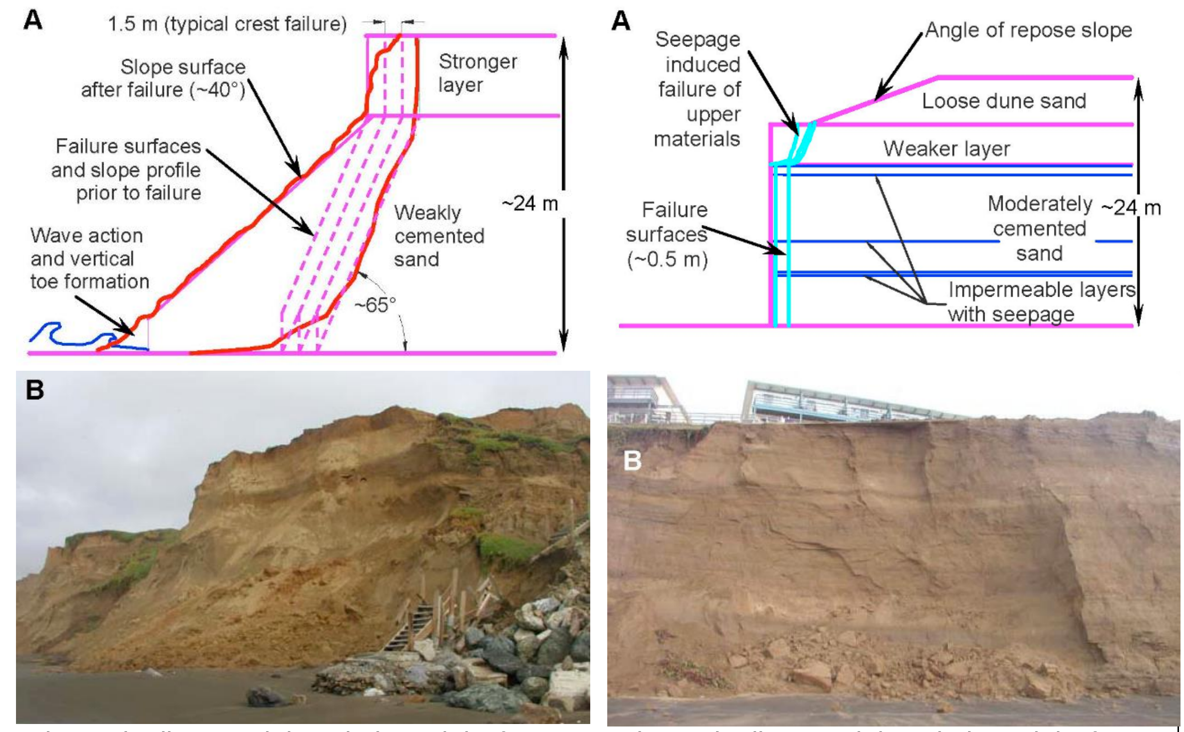
The most dramatic bathymetric features in the area are the 374-foot deep narrow channel through the Golden Gate and the San Francisco ebb tidal delta, also called the San Francisco Bar (Bar). Together, these features focus wave energy and tidal currents in a way that creates patterns of sediment movement spanning sub-monthly to multi-year timescales. For example, in 2008 ESA PWA (2011) identified a sand deposit of about 150,000 yd^3 just east of Fort Point (which is the northern boundary of the area addressed in this report) that was attributable to storms. Similar patterns of large-scale movement occur along Ocean Beach, but human manipulation of the shoreline since the latter part of the nineteenth century has changed how the coastal processes affect the coast. In particular, between 1915 and 1929 the placement of sand on Ocean Beach shifted the shoreline approximately 300 feet seaward of its 1899 position (Olmsted, 1979). The CSMW Beach Erosion Assessment Survey (2010) identified 0.6 miles of the southern portion of the beach as a severe erosion problem.

1.1.2 Regional Sediment Volume Changes and Sediment Budgets

During the past 150 years, the most significant changes to sediment delivery to the SFLC coastline include hydraulic mining in the Sierras, infilling of San Francisco Bay for development, elimination of most coastal watersheds' connection to the ocean, dredging of the Main Ship Channel (MSC) through the Bar and associated sand practices, and commercial mining of the bay sand shoals. Studies quantifying these changes extend back almost a century. For example, Gilbert (1917) estimated 1.11 billion yd^3 of sediment entered the bay from Gold Rush mining during the latter half of the 1800s. Over decades, the Gold Rush sediment became sorted by the currents and migrated out to the Pacific Ocean where some likely deposited in the nearshore on the Bar and surrounding areas (e.g., beaches). But much of the sediment may have deposited on the shelf beyond the zone of wave breaking. Countering this surge of sediment, the tidal prism and surface area of the bay were reduced by 10% and 66% respectively by the destruction of 95% of fringing tidal wetlands (Atwater et al, 1979; Conomos, 1979; Gilbert, 1917; Dallas and Barnard, 2011; Keller, 2009). Since its inception in the 1930s, commercial seabed sand mining has removed at least 70 million yd^3 of sand-sized and coarser material from Central Bay (Dallas and Barnard, 2011). That volume is in addition to 191 million yd^3 removed by navigation projects and other dredging (Barnard et al, 2012). Detailed estimates of sand transport rates and volumes can be found in other reports including Battalio & Trivedi (1996) and Battalio (2014).

The fluctuation of sediment exiting the bay to supply sand to local beaches has been exacerbated by changes to coastal watersheds and construction of protective structures in front of coastal bluffs. The volume of sediment delivered historically and currently has not been quantified because of a lack of data, but the construction of Highway 1 effectively shut down the direct pathways to the ocean in Pacifica, except via storm drain culverts, San Pedro Creek, and local drainages. Another source of coastal sediment is derived from landslides and collapse of the coastal bluffs in Daly City and Pacifica (Figure 4). Collins et al (2007) identified 52 failures in the weakly-cemented cliffs of Pacifica over a five-year period caused by wave action and precipitation (Figure 5). Although the volume of sediment was not quantified, over the decades, large and catastrophic slides have occurred during El Niños and tectonic movement. Once waves sort the sediment delivered by the landslides to the beaches, the fine-grained material moves offshore and the sand is transported along the coast to feed beaches. Humans have directly altered this process through the construction of revetments and seawalls along the San Francisco, Daly City, and Pacifica shorelines that choke off the input of sand to the beach.

Figure 4: Daly City Coastal Landslide



Schematic diagram (A) and photo (B) of weakly-cemented, coastal-cliff failure mode. The failure surface is typically inclined at 65° to the horizontal.

Schematic diagram (A) and photo (B) of moderately-cemented coastal cliff failure mode. The failure surface is typically near-vertical

Figure 5: Cliff-Failure Mechanisms, Pacifica Source: Collins et al, 2007

A third significant change to the regional sediment system involves annual dredging of the MSC by the USACE to ensure egress and ingress of all deep-draft vessels to the ports and refineries of San Francisco Bay. Until 1971, clean sand removed from the

MSC was dumped into the deep ocean, which permanently removed that sand from the region's littoral system. Since 1971 the sand has been placed southeast of the MSC atop the Bar. Since 2005 dredged sand has also been placed close to a southern stretch of Ocean Beach just offshore of an erosional hotspot (near Sloat Avenue). This hotspot is the result of a confluence of events: shoreline manipulation, changes to the sediment patterns, and coastal armoring to protect infrastructure. These dredging practices are the most direct intervention on offshore circulation patterns. Sand was also placed on Ocean Beach over the years, being taken from the large sand dunes and from excavations, but the volume of placed sand is much smaller than the excavated volumes. Battalio and Trivedi (1996) believe that sand placed atop the bar has effectively nourished Ocean Beach since the 1970s though other researchers question that assumption especially because annual USACE surveys of SF–8 show that sand is not dispersing as expected. More recent sand-transport research has emphasized other processes, such as shore rotation, at Ocean beach. Though the dominate drivers of shore change vary between studies, it is agreed the system has been disturbed by interventions. Further research is needed to better understand the impact of such interventions and sediment transport in the SFLC.

Given the changes to the natural sediment supply and pathways, response by the beaches has become increasingly visible in recent decades. As early as 1980, the San Francisco Clean Water Program designed plans for placing up to 400,000 yd^3 of sand at Ocean Beach. Subsequently, many studies by USACE, the USGS, academic institutions, and private consultants investigated the sand circulation to develop workable sediment budgets for nourishment activities. Battalio and Trivedi (1996) established transport rates of 100,000-270,000 yd^3/year onshore and northwards along Ocean Beach. Barnard et al (2012) found bathymetric accretion of more than 5 feet between 1956 and 2005 on the northern end of the beach and erosion of the same scale towards the southern end. The newly released OBMP calls for sustained nourishment activities as part of a comprehensive realignment of the infrastructure and recreational facilities.

In the southern portion of the littoral cell at Pacifica State Beach in Linda Mar Cove, a master plan was developed in 1990 to restore the beach as part of a flood-control renovation of San Pedro Creek. Because it was recognized that previous watershed modifications had negatively affected the beach, the Pacifica State Beach Master Plan focused on removal of infrastructure impeding natural processes (PWA, 2002). When completed in 2005, the restoration gained national attention for innovation and anticipated resilience to rising sea levels.

1.2 COORDINATION

Although the SFLC shoreline is only 17 miles long and only covers two county and three municipal jurisdictions, the sediment and erosion problems require a regional perspective. For example, at Ocean Beach the southern portion is eroding, while in recent years the northern portion has accreted hundreds of feet. Sediment that enters the nearshore from slides in Daly City supplies beaches in Pacifica with sand. The natural system is interlinked along the north-south axis of the coast and east-west with the San Francisco Bay.

Conversely, the political and management systems in place do not currently view the sediment pathways as linked. The three municipalities have not engaged in a joint planning approach. Federal landowner s, such as the National Park Service Golden Gate National Recreation Area (GGNRA), have worked with the individual cities on local projects when the need and funding has allowed. State landownership is limited, but resource-protection agencies have been engaged when appropriate to address habitat or development concerns. The Bay Conservation and Development Commission (BCDC) is the most active local sediment-management agency, but their jurisdiction does not extend outside of the Golden Gate. The San Francisco Planning and Urban Research Association (SPUR) has taken the lead role in development of the OBMP, raising the profile of non-governmental groups in the region's sediment management issues. All of the above groups and agencies plus many others (e.g., the CSMW, USACE, the California Coastal Commission [CCC]) must be brought together to establish basic parameters for sediment management on a regional level that acknowledges and leverages the interconnectedness of the natural system.

1.2.1 Challenges

The challenges facing the San Francisco Littoral Cell CRSMP fall into two categories – technical and political. Both are explored in more detail in this Plan. In summary, technical challenges encompass our knowledge and understanding of natural processes while political challenges relate to stakeholders actions, funding streams, and competing uses of the land and ocean specific to the littoral cell.

1.2.2 Goals and Objectives

The CSMW is developing a SMP for the entire California Coast whose goal is to evaluate California's coastal sediment management needs and promote regional, system-wide solutions. Completed CRSMPs, usually based on one or more of the littoral cell boundaries proposed by Habel and Armstrong (1978), will eventually be combined as the underpinnings of the SMP. To achieve uniformity across the regional plans and aid in future synthesis, the following objectives were established by the CSMW for each CRSMP:

- Strategizing to Restore and Maintain Coastal Beaches and Critical Erosion Hotspots
- Reducing the Proliferation of Protective Shoreline Structures
- Sustaining Recreation and Tourism
- Enhancing Public Safety and Access
- Restoring Coastal Sandy Habitats Through the Littoral Cell(s)
- Addressing Areas with Excessive Sediment

1.3 REPORT ORGANIZATION

This Plan is organized to first provide the geologic, geomorphic, and ecological framework of the region and identify erosion areas of concern. A variety of ideas to address erosion areas, called alternatives, is presented for consideration in future detailed feasibility studies by local and regional sponsors. Following the alternatives, the economics, policies, and governance relevant to sediment management in the region are explored. Concluding the Plan is a suite of monitoring recommendations and identified data gaps to encourage next steps.

1.4 DEFINITIONS

The following definitions have been adapted from the USACE Water and Water Resources Glossary (USACE 2015).

Backshore: The zone of the shore or beach lying between the foreshore and the coastline comprising the berm or berms and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

Beach: That portion of land and seabed above Mean Lower Low Water (MLLW) extending upwards to a boundary marked by a physical change of material or by permanent vegetation. Includes the foreshore and backshore.

Beach Profile: A cross-section through the beach perpendicular to the beach slope; it may include a dune face or sea wall and extends across the beach into the nearshore zone to the depth of closure.

Beach Sediment: Fine grained particles derived from rocks or biological materials that are suitable for placement at the coast to nourish the littoral zone. This material is assumed to possess a significant fraction of sand, upwards of 75%. In some instances, however, sediment with a sand fraction from 51% to 75% may also be suitable for beneficial use at the coast, depending on location.

Compatibility: When the range of grain sizes of a potential sand source lies within the range (envelope) of natural grain sizes existing at the receiver site.

Continental Shelf: The zone bordering a continent extending from the line of permanent immersion to the depth, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths of the ocean.

Depth of Closure: The water depth beyond which repetitive profile or topographic surveys (collected over several years) do not detect vertical sea bed changes, generally considered the seaward limit of littoral transport. The depth can be determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Note that this does not imply the lack of sediment motion beyond this depth.

Fine-grained Materials (or Fines): Clays and silts, passing the #200 soil grain size sieve, or less than 0.075 millimeters in diameter.

Foreshore: The beach face, the portion of the shore extending from the low-water line up to the limit of wave uprush at high tide.

Inshore (zone): In beach terminology, the zone of variable width extending from the low water line through the breaker zone (also the shoreface).

Less-than-Optimum Beach-Fill Material: Material that is not compatible in grain size with sand at the dry beach, but is compatible with material within the nearshore portion (between MLLW and the depth of closure) of the receiver site. The fines fraction should be within 10% of that contained within existing nearshore sediments that exist along a profile. Typically, the percent fines of the nearshore portion of a beach profile in California can range from 5% to 35%. Therefore, less-than-optimum beach fill material may contain between 15% and 45% fines.

Littoral Cell: A reach, or compartment, of the shoreline in which sediment transport is bounded. In theory, it has zero longshore sediment transport beyond its updrift and downdrift boundaries. It contains sediment sources (e.g., rivers, coastal bluffs), storage areas (beaches), and sinks (submarine canyons). Each cell is sedimentologically isolated from nearby coastlines.

Nearshore (Zone): An indefinite zone extending seaward from the shoreline well beyond the breaker zone. It is the inner part of the continental shelf.

Offshore (Zone): The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind. The sea bed is seaward of the depth of closure.

Opportunistic Sand: Surplus sand from various source materials, including upland construction, development projects, and flood control (e.g., dams, channels, and debris basins).

Optimum Beach Fill Material: Material compatible with the dry-beach portion of the beach profile. The fines fraction of the grain size of this material can be within 10% of that of the existing dry-beach sediments, which typically range from 0% to 5% fines. Therefore, optimum beach fill material may contain up to 15% fines.

Receiver Site: The entire related system of coastal environments that would receive opportunistic materials, including the beach, nearshore, and offshore regions.

Sand: Sediment particles, often largely composed of quartz, with a diameter of between 0.062 mm and 2 mm, generally classified as fine, medium, coarse or very coarse. Beach sand may sometimes be composed of organic sediments such as calcareous reef debris or shell fragments.

Shoreface: The narrow zone seaward from the low tide shoreline, covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions (also the inshore zone).

Shoreline: The intersection of the land with the water surface. The shoreline shown on charts represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is the mean high water line.

Upland Sediment: Surplus sandy material available for beach fill from sources located inland from the mean high tide line. They can constitute dry sources away from rivers and lakes, or wet sources at rivers and lakes.

CHAPTER 2. SCOPE OF WORK

A comprehensive CRSMP includes many topics – e.g., information on physical processes, geomorphology, ecology, economics, policy, and governance. Combining these elements requires several stages.

2.1 DATA COLLECTION AND COMPILATION

The project team collected existing data and other information from publicly available sources. This included compiling relevant coastal references and sediment information from pertinent sources such as the CSMW website, the SMP Coastal References Database, the CCC coastal armor database, USACE, and academic studies on coastal physical processes in the region. The ecology portion of the project relied on data from the GGNRA, historical T-sheets, NOAA, and relevant academic and agency studies. Economic data were acquired from cities and academic studies while policy information came from federal, state, and local jurisdictions. Erosion concern areas along the coast were identified and mapped with input from federal, state and local entities. Potential sediment sources were identified throughout the immediate area. Geospatial data was provided to CSMW in a GIS database along with a narrative for non-geospatial data.

2.2 PLAN FORMULATION

This Plan resulted from a series of agency and public workshops, analytical processing of geospatial data and geomorphic models, synthesis of historical ecological and economic information, and assessment of existing policy documents (or those in the process of being updated). After CSMW review, ideas to address erosion areas were refined to consider technical feasibilities, innovation, ecology, and agency and public interests. Four broad categories of alternatives were established that range from more traditional approaches to more self-sustainable creative solutions that benefit many stakeholder interests in the face of sea level rise. Sea level rise was incorporated into coastal erosion models that formed the basis of establishing hazard zones, threats to ecology and infrastructure, as well as understanding policies that may need revision to properly include sediment management as an adaptation tool. Funding future work was also explored by the project team by identifying potential local, regional, state, and federal funding streams to encourage the development of Plan elements.

2.3 CRSMP PREPARATION

The Plan was developed in three stages to maximize stakeholder participation. Engagement with the cities and resource management agencies was followed by a public review period. After each stage of review, the project team revised the Plan in consultation with the CSMW.

2.4 OUTREACH

As part of the project outreach, the project team conducted several meetings with a Stakeholder Advisory Group (SAG) and the public (Table 2). The SAG consisted of federal, state, regional, and local agencies; academics; and non-governmental groups to guide the project team through Plan development.

Table 2: Outreach in 2012

DATE	MEETING
March 28	CSMW and Stakeholder Advisory Group (SAG) #1
June 4	City of Pacifica staff
June 6	SAG #2
June 26	City of Daly City staff
July 12	Gulf of the Farallones National Marine Sanctuary (GFNMS)
July 16 and July 19	Public meeting #1 (San Francisco and Pacifica)
July 23	Golden Gate National Recreation Area (GGNRA)
November 14	Stakeholder and Public Workshop Pacifica

CHAPTER 3. REGIONAL SETTING AND PROCESSES

3.1 THE SAN FRANCISCO LITTORAL CELL AND PLAN FOOTPRINT

This Plan focuses on the SFLC (as defined by Habel and Armstrong [1978]) and environs. The cell, which is 17 miles long, starts at the Golden Gate, where it is adjacent to the Bolinas Littoral Cell, and extends south along the coastline of San Francisco and San Mateo Counties. The southern boundary has been defined as Pt. San Pedro in Pacifica. The cell is generally understood to be connected to San Francisco Bay, with sediment exchange extending into the Central Bay region north of Crissy Beach (ESA PWA, 2011).

The SFLC incorporates multiple jurisdictions – GGNRA, City and County of San Francisco, City of Daly City, City of Pacifica, and California State Parks (Thornton State Beach and Pacifica State Beach). The Plan's inland boundary is taken as approximately the upper reaches of coastal watersheds. On the marine side, the California State Lands Commission and CCC maintain jurisdiction for the State of California to three nautical miles offshore. As of this report, no federal land management agency claims oversight in the ocean zone, which is called the San Francisco-Pacifica Exclusionary Zone by NOAA.

The study shoreline was divided into 16 reaches (Table 3 and Figure 6) that are based on geographic, geomorphic, ecological, oceanographic, and political considerations including:

- Nearshore conditions (wave exposure, shore face geometry, bed conditions)
- Backshore conditions (land feature, such as dune or bluff)
- Alongshore conditions (between headlands).

Judgment was used to delimit the reaches while maintaining a practical number consistent with the scope of the study and available information.

Table 3: SHORE REACHES AND PHYSICAL CHARACTERISTICS

Reach			Wave Exposure	Beach Width	Backshore Type	Sand Content in Backshore	Geology	
#	name	Length (feet)	(qualitative intensity)	Range (feet)	Dune, bluff, cliff, armor	(qualitative amount)	Offshore[8]	Terrestrial[9]
1	Baker Beach	8,300	Moderate	0 - 210	Bluff	Low	Franciscan complex, Quaternary sands	northern half: serpentinite, Franciscan chert southern half: beach and dune sand, Franciscan sedimentary, alluvium
2	China Beach	1,100	Low	0 - 110	Bluff	Low	Quaternary sands	beach and dune sand, Franciscan sedimentary, serpentinite, hillslope deposits
3	Pt Lobos	8,000	High	0 - 130	Bluff	Low	Franciscan complex, Quaternary sands	beach and dune sand, Franciscan sedimentary, Franciscan volcanic, Franciscan melange, serpentinite, hillslope deposits, artificial fill
4	North Ocean Beach	5,600	Moderate	0 - 550	Armor	Low	Quaternary sands	beach and dune sand, Franciscan sedimentary
5	Middle Ocean Beach	10,500	High	40 - 310	Armor, Dune	Low	Quaternary sands	beach and dune sand, alluvium, artificial fill
6	South Ocean Beach	7,500	High	0 - 200	Armor, Dune	Moderate	Quaternary sands	beach and dune sand, alluvium, artificial fill, hillslope deposits, overlying Pliocene/Plesitocene sediment
7	Fort Funston	2,500	High	0 - 140	Cliff	High	Quaternary sands	hillslope deposits, overlying Pliocene/Plesitocene sediment
8	Daly City	14,700	High	0 - 160	Cliff	High	Quaternary sands, gravel/sand/ reworked tuff/clay of unknown age	beach and dune sand, alluvium, artificial fill, hillslope deposits, overlying Pliocene/Plesitocene sediment
9	Mussel Rock	1,800	High	0 - 100	Cliff	High	Franciscan	beach and dune

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[8] Center for Habitat Studies/Moss Landing Marine Laboratories 2009

[9] USGS 2006

Reach			Wave Exposure	Beach Width	Backshore Type	Sand Content in Backshore	Geology	
#	name	Length (feet)	(qualitative intensity)	Range (feet)	Dune, bluff, cliff, armor	(qualitative amount)	Offshore[8]	Terrestrial[9]
							complex, Quaternary sands	sand, alluvium, hillslope deposits, Franciscan volcanic
10	Manor District	6,900	High	0 - 180	Armor, Bluff	Low	Franciscan complex, Quaternary sands	beach and dune sand, alluvium, hillslope deposits, Franciscan volcanic
11	Beach Blvd	5,200	High	20 - 170	Armor	Low	Franciscan complex, Quaternary sands	beach and dune sand, alluvium, hillslope deposits, Franciscan volcanic, Franciscan sedimentary
12	Sharp Park	4,000	High	0 - 260	Armor, Bluff	Low	Franciscan complex, Quaternary sands	beach and dune sand, alluvium, hillslope deposits, Franciscan volcanic, artificial fill, mud deposits
13	Hidden Cove	3,200	High	0 - 60	Bluff	Moderate	Franciscan complex, Quaternary sands	Franciscan volcanic, hillslope deposits, Franciscan sedimentary
14	Rockaway Cove	2,700	Moderate	0 - 150	Armor, Bluff	Moderate	Franciscan complex, Quaternary sands	Franciscan volcanic, Franciscan sedimentary, alluvium, artificial fill
15	Linda Mar	7,500	Moderate	0 - 280	Armor, Dune	Low	Franciscan complex, Quaternary sands	Franciscan volcanic, Franciscan sedimentary, alluvium, artificial fill, hillslope deposits, Paleocene sedimentary
16	Shelter Cove	3,000	Moderate	0 - 80	Bluff	Low	Franciscan complex, Quaternary sands, Salian plutonic (granite)	Paleocene sedimentary, hillslope deposits

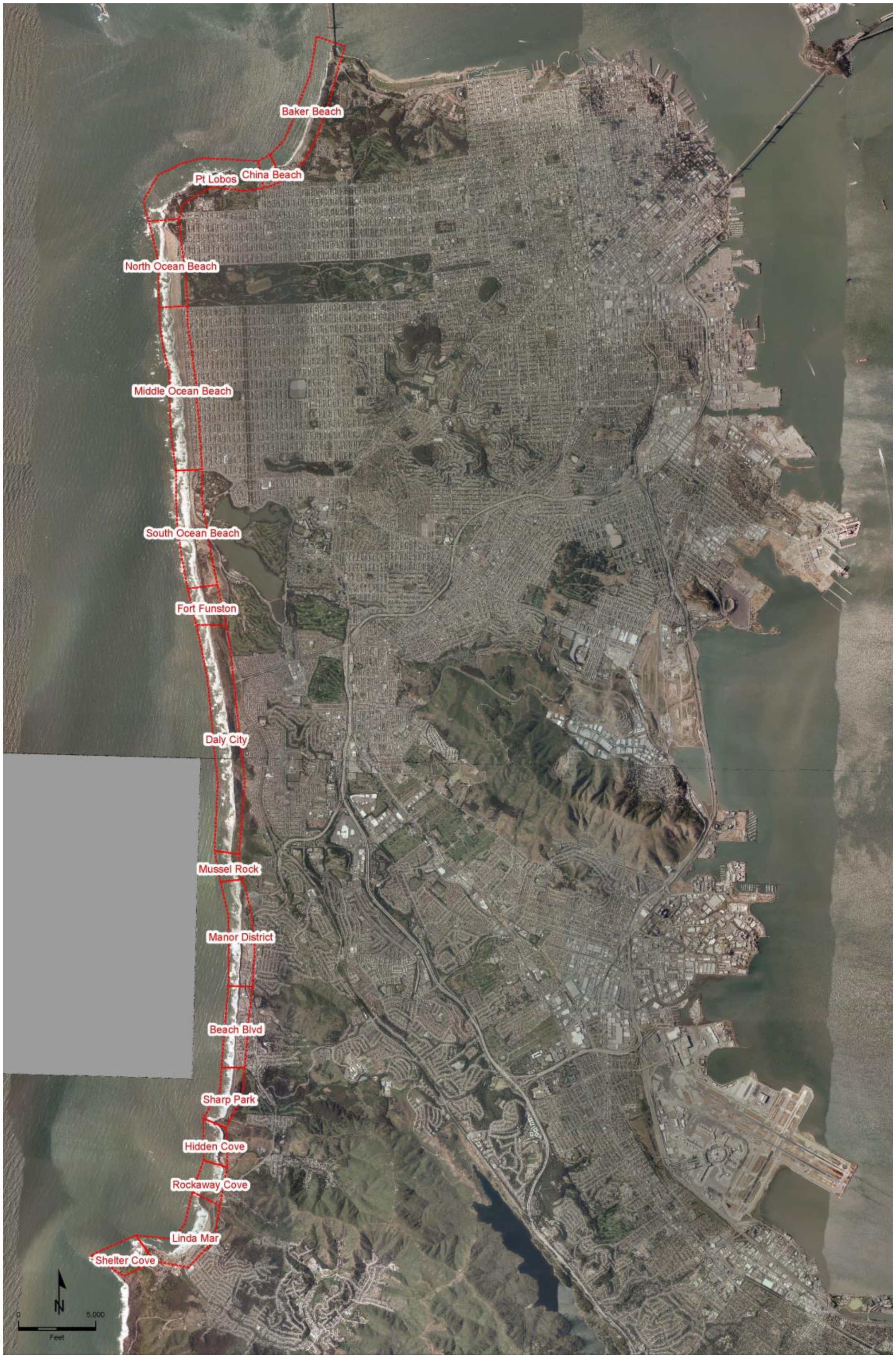

Figure 6: Shoreline reaches for the San Francisco Littoral Cell CRSMP

Reach Descriptions:

1. *The Baker Beach Reach* extends 8,300 feet from Fort Point to a rock outcrop below the Seacliff neighborhood of San Francisco. The northern part of this reach has a narrow beach with rock outcrops and a steep, rocky backshore. The southern part comprises a sandy beach approximately 3,700 feet long within the GGNRA. The shore is backed by cliffs, one upon which sits the Presidio of San Francisco, a historic area that was formerly a military base.
2. *The China Beach Reach* extends 1,100 ft between rock outcops. It is a public beach within the GGNRA with public parking, and visitor amenities. China Beach is located at the base of cliffs below the Seacliff neighborhood of the City and County San Francisco.
3. *The Pt. Lobos Reach* extends 8,000 ft from China Beach around the northwest tip of San Francisco, called “Lands End”, to the north end of Ocean Beach. This area, which is part of the GGNRA, includes the Sutro Bath ruins and the Cliff House, as well as Seal Rocks offshore. The area is rocky with eroding cliffs and pocket beaches.
4. *The North Ocean Beach (NOB) Reach* extends 5,600 ft from the Cliff House and Seal Rocks southward to Lincoln Way, which forms the southern border of the Golden Gate Park of the CCSF. The beach is approximately 800 feet wide in front of the historic O'Shaughnessy Seawall – constructed in the early 1900s – and is backed by a large, paved parking area. The seawall was exposed to waves until the late 1970s when sand began to accumulate Battalio (2014). The beach is part of the GGNRA.
5. *The Middle Ocean Beach (MOB) Reach* extends 10,500 ft from Lincoln Way to Sloat Boulevard. This section of shore consists of a beach backed by vegetated sand dunes or a seawall, and a linear sandy embankment. The embankment was constructed in the early 1900s as a foundation for the Great Highway, and the shore was built seaward about 200 to 300 feet using sand from the massive dune fields (Olmsted, 1979). Shore erosion resulted in continued sand placement and seawall construction in a few areas. A large box sewer was installed in the road embankment, and the area was renovated in the 1980s as part of a large sanitary sewer project called the Clean Water Program. Seawall construction was expanded significantly in the 1980s for the center two thirds of this reach to protect the sewer and roadway. The beach is part of the GGNRA. Middle Ocean Beach was identified as a critical erosion hotspot.
6. *The South Ocean Beach (SOB) Reach* extends 7,500 ft from Sloat Boulevard to Fort Funston. This area has a narrow sandy beach encroached upon by rubble and rock placed to mitigate erosion. The backshore erosion has damaged parking lots constructed in the 1980s as part of the Clean Water Program and has led to concerns about impacts to public access, the roadway (southern extension of the Great Highway) and substantial sewer treatment facilities. The Ocean Beach Master Plan envisions retreat, beach nourishment, and low-profile armoring for the area to both protect sewer infrastructure and provide for recreation and ecology. The backshore transitions from a low sandy dune at the north end to a cliff about 30 feet above grade in front of a sewer plant. The height of the cliff extends to about 100 feet moving southward towards Fort Funston. The beach is part of the GGNRA. South Ocean Beach was identified as a critical erosion hotspot.
7. *The Fort Funston Reach* extends 2,500 ft from South Ocean Beach to the San Mateo County Line. The area, which was a military base, is now part of the GGNRA. There is a narrow beach with some rock outcrops, backed by tall bluffs comprised of old,

sandy seabed uplifted by tectonic activity. Sanitary and storm sewer outfalls exist in this reach with the structures partially exposed across the beach. These structures are being modified to mitigate damage hazards (PWA, 2007).

8. *The Daly City Reach* extends 14,700 ft from Fort Funston to Mussel Rock. The San Andreas Fault complex crosses the shore at the southern boundary of this Reach, which is a part of the North American Plate. This Reach comprises narrow beaches, some rock outcrops and eroding cliffs hundreds of feet tall, which are prone to large slides and slumps. It is divided into three subreaches:
    a. *North (Section 1)*: Approximately 5,000 feet of shore backed by a bluff and State Route 35, also known as Skyline Drive. The bluff includes the remnants of a massive landslide and a perched wetland below the bluff top. Thornton State Beach occupies the southern end of this subreach. Horse stables exist inland of the cliff and several informal trails lead through the wetlands to the beach.
    b. *Middle (Section 2)*: This middle subreach, which is approximately 7,700 feet long, extends from Thornton State Beach to the Landfill. This area consists of narrow beaches and tall bluffs subject to large landslides with residential development along and inland of the cliff top. Beach access is limited to one switchback trail installed above a storm drain in a canyon-like feature. The Middle Reach of Daly City was identified as a critical erosion hotspot.
    c. *South (Section 3)*: The southern subreach, which is about 2,000 feet long, comprises a landfill and armored shore (rock revetment) that extends about halfway up the bluff. Residential housing exists around the bluff crest. The landfill is closed. The South Reach of Daly City was identified as a critical erosion hotspot.
9. *The Mussel Rock Reach* extends 1,800 ft from the landfill to north Pacifica. This is a rocky outcrop on the Pacific Plate south of the San Andreas Fault.
10. *The Manor District Reach* extends for 6,900 ft near the Daly City – City of Pacifica border. The reach has narrow beaches and bluffs consisting of uplifted seafloor comprised of weak sedimentary rock. This is an area of substantial bluff erosion that included damages to residential property in rough, El Niño winters of 1982-83, 1997-98 and 2009-2010. Much of the backshore is armored with rock revetments, and some of the bluffs are armored with reinforced concrete walls. Storm drains discharge on the beach while natural drainages have been filled and developed. Between armoring, bluffs continue to erode and pocket beaches exist. Access to the beach is limited to a few locations where ramps have been cut into the bluffs. Manor District Reach was identified as a critical erosion hotspot.
11. *The Beach Boulevard Reach* extends 5,200 ft from Paloma Drive to Clarendon Road. This area includes a large reinforced concrete seawall fronted by rock revetment with a paved promenade adjacent to Beach Boulevard. Wave overtopping occurs frequently, and the area has warning signs during high spring tides. Roads are occasionally closed when overtopping is extreme. A public fishing pier extends from the shore, and a linear park exists along the southern portion. The area is relatively dense residential along the shore except for City Hall, just south of the pier. Beach Boulevard Reach was identified as a critical erosion hotspot.
12. *The Sharp Park Reach* extends 4,000 ft from Clarendon Road to Mori Point. A beach, which extends the entire reach, widens to face more northwest at the southern terminus. The beach face is typically steep with coarse sand and a strong shore break. Multiple drownings have occurred in this area. Behind the beach is a long earthen embankment with some armoring that was constructed following erosion and flooding in 1983. The embankment is used for public access to the shore

by walkers and bicyclists. The Sharp Park Public Golf Course and Laguna Salada wetlands, owned and operated by the CCSF, exist just landward of the levee. To the south, Mori Point Headland and restored wetlands are part of the GGNRA. Sharp Park Reach was identified as a critical erosion hotspot.

13. *The Hidden Cove Reach* extends 3,200 ft from Mori Point to Rockaway Cove. Tall, steep bluffs back the shore, which comprises small, steep coves with coarse sands between rock cliffs. The area, which is exposed to large waves, has limited access and no development. The northern portion, which is part of the Mori Point unit of the GGNRA, has improved trails. The southern part is privately held but not developed. The City's sewage treatment plant is located inland in lowlands behind the coastal cliffs in what was historically a rock quarry.
14. *The Rockaway Cove Reach* extends 2,700 ft between headlands. Calera Creek discharges in the north part of the cove. This creek has been extensively modified and carries treated wastewater from the City's sewage treatment plant. The cove has a narrow sandy shore backed by armoring. Near the terminus of Rockaway Boulevard in the central part of the cove, the armoring extends to the water. Waves frequently overtop the armoring, whence water flows across the pavement. There is a commercial district with hotels, restaurants and shops at Rockaway. Public parking is provided in multiple parking lots, and public restrooms exist at the southern parking lot. Rockaway Cove Reach was identified as a critical erosion hotspot.
15. *The Linda Mar Reach* extends 7,500 ft from the Rockaway headland to Point San Pedro. The reach is primarily a large, sandy cove with dunes along the northern portion and development along the southern portion. The beach is underlain by cobble that is exposed in the southern portion of the cove and near the mouth of San Pedro Creek. Highway One (the Coast Road) is close to the shore with residential and commercial development farther inland. The Pacifica State Beach exists in the center and north section: A managed retreat project was implemented here in 2005. A remnant of the old coast railway embankment backs the shore on the south end of the cove, with residences perched above the shore in an area called "boat docks," owing to the small boats stored and launched from this area. Sewer force mains run along the shore with several pump stations. The beach is a popular local and regional destination. Linda Mar Reach was identified as a critical erosion hotspot.
16. *The Shelter Cove Reach* is a sandy cove located at Pedro Point. The area includes privately held residences along the shore. The area is backed by tall, steep bluffs with no automobile access.

Nine of the reaches were identified as critical erosion hotspots. Section 4 provides details on the determination of critical hotspots, and Section 5 provides additional information about each critical reach.

3.2 GEOLOGY

3.2.1 Tectonics

Geologists estimate that the modern assemblage of rock formations and geomorphology in the San Francisco Bay area results from more than 140 million years of tectonic activity. Although most attention is given to the San Andreas Fault line (e.g., the break associated with the 1906 earthquake), the boundary between the North American and Pacific Plates is actually a 100-mile wide zone of multiple fault lines collectively referred to as the San Andreas Fault System (Sloan, 2006). The San

Francisco Peninsula straddles the two major faults of the western branch of the fault system: the San Andreas and the San Gregorio. The rate of slippage averages approximately 1.3-1.5 inches annually across California along a northwest-southeast direction (Wallace, 1990). In the San Francisco Bay area, the fault system continues to produce horizontal and vertical land motion through strike-slip movement and compression forces, respectively.

Moore (1965) described the geology of the region south of the Golden Gate as:

> Franciscan cliffs give way to unconsolidated or slightly consolidated dune sands. These sands are in turn replaced by sediments of the Colma formation near Lake Merced. South of Lake Merced, cliffs of the Merced group [*sic*] as high as 500 feet line the coast to Mussel Rock. Broad beaches extend from Point Lobos, just south of the Golden Gate, to Mussel Rock. South of Mussel Rock, cliffs of the Franciscan formation extend to the water's edge. At Pt. San Pedro, the coastline is displaced westward, with the apparently very resistant Montara granite forming seacliffs [*sic*] from just south of Pt. San Pedro almost as far south as Half Moon Bay.

Geologists such as Sloan (2005) identified the Merced and Colma Formations as mainly sandstone, which is a sedimentary rock consisting of sand, usually quartz, cemented together by various substances – e.g., silica, calcium carbonate, iron oxide, or clay. Deposition of the Merced Formation occurred from approximately 2–3 million to half a million years ago. Deposition of the Colma Formation occurred from approximately 125,000 to 55,000 years ago, which was during the most recent interglacial period. Activity from the San Andreas Fault has uplifted both formations to their present positions.

The California Geological Survey‘s landslide susceptibility map for the state shows high slide probabilities in many of the 16 reaches (Figure 7; Wills et al, 2011). The combination of tectonic, terrestrial and marine forces creates large landslides, especially in the Daly City area. For example, the Northridge Bluff Landslide of December 2003 moved approximately 500,000 yd^3 of material that deposited sediment and rock more than 100 yd into the surf zone. A second slide in January 2007 deposited an additional 150,000 yd^3 of debris in the same location (Collins et al, 2007). The weak bonds among the Merced and Colma rocks make them susceptible to erosion from tectonic movement, and the cliffs are also undercut by wave action. Large waves often attack the cliff bases during winter storms and swell conditions, which enhance the normal coastal erosion. In addition, anthropogenic activities at the bottom and top of the cliff have caused further destabilization.

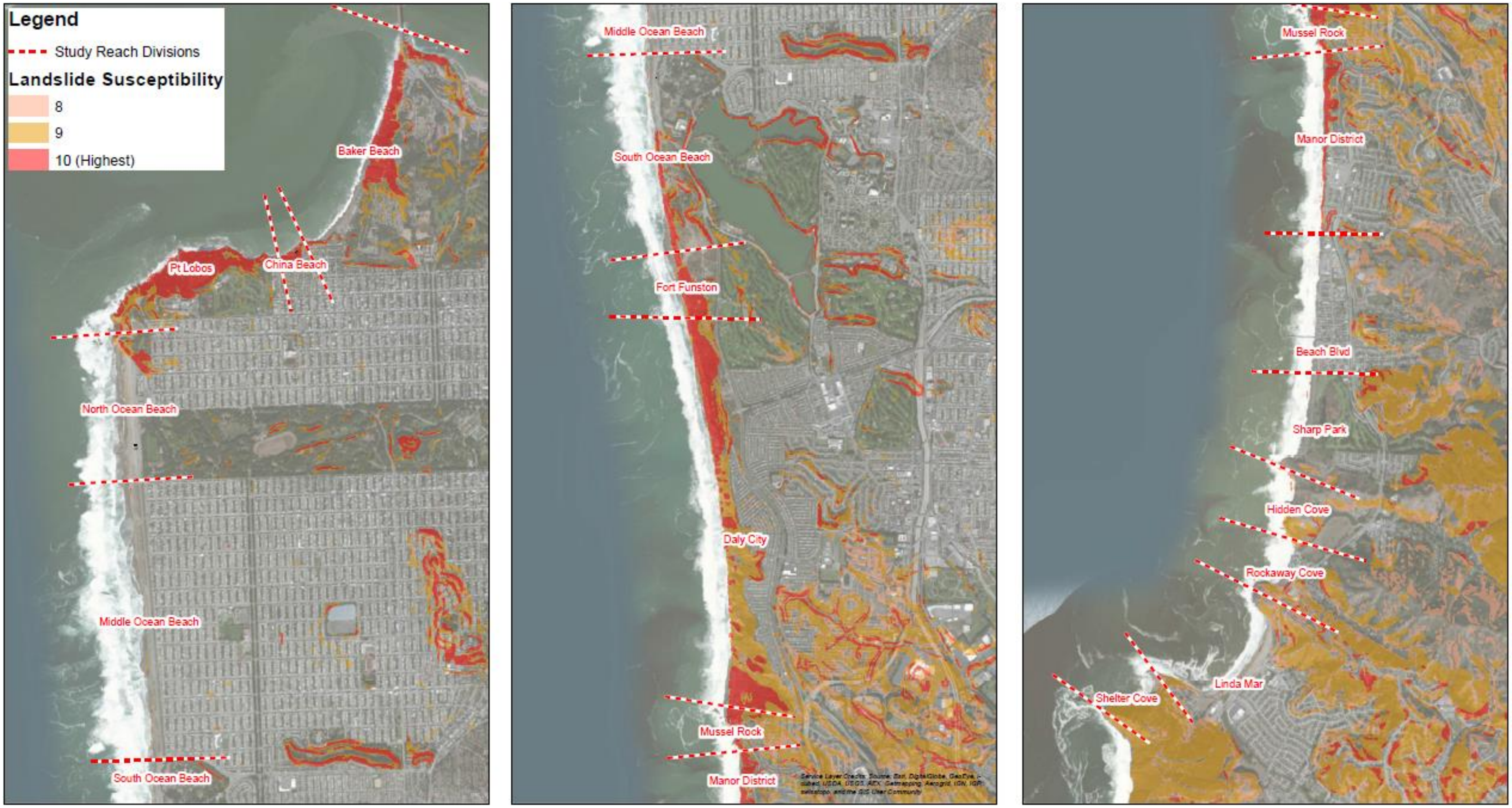

Figure 7: CGS Landslide Susceptibility Map. Landslide susceptibility classes, which are based on rock strength and slope, increase from 0 (Low) to 10 (Very High). Only the top three levels are displayed. Source: California Geological Survey, Willis et al. 2011

3.2.2 Mineralogy

The primary sources of sediment differ regionally within the SFLC region. The mineralogy of beach sand is a blend of rocks derived from the active tectonic uplift and the erosion of distant (Sierra Nevada, 200 miles to the east) and local (Coast Ranges) mountains. Studies by Moore (1965) and Barnard et al. (2013) characterized the origins of sediment in the area. Both describe the complexity in determining clear origins of the offshore sediment. Moore (1965), comparing heavy minerals in offshore sediment and found a relatively consistent ratio of hornblende to augite (2-4%) and hornblende to hypersthene (<3%). A more robust geochemical analysis using isotopic comparisons, rare earth element composition, and heavy mineral composition showed more nuances (Barnard et al, 2013). Sand from the Sierras, delivered through the Golden Gate by the Sacramento River, dominates the northern beaches of the SFLC shoreline (San Francisco beaches as far south as the southern end of Ocean Beach). That sand has higher aluminum to iron (Al/Fe) ratios than sand south of Ocean Beach does. Geochemical analysis suggests that local sand sources dominate south of San Francisco, indicating a split in the SFLC sediment type at the southern end of Ocean Beach. This is consistent with the shift in geology because the San Andreas Fault crosses the coast in that area. The local watersheds would therefore be supplying sand to the coast in Daly City and Pacifica. The mineralogical connection of beach sands to the Sierras likely goes far back in geologic time, while recent stands of sea level (past 5,000 years) have likely reduced the rate of new sand delivery (Battalio & Trivedi, 1996). But, new research indicates that inland California may still supply some sand (Barnard et al, 2013).

3.2.3 Watersheds

Historically, the coastal watersheds (Figure 8) are the primary nearshore and beach sand sources for the southern half of the littoral cell. The terrain of the San Francisco Peninsula tilts most drainages east and north to the San Francisco Bay. The natural watersheds in the SFLC region that connect directly to the Pacific Ocean are San Pedro Creek (5,300 acres), Laguna Salada (1,200 acres), Calera Creek (1,100 acres), and several smaller unnamed watersheds of less than 1,000 acres. In San Francisco, the Sunset (5,300 acres) and Richmond (1,700 acres) watersheds are heavily manipulated into below-ground water systems and connect to the Oceanside Water Pollution Control Plant, allowing for comparatively minimal surface runoff to the ocean. The Vista Grande Canal watershed in Daly City and San Francisco (1,700 acres) is also manipulated to drain via a tunnel to the ocean instead of through a creek mouth.

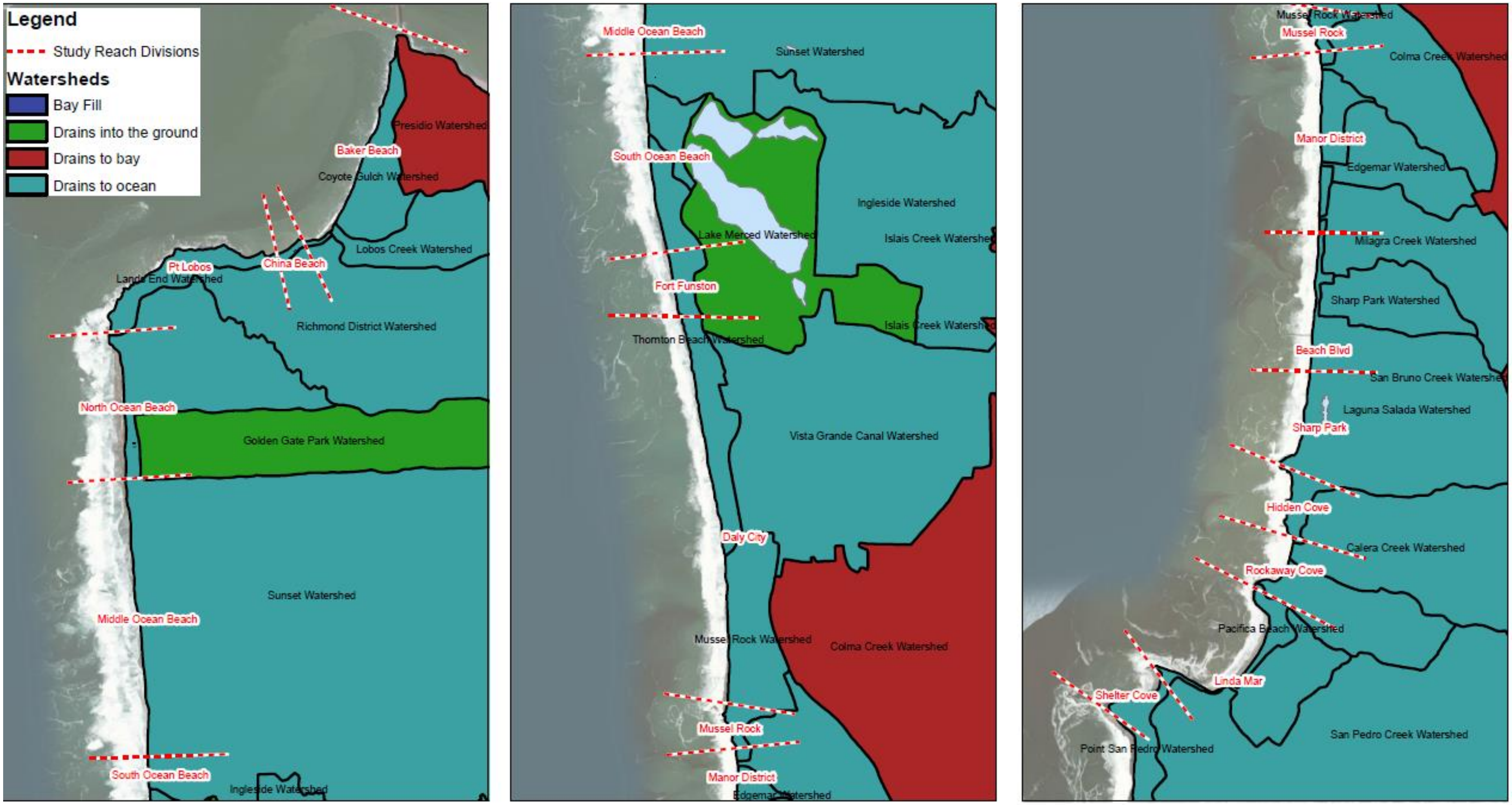

Figure 8: Watersheds in SFLC region. SOURCE: Oakland Museum of California, 2007

3.2.4 Vertical land motions

The tectonic activity described above translates into vertical land movement that affects sediment management. Vertical uplift can increase the steepness of the coastal bluffs and hillsides, destabilizing land masses. Uplift can also be larger than rates of sea level rise, which would mitigate the flooding potential from higher stands of the ocean. Conversely, vertical dropping can increase flood exposure and inundation of the beaches. Although the National Geodetic Survey maintains 17 benchmarks in the vicinity of the SFLC shoreline along Route 1 and in a few off-highway locations, the vertical land motion has not been accurately quantified. The USGS published estimates of regional uplift just south of the littoral cell after the 1989 Loma Prieta earthquake to be 0.8 mm/yr by accounting for isostatic compensation (USGS, 1994). But, an estimate specific to San Francisco, Daly City, and Pacifica would better reflect the local tectonics.

3.3 GEOMORPHOLOGY

Geomorphology that is relevant to the CRSMP includes beach processes and seasonal cycles, terrestrial bluff processes, and offshore sediment deposition.

3.3.1 Beaches

Grain sizes on the beaches in the SFLC vary from medium sand in San Francisco to fine gravel and cobble in parts of Linda Mar. The beach slopes reflect the grain size, wave action, and tidal range. The majority of the sand movement occurs on the beach face (aka foreshore), which is typically the front of the seaward-most berm, although human manipulation of a beach (e.g., by grading) can greatly expand the area of active transport by wind and waves. This zone of active wave transport is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Because waves change their dominant directions and heights seasonally and the maximum monthly tide ranges tend to be greater during the late fall and winter, the seasonal response of beaches is one of the fundamental components of coastal geomorphology and, consequently, sediment management. Beaches build higher profiles during the summer and fall months when the wave climate is more quiescent and tidal ranges are smaller. With the beginning of the late-fall and early-winter large swells, the beach profiles start to transform to steeper slopes and lower foreshores. Sand stripped from the beach is typically redeposited immediately offshore where the wave energy decreases to the point that the sediment settles to the bottom. Offshore bars build throughout the winter and into spring. During late spring and summer, those bars provide a source of sand for rebuilding the beaches.

When waves break at an angle to the beach, the sand moved by the uprush moves alongshore away from the direction from which the waves came. This results in a “river of sand” moving parallel to the coast on the beach face and in the swash zone. This phenomena is called littoral drift. Understanding this process is vital to sediment management activities that involve placing sand on beaches because the beach width will not remain constant throughout the year, and the sand could move to and possibly have a negative effect on nearby coastal locations.

In much of the SFLC, the beach and nearshore sand is thick. The beaches of Daly City and north Pacifica, however, appear to consist of a thin layer of sand atop a wave-cut, non-erodible platform. For example, rocky outcrops are visible at several locations during low tides, especially in the winter when the thickness of beach sand is lowest (Figure 9).

Figure 9: Exposed wave-cut rock platform with scattered riprap at the bluff-beach interface, Pacifica

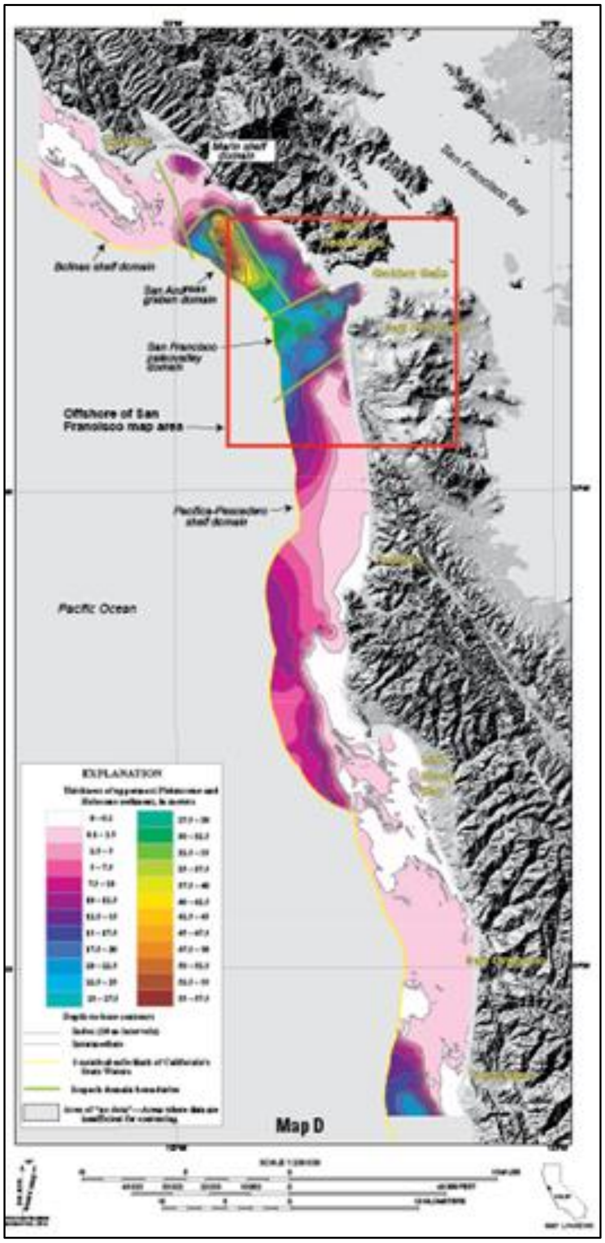

Figure 10: Sediment thickness map in SFLC. Source (USGS, 2015)

3.3.2 Bluff Processes

The geology of the cliffs underpins the contribution of the bluffs in Daly City and Pacifica to sediment in that part of the SFLC. Large amounts of material can be dislodged by undercutting of the bluffs because of wave action or weakening of the hillsides from rainfall. Tectonics also play a role in reshaping the vertical faces of the land. When slides occur, the sediment that is delivered to the beaches is sorted by grain size under constant wave action. Beach-size sand and gravel are less mobile and remain closer to shore, while mud and fine-grain sand are typically transported away by currents. No definitive study has been conducted on the amount of sand in the cliffs.

3.3.3 Nearshore and Offshore Deposition

In general there is a grain-size gradient across the continental shelf with the largest sediment being closest to shore. In the nearshore zone, waves keep silts and clays in suspension and move sand onshore and offshore. Over time, currents transport the fines into the offshore where they slowly settle out. Sand also can move to the offshore but generally stops moving around the depth of closure. Limber et al (2008) define a parameter –the Local Cutoff Diameter (LCD) – that designates the smallest sand diameter that will remain on a given beach. Locally, they determined that the LCD was 125 µm and that the Merced Formation was a major contributor to the beach, nearshore, and offshore. In the Pacifica and Daly City nearshore, however, the amount of sand is limited to a thin layer atop the wave-cut platform (Moore, 1965; USGS, 2015). On the other hand, the USGS (2015) found thicker deposits occurring north of the Golden Gate near Bolinas Lagoon. Those deposits are not in the geographic boundaries of the San Francisco Littoral Cell, and Limber et al (2008) did not identify the grain sizes there.

3.4 COASTAL PROCESSES

3.4.1 Meteorology

Atmospheric rivers consist of narrow bands of enhanced water vapor transport, typically along the boundaries between large areas of divergent surface air flow, including some frontal zones in association with extratropical cyclones that form over the oceans. The term was originally coined by researchers Reginald Newell and Yong Zhu of the Massachusetts Institute of Technology in the early 1990s (Zhu et. al., 1994), to reflect the narrowness of the moisture plumes involved. Atmospheric rivers are typically several thousand kilometers long and only a few hundred kilometers wide. A single atmospheric river can carry a greater flux of water than the Earth's largest river, the Amazon River. There are typically 3-5 of these narrow plumes present within a hemisphere at any given time. Atmospheric rivers have a central role in the global water cycle. On any given day, they account for over 90% of the global meridional (north-south) water vapor transport, yet they cover less than 10% of the Earth's circumference. They also are the major cause of the extreme precipitation events that result in severe flooding in many mid-latitude, westerly coastal regions of the world, including the West Coast of North America, Western Europe, and the west coast of North Africa.

Local storms, which can be frequent from November to May, often include large atmospheric rivers. During years with intense storms, atmospheric rivers cause a wetter-than-average winter and spring. Locally, an average of nearly 19.4 in (490 mm) of precipitation falls between the beginning of November and the end of May (NWS, 2014). Following the stormy season, an extensive dry period occurs during the summer and autumn months with few storms. Coastal fog is the primary source of precipitation during this time. The resulting connection between precipitation and land-slides in the San Francisco area has been well documented (e.g., Ellen & Wieczorek, 1988; Godt, 1999).

3.4.2 Hydrodynamics

Hydrodynamic processes affecting the littoral cell include waves, tidal currents, and freshwater outflow from the bay. Swell from the Pacific Ocean is the dominant process affecting the beaches. Ocean conditions are seasonal with south swell being more common in the summer and west-to-northwest swell dominating the rest of the year. Wave heights and directions change substantially as the swell approaches the coastline in response to the bathymetry around the Cordell Bank and Farallon Islands as well as the San Francisco Bar (Battalio and Trivedi, 1996). Annual maximum significant wave heights (H_s) typically exceed 26 ft and average 8 ft (Scripps Institution of Oceanography, 2012 in Barnard et al, 2013). An analysis of three Monitoring and Prediction Stations (MOPS) along Ocean Beach from 2000–2010 examined the refraction of waves caused by the shelf and nearshore bathymetry. Comparisons between Point Reyes and MOPS wave data show that deep water waves refract from 320˚ at Point Reyes to 250–270˚ at Ocean Beach.

Tides at the Golden Gate (NOAA/Co-ops station 9414290) are mixed, semi-diurnal, and have a maximum range of 5.8 ft (MLLW-MHHW, 1983–2001 Tidal Epoch). The tidal currents are enhanced by freshwater discharge through the Sacramento-San Joaquin Delta and local tributaries in the San Francisco Bay watershed as well as by the large surface area of the Bay. Peak ebb-tidal currents can exceed 8 ft/s at the Golden Gate and can be 3 ft/s on the outer edge of the ebb-tidal delta (Rubin and McCulloch, 1979). Downcoast from Ocean Beach, data on waves and tidal currents are not available, leaving a gap in quantifying conditions along Daly City and Pacifica.

3.4.3 Sand

Littoral-cell sand is both relic from prior low stands of sea level and from recent deposits (Battalio & Trivedi, 2006). Relic sands are primarily from the San Andreas Mountains of inland California while recently deposited sands are from San Francisco Bay, dunes, Merced Formation bluffs, and coastal watersheds. Limber et al (2008) determined that the Merced Formation is responsible for an annual flux of sand of approximately 63,000 yd^3 ± 17%. The volume of sand from cliffs in Pacifica has not been quantified, leaving a gap in estimating the total sand budget. Another gap in the budget comes from the lack of information on coarse sand and gravel input from the coastal watersheds. Because the watersheds no longer connect directly to the ocean, their sediment delivery is less than under pre-development conditions.

Recent research indicates that sediment delivered to the beaches during high river runoff may include beach-size sand (Barnard, et al, 2013). Prior studies concluded that beach size sand probably cannot migrate through San Francisco Bay at rates significant to beaches since sea level rose to present levels about 6,000 years ago (Gilbert, 1917; Battalio & Trivedi, 1996). These studies did hypothesize that sand migrated out the Golden Gate to the beaches under currents, but did not expect much contribution from farther inland. The recent work undermines these prior assumptions and raises the question as to whether inland changes such as dams have decreased sand supply to the coast, and prior activities such as hydraulic gold mining prevalent in the mid1800s may have increased sand supply. Also, sand mining that is currently occurring in the central Bay shoals may contribute to coastal erosion.

In addition to questions about sediment supply to the SFLC, sediment transport within the SFLC is not fully understood. Battalio and Trivedi (1996) believe that sand placed atop the San Francisco Bar has effectively nourished Ocean Beach since the 1970s. Barnard, et al, (2013) attribute accretion in north Ocean Beach to shore rotation associated with the changes in the offshore San Francisco Bar. They also conclude that

South Ocean Beach is an erosion hot spot caused by shrinkage of the San Francisco Bar, and that erosion is potentially further increased by wave focusing from an exposed offshore wastewater pipeline on the seafloor. Furthermore, they emphasize the correlation of beach erosion with sand mining in central San Francisco Bay and dredging in the Bay and Ocean. It is important to recognize that changes to the offshore San Francisco Bar were noted to have started in the 1800s (Gilbert, 1917), prior to substantial navigation dredging and sand mining (Battalio and Trivedi, 1996). Battalio (2014) reiterates that the massive accretion at North Ocean Beach since the 1970s and along the north shore of San Francisco since the mid-1980s correlates well with an increase in sand supply associated with the change in dredging practice in the 1970s. Recent studies are in agreement that the Pacific Ocean and San Francisco Bay are linked via sediment transport. It should be noted that the differences in recent findings are a matter of emphasis and focus in terms of the dominant drivers of shore change but are not otherwise in conflict. Substantive uncertainties remain despite the long period of investigation (e.g., Gilbert, 1917; Battalio, 2014). While more study is needed, these recent studies agree that the system has been disturbed by interventions and that these interventions and their implications are pertinent to assessing future conditions and adaptive actions.

3.4.4 Sea Level Rise and Timeframe of the Plan

The timeframe for this Plan was based on several factors, including observed sea level rise rates on the West Coast, accepted planning horizons for sea level rise, and the USACE sea level rise curve. For the past several decades, sea level rise has been minimal on the West Coast potentially because of ocean circulation as affected by cooler water temperatures and wind stress patterns associated with the Pacific Decadal Oscillation (Bromirski et al., 2011). The record of water elevation at the San Francisco tide gage shows a trend of 0.07 in/yr (1.9 mm/yr) from 1980 to the present. Many planning documents use 2000 as a baseline year for sea level rise with 2050 and 2100 as planning horizon years. Because a baseline shoreline position is essential in calculating how sea level rise will affect a location, the most reliable shoreline should be selected. The 2010 shoreline gathered by the State of California serves this purpose for this project. Because the actual sea level rise in the first decade of the 21st century has been minimal, to match guidance documents, existing studies, and observed sea level rise rates, 2050 and 2100 were selected as project timeframes.

3.5 ECOLOGY

3.5.1 Overview

The coastal habitats considered for the littoral cell are based on the potentially significant biological effects of natural physical processes closely linked with shoreline retreat. Also included is the backshore zone that would be affected by engineered shoreline structures or soft engineering adaptations. The ecologically significant natural physical processes affecting terrestrial coastal communities include slope processes (e.g., erosion, slope failure); sand transport; wave overwash; and seawater flooding of lowland, wetland, or aquatic backshore habitats. The distance landward of the shoreline considered for analysis varies according to the distribution of existing habitats and the physical reach of shoreline processes. The seaward extent of the SFLC is also based on an approximation of the limit of potential effects of natural physical processes of shoreline retreat, artificial structures, or sediment management (e.g., turbidity plumes from bluff erosion or artificial sediment placement, vessel traffic).

3.5.2 State and Federal Marine Protected Areas

The National Marine Sanctuaries Act (1972) and the California Marine Life Protection Act (1999) authorized the establishment of habitat protection zones in state and federal waters, although none currently exist in the immediate vicinity of the SFLC. The eastern boundary of the Monterey Bay National Marine Sanctuary (MBNMS) is approximately 6 mi offshore of the San Francisco Peninsula, and the Gulf of the Farallones National Marine Sanctuary (GFNMS) is immediately west of the MBNMS. There are no state reserves in the SFLC. The closest state reserves to the south are: the Egg Rock to Devil's Slide Special Closure; Montara State Marine Reserve, and; Pillar Point State Marine Conservation Area. To the north of the SFLC is the Duxbury Reef Marine Conservation Area. All of these reserves have guidelines to protect the habitats for resident and transient species, including limitations to altering the seabed through dredging or placement activities.

3.5.3 Indicator Species and Communities

The availability of contemporary, reliable data on the distribution of sensitive coastal species and habitats is uneven within the area. Some important habitats and sensitive-species populations are relatively well-studied and inventoried, such as within GGNRA boundaries or special management areas (e.g., Sharp Park). This may produce sampling bias regarding important coastal resources because some of the same species and communities occur in other reaches of the SFLC, but with less available contemporary or rigorous survey data. Because many of the coastal habitats are highly dynamic, relying on short-term, high resolution spatial data on coastal habitat distributions from relatively well-studied areas may be less relevant to long-term coastal sediment management planning than identifying indicator species that correspond with sensitive habitat complexes. A set of indicator species was selected to identify likely coastal settings for sensitive biological resources based on high ecological fidelity for specific high-value coastal ecosystem conditions or "hot spots" of biological diversity (Table 4). Review of indicator species (including special-status species) supplements the general approach of describing discrete ecogeomorphic coastal zones for early identification of important biological resources.

Table 4: Indicator species for the San Francisco Littoral Cell CRSMP

ANIMALS	VEGETATION
Steelhead	Beach saltbush, Atriplex leucophylla
California red-legged frog	Beach wildrye, *Elymus mollis*
San Francisco garter snake	Pacific wildrye, *Elymus pacificus*
Leatherback sea turtle	Mock-heather, dune golden heather, *Ericameria ericoides*
Bank swallow	Silvery beach-pea, *Lathyrus littoralis*
Western snowy plover	Native coastal dune annual forbs
Marine mammals (cetaceans and pinnipeds)	Dune tansy, *Tanacetum bipinnatum* Perennial coastal wetland plants species Hemiparasitic and holoparasitic perennial coastal scrub forbs

As a result of the coast in the SFLC being highly urbanized, historical coastal habitats have been severely degraded. With the threat of sea level rise, species and habitats are expected to experience “coastal squeeze” as coastal development limits the inland migration of ecosystems. Activities that could affect these indicator species either by increasing or decreasing their habitats were assessed. The activities associated with sand placement (dredging, transportation, and placement) generally have immediate negative consequences on the affected ecosystems. There are also spatial and temporal restrictions on sand placement activities during mating, breeding, and rearing seasons for different species. In the nearshore and offshore zones, sand placement has a more transient impact from smothering and raising the seabed – both relevant to the sand dollar populations found in the SFLC. On the other hand, benefits to habitats can be qualitatively described by considering that wider beaches provide additional dune, shoreface, and better-protected coastal-bluff habitats. With beach nourishment, these habitats will cover larger, albeit gradually shrinking, areas and encourage species population growth after sand placement ends (Appendix C). The Biological Assessment expands on the biological impacts of the proposed alternatives by reach as well as presenting a narrative of historical habitats as determined by T-sheets from 1869.

3.6 RECREATION AND ECONOMICS

Recreation is a major economic driver in the area – be it in the ocean, on the beaches, or along coastal cliffs. With varying terrain, climate, and access, the reaches have a diverse spread of activities and resulting economic importance. The following list characterizes how the populace uses the region’s coastal zone.

3.6.1 Recreation Overview

San Francisco

The terrain along the San Francisco outer coast varies from rocky cliffs to sandy beaches (Figure 6). Analogously, recreational opportunities vary greatly along that stretch of coast: extensive coastal trails through historical military facilities at the Presidio; dramatic views and historical cultural ruins along Lands End; and a variety of sand and wave conditions at Baker Beach, China Beach, and Ocean Beach. For example:

- Year-round hiking and walking are popular throughout the GGNRA-managed headlands. The Palace of the Legion of Honor in Lincoln Park is a cultural and historical draw. Parking is scattered throughout the area, and several Muni bus lines service the Presidio. It is also a popular biking destination from other parts of the city and Marin County.
- Ocean Beach is popular for general beach activities, surf fishing, and surfing. Swimming and wading are less common because of the cold weather and strong currents. There are relatively few amenities at the beach, but restaurants and other businesses abound across the Great Highway, and there are a number of restaurants and shops near Seal Rocks. Parking lots at the north and south ends of the beach and several crosswalks in between provide access to the entire beach, although the largest concentrations of visitors are at the north and south ends. NOB is quite wide and accreting, but SOB is narrow to non-existent and eroding. Parking is becoming less available because bluff erosion has removed parts of the parking lot

at Sloat Boulevard. Surfing is most popular at the north and south ends. Visitors can reach the beach by car or mass transit, although parking might be difficult to find on some days.

- Fort Funston, which occupies a high bluff south of Ocean Beach, is a popular destination because of the variety of activities and spectacular views. The area, which is part of the GGNRA, is particularly popular for dog walkers. Because of consistently strong winds, it is also a popular hang-gliding site. Over 90% of its visitors hike on trails on the bluff and down to the beach.

Daly City

The Daly City shoreline comprises sandy beaches below steep bluffs and a rocky headland at the southern end (Figure 6), making beach access difficult. Many potential access locations have been fenced off by the city because of landslide and erosion concerns. Note that the northern part of the Reach called Daly City in this report is actually unincorporated San Mateo County that comprises parcels associated with Thornton State Beach and the Olympic Club.

- Thornton State Park has a small parking lot at the west end of John Daly Boulevard. Because beach access is closed, visitors can only look down from the bluff. There are coastal trails that run through the park, but on most days the beach has few visitors.
- Mussel Rock Park provides parking and coastal access (trails) with few amenities. Most visitors stay on the bluff above.

Pacifica

The City of Pacifica has a number of recreational beaches with differing amenities.

- The Manor District has two beach access points off of Esplanade Avenue. The beach is popular for walking.
- West of Palmetto Avenue between Esplanade Avenue and Beach Boulevard the bluff is largely fenced off because of coastal erosion, affording little or no beach access. Much of that stretch of bluff is occupied by a trailer park and other residences as well as some industrial buildings. Access is extremely limited.
- The Sharp Park Promenade along Beach Boulevard affords access to the beach, the Pacifica Municipal Pier, bathroom facilities, and a popular coastal trail that runs south from the pier to Rockaway Beach. The trail passes between the beach and the Sharp Park Golf Course. The park is particularly popular with fishermen, most of whom are on the pier, though some fish off of the beach. The rip currents and cold weather limit swimming and wading, and most walkers prefer the coastal trail. The beach, however, acts as an added amenity for all visitors. There is ample parking across the street.
- As the name implies, Hidden Cove is difficult to access. One must climb a relatively steep bluff from either Rockaway Beach to the south or Sharp Park to the north. There is no official access down to the beach, and we did not observe any trails.
- Rockaway Cove is a small beach adjacent to two hotels and a number of other small businesses. It is popular with walkers and surfers. There is ample parking and access off of Route 1.
- Linda Mar Beach, at the south end of Pacifica, is popular with surfers and walkers, and wading is popular during warm weather. The beach, which is adjacent to Highway 1, has ample parking and restroom facilities. The popular Taco Bell

between the Highway and the beach provides nice views of the beach and Point San Pedro.

- Shelter Cove is a small, isolated cove beach on the north side of Point San Pedro. To access the beach, one must drive through a residential neighborhood where parking is limited. The stairway down to the cove is well maintained.

3.6.2 Attendance and Beach Amenities

Because few socioeconomic studies exist in this region, attendance estimates are based on actual counts at the beaches. In an attempt to fill the gap, spending data from studies of other beaches in California also have been used in this study.

Ocean Beach attendance estimates come from a detailed San Francisco Public Utilities Commission (SFPUC) survey conducted from 1998 to 2000. The estimates were confirmed by a number of independent observations and conversations with people familiar with recreational use patterns at Ocean Beach. Although these data are over a decade old, San Francisco’s population has remained relatively stable. Surfing, however, is the one activity that has increased significantly since the survey was taken, particularly south of Sloat Boulevard.

The SFPUC survey was conducted at specific sites along Ocean Beach. The site estimates were translated into the three reaches – NOB, MOB, and SOB – used throughout the Plan. The major uncertainty with using the SFPUC data is post-survey changes in recreational activity and yearly fluctuations. Annually, beach attendance varies with the weather, which fluctuates notably with season. Interannually, the weather at Ocean Beach is consistent.

Because even fewer data were available for other beaches, San Francisco State University research assistants counted people at each of the other beaches four times in February. Counts were made on both weekdays and weekends and during various types of weather. Because attendance in this area is less seasonal than many other areas, counting in February is less of a limitation. Nevertheless, the estimates made from these counts have a high error band.

Within the SFLC, none of the beaches have lifeguards, camping, volleyball, or some of the amenities popular in southern California beaches. Most of the beaches in the littoral cell are more popular for walking, whereas swimming is uncommon at all of those beaches. On the other hand, surfing has become increasingly popular throughout the area, especially at Ocean Beach and Linda Mar Beach. The beaches also provide amenities to people who never set foot on the sand, and this should be accounted for.

Table 5 summarizes the survey and other data and rates each beach in terms of access. Beaches close to major roads and public transportation rank more highly than beaches that are harder to access. A few of the beaches have low access, such as for most of Daly City’s coastline, because of the possibility of landslides. Yet, those beaches can be accessed by coastal trails. Hidden Cove has no trails down to the beach and hence has low access.

Table 5: San Francisco Littoral Cell beach access and amenities

Beach	Access out of 10	Restrooms	Showers	Public Transportation	Number of Official Parking Spots	Parking Fee	Number of Free Street Parking Spots	% Available for Beach Tourism
Baker Beach	7	Y	N	Y	187	0	100	100%
China Beach	5	Y	Y	N	37	0	50	20%
North Ocean Beach	8	Y	N	Y	>500	0	>500	40%
Middle Ocean Beach	8	Y	N	Y	0	0	>500	40%
South Ocean Beach	9	Y	N	Y	65	0	40	30%
Fort Funston	7	Y	N	N	260	0	30	100%
Thornton Beach	3	N	N	N	24	0	0	100%
Mussel Rock	3	N	N	N	60	0	25	0%
Manor District	5	N	N	N	0	0	80	10%
Beach Boulevard	5	Y	N	N	0	0	79	30%
Sharp Park	5	Y	N	N	33	0	100	30%
Hidden Cove	1	N	N	N	50	0	20	60%
Rockaway Cove	7	N	N	N	55	0	0	0%
Linda Mar	8	Y	Y	N	136	0	10	60%
Shelter Cove	4	Y	Y	N	0	0	6	0%

Many of the beaches have nearby parking lots, and some (e.g., SOB) have ample nearby street parking. In general, parking is adequate at all of the beaches, except perhaps during peak times.

Table 6 presents estimates of attendance and economic impact (spending and selected local taxes) for beaches in the region. Except for Ocean Beach, these attendance estimates are based on limited data and inadequately evaluate people who walk adjacent to the beach or on the pier but do not set foot on the sand.

The estimates of economic impacts, which used spending per visitor per day from King and Symes (2004), are a decade old, but the values have been updated for inflation. Note that the King and Symes data were collected at southern California beaches where the spending patterns may be different. For example, gas and auto costs may be lower for SFLC beaches because people drive shorter distances to go to peninsula beaches. Because none of the beaches in the littoral cell charge parking fees, that element of King and Symes' estimates was omitted. Local tax rates were applied for estimates of tax revenue. Parking availability and amenities were estimated from site visits and publically available data including:

- Interviews with people knowledgeable about beach amenities and habits;
- The California Coastal Access Guide (2003);

Google Earth and Google Maps (used to estimate available parking);Street parking capacity was evaluated based on observed capacity from previous high-season parking habits and interviews with people familiar with beach parking patterns. After speaking to residents and local beach users, it was determined that visitors are willing to park from two to five blocks away on a busy summer day. Each beach was evaluated separately, and the information was used to construct geographical zones that encompass the area used for beach parking. The number of parking spaces was counted during site visits or from Google Maps. The percentage of parking in the geographical zone that is available for beach use is also based on observed parking habits.

- A beach is considered to have public transportation access if a stop is within three blocks.
- The general access rating is based on accessibility by auto, public transportation, and foot (e.g., beaches closer to major roads were considered more accessible).

Table 6: Attendance and economic impact of selected beaches

Beach	Est. Yearly Attendance	% Overnight Visitors	Est. Total Annual Spending	Total Sales Tax	State Portion	Local Sales Tax	State Sales Tax Revenues	Local Sales Tax Revenue	Transient Occupancy Tax	Est. TOT Revenues
Baker Beach	150,000	20%	$ 8,543,000	8.50%	6.25%	2.25%	208,000	74,711	14%	94,000
China Beach	25,000	10%	$ 1,516,000	8.50%	6.25%	2.25%	34,000	12,287	14%	8,000
North Ocean Beach	160,000	40%	$ 7,935,000	8.50%	6.25%	2.25%	227,000	81,798	14%	199,000
Middle Ocean Beach	140,000	10%	$ 8,489,000	8.50%	6.25%	2.25%	191,000	68,808	14%	44,000
South Ocean Beach	40,000	10%	$ 2,425,000	8.50%	6.25%	2.25%	55,000	19,660	14%	12,000
Fort Funston	130,000	20%	$ 7,404,000	8.25%	6.25%	2.00%	180,000	57,555	10%	58,000
Thornton Beach	15,000	10%	$910,000	8.25%	6.25%	2.00%	20,000	6,553	10%	3,000
Mussel Rock	10,000	10%	$606,000	8.25%	6.25%	2.00%	14,000	4,369	10%	2,000
Manor District	8,000	10%	$485,000	8.25%	6.25%	2.00%	11,000	3,495	10%	2,000
Beach BLVD	40,000	10%	$2,425,000	8.25%	6.25%	2.00%	55,000	17,475	10%	9,000
Sharp Park	50,000	10%	$3,032,000	8.25%	6.25%	2.00%	68,000	21,844	10%	11,000
Hidden Cove	10,000	10%	$606,000	8.25%	6.25%	2.00%	14,000	4,369	10%	2,000
Rockaway Cove	40,000	10%	$2,425,000	8.25%	6.25%	2.00%	55,000	17,475	10%	9,000
Linda Mar	80,000	10%	$4,851,000	8.25%	6.25%	2.00%	109,000	34,950	10%	18,000
Shelter Cove	25,000	10%	$1,516,000	8.25%	6.25%	2.00%	34,000	10,922	10%	6,000
Total/Avg.	**923,000**		**$53,168,000**				**1,274,000**	**436,271**		**477,000**

3.7 CLIMATE CHANGE IMPACTS TO THE REGION

Climate change and the resulting impacts of sea level rise, increased storminess, and large-scale ecological disturbances will influence sediment management strategies in California. When sea level rises, beaches narrow and access to accessible offshore sand deposits becomes more difficult and expensive. For southern California beaches, Flick and Ewing (2009) determined that required sand-placement volumes could be 7-9 times larger when the rate of sea level rise increases from 20 to 150 cm/yr. The USGS (2005) produced a coastal vulnerability study for the GGNRA that examined how climate change could affect the holdings of the federal government. They determined that most of the SFLC coastline had a ‘very high’ to ‘high’ level of vulnerability with only a small section at Point Lobos identified as ‘moderate’. Because of this knowledge, sea level rise was included equally in analyses throughout the SFLC.

3.7.1 Guidance for Climate Change Planning

The USACE (2011) guidance for the incorporation of direct and indirect physical effects of projected future sea level rise (recently updated in 2014) states that planning studies and engineering designs should evaluate alternatives against a range of local-sea-level-rise projections that are defined by “low”, “intermediate”, and “high” rates of local sea level rise. The “low” local sea level rise projection is the historic sea level trend as observed at a nearby long-term tide gauge. The USACE recommends using the National Research Council (NRC, 1987) curves to calculate the “medium” and “high” sea level rise estimates (based on NRC Curves I and III, respectively).

These scenarios were adjusted to local San Francisco historical trends of sea level rise, but there was not reliable vertical land movement data to incorporate. Three planning horizons of 2025, 2050 and 2100 were selected for use in determining coastal hazard zones for the CRSMP (Table 7).

Table 7: Sea level rise estimates (with 2000 as the baseline)

Year	“Low” (Historic Trend) (m)	“Intermediate” (NRC Curve I) (m)	“High” (NRC Curve III) (m)
2025	0.05	0.08	0.17
2050	0.10	0.19	0.47
2100	0.20	0.52	1.51

Based on USACE (2011) using the SLR trend of 2.01 mm/year measured at the San Francisco NOAA tide gauge.

The sea level rise scenarios do not include increased risks from storms. As part of a study for the Ocean Protection Council (OPC), PWA (2009) and Revell et al (2011) calculated the 100-year storm total water level (i.e., high water from tides plus wave runup) for each of the alongshore wave transformation points. Each erosion hazard zone is associated with one wave transformation point. The total water levels were estimated by selecting the maximum total water level from a 100-year time series of total water levels (with sea level rise removed). This time series was calculated using wave and water level outputs generated by global climate modeling efforts at Scripps Institute of Oceanography (Cayan et al, 2008).

The NRC (2012) report combines the major contributors to global sea-level rise (thermal expansion of the ocean and melting of global ice) to provide values of sea level rise at various planning horizons for the West Coast. The report also discusses regional and local contributions to sea level rise. The report gives four regional sea level rise estimates for California. The values for San Francisco Bay include an estimate for vertical land motion of -1.5 ± 1.3 mm/year, which is the same for all of California south of Cape Mendocino (Table 8).

Table 8: San Francisco Regional Sea Level Rise Projections Relative to Year 2000

YEAR	PROJECTION A1B SCENARIO	RANGE B1 AND A1F1 SCENARIO
2030	14.4 cm (5.7 in)	4.3 - 29.7 cm (1.7 - 11.7 in)
2050	28 cm (11.0 in)	12.3 - 60.8 cm (4.8 - 23.9 in)
2100	91.9 cm (36.2 in)	42.4 - 166.4 cm (16.7 - 65.5 in)

Guidance for planning agencies and municipalities continues to evolve as understanding and modeling improve, and future projects might have to revise elements of this Plan related to sea level rise. For example, in late 2012 the CCC developed a set of guidelines for incorporating sea level rise into Local Coastal Programs and Coastal Development Permits. Note that the alternative responses presented herein should be considered as base cases that use the USACE (2011) guidance with components of storm hazards from the OPC study.

3.7.2 Ecological Implications

Loss of habitat – e.g., sandy beach, bluff, lagoon – is a significant threat to coastal species. When unconstrained, beaches are resilient, changing shape and extent naturally in response to storms and variations in wave climate and currents. Hard structures (armor) that protect land and infrastructure from erosion or flooding lock the coastline in place. This is particularly stressful where it affects habitats and ecosystems that would normally move landward as the shoreline retreats. Consequently, a coastal squeeze develops in armored locations when there is a rise in sea level relative to the land (Doody, 2004). Onshore migration of the shore in response to sea level rise is expected as waves redistribute sediment and rework the shore face to conform with the higher water levels (Dean and Dalrymple, 2004), Shore armoring can block the shore migration, and change the shore condition. In this way, beach and other natural shores can be trapped between the impacts of urbanization on the terrestrial side and manifestations of climate change at sea. The effect of accelerating sea level rise is to increase the potential shore migration rate and also increase the loss of natural shores and beaches where armoring exists (Mellius and Caldwell, 2015; Caldwell and Segall, 2007). As described in the vulnerability assessment of the GGNRA (USGS, 2005), increased storminess along the San Francisco Peninsula will likely result in increased cliff erosion, retreat of beaches, loss of salt marsh, and dune scarping with vegetation loss. Anthropogenic modifications of the coastal zone severely limits this flexibility (Nordstrom, 2000). Furthermore, some of the climate change adaptation or erosion mitigation techniques (e.g., sand placement) can cause extensive habitat damage (Schlacher et al, 2007).

CHAPTER 4. EROSION AND COASTAL HAZARDS

4.1 BEACH EROSION CONCERN AREAS AS CRITICAL EROSION HOTSPOTS

The CSMW (2010) developed a preliminary list of Beach Erosion Concern Areas (BECAs) for the entire California coast and that list grows as more information becomes available. Criteria used to develop the list include:

1. The California Department of Boating and Waterways conducted a mail survey and subsequently field verified the responses,
2. Locations under investigation by USACE to determine federal interest in coastal erosion were added,
3. Various local and regional entities contributed their concerns,
4. Locations identified within completed CRSMPs were incorporated, and
5. Areas of coastal erosion known by CSMW members to be of concern to some jurisdictional entity that had not been identified through one of the above methods were added to the list.

Through this process, a location in the southern portion of Ocean Beach was identified as a BECA. No other SFLC beaches appear on the 2010 BECA list, so additional work was needed to determine if there are BECAS to add to the list (Criteria 4).

4.2 QUANTIFIED GEOMORPHIC MODELING OF HAZARD ZONES

This section provides an overview of the analysis methods used to establish wave-induced hazard zones for stretches of the coast that are not armored. For armored stretches, hypothetical hazard zones can be established by assuming that the armor is removed or fails, as well as allowing for increased wave overtopping. In the Daly City area, the upper bluff recession that has affected development is manifested by landslides, and therefore a separate landslide model is applied in this Reach. The datasets, methods, and assumptions are described in greater detail in Appendix A. The conceptual model tracks the shoreline location, backshore location[10], and beach width through time using the following criteria:

- Shoreline location: Three processes contribute to shoreline change: changes in sea level, changes in wave climate and wind patterns, and natural and anthropogenic changes in sediment supply. All of those processes can lead to erosion or accretion of a beach, but in the SFLC, beach and bluff retreat is forecast to be the dominant response. The impact of sea level rise is incorporated by assuming that the shoreline will move inland based on the shoreface slope and the amount of rise. The sea level rise curve used in this analysis is based on the “High” sea level rise scenario described in USACE (2011). This curve predicts 1.6 feet of sea level rise by 2050 and 5.0 feet by 2100 (relative to 2000). Prior studies indicate that the potential rate of shore recession caused by sea level rise will exceed the historic rate of shore erosion (Revell et al, 2012; PWA, 2009).

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[10] For beaches backed by dunes or structures, the backshore location represents the toe of the dune or structure. For reaches backed by bluffs, the backshore location is the toe of the bluff.

- Erosion from other coastal processes is estimated by adjusting historic erosion rates based on the beach width: a wider-than-natural beach experiences slightly higher shoreline erosion rates while a narrower-than-natural beach has lower erosion rates. This concept is predicated upon the assumption that the change (wider or narrower than "normal" beach) is a limited "perturbation" within the equilibrated shore morphology, and hence wave-driven sand transport will increase in proportion to the perturbation to remove it (Larson, Hansen and Kraus, 1987). The quantitative interpretation is that the potential rate of sand movement is greater than the magnitude of the sand placement. This presumption is considered appropriate for this study based on historic changes: Ocean Beach was "nourished" with sand and widened seaward hundreds of feet between 1900 and 1930, and then receded landward (Olmsted, 1979; Battalio and Trivedi, 1996; Battalio, 2014). If an offshore reef is present, the erosion rates are presumed lower because the wave power reaching the shore is reduced.
- Backshore location: The temporal response of the backshore depends on the chosen option. For example, armoring (e.g., a seawall) is designed to prevent backshore erosion, and the model assumes it prevents backshore erosion. For options where erosion is allowed to occur (i.e., no armoring), backshore location was modeled to move landward at a rate affected by beach width. The historic backshore erosion rate was reduced for wider beaches under the assumption that a wider beach would reduce the intensity and duration of waves reaching the backshore. Conversely, a narrower beach is assumed to increase backshore exposure to waves, so increased landward movement of the backshore is modeled.
- Beach width: Beach width is the distance between the shoreline and backshore.

The model provides some outputs that were used in the economic analysis including average beach widths over time, long-term backshore erosion, and the frequency of sand placement. This conceptual model does have some limitations, the most important of which are:

- It is not a hydrodynamic or sediment transport model.
- There is a lack of site-specific data to use as inputs and to calibrate the model. In particular:
    - Impact of offshore reefs on erosion rates, especially in combination with sea level rise.
    - Relationship of beach width to shoreline erosion and backshore erosion has been qualitatively observed, but limited data exist to calibrate the empirical relationships.
- The model assumes that sand placement is a temporary perturbation rather than one that is sufficient to permanently change the shore.
- It does not address erosion caused by terrestrial processes (e.g., landslides), which likely pose a greater threat than incremental annual shoreline erosion anywhere they are prone to happen.

4.3 EROSION HAZARD ZONES

Erosion hazard zones are used to analyze the economics and visualize the impacts of various management scenarios. The computation of erosion hazard zones was based on historic erosion rates and was modified for future climate and adaptation scenarios using the previously described model. A separate analysis of landslide potential was carried out for the Daly City reaches where tall bluffs exist. These Coastal Erosion and Landslide Hazard Zones are described below.

Coastal Erosion Hazard Zones

For areas that are not landslide dominant, the hazard zone distance was estimated as:

$HZ_{non\text{-}landslide} = E_{backshore} + Offset_{geometric} + E_{storm}$

Where:

Where: $HZ_{non\text{-}landslide}$ = Hazard zone width for non-landslide areas relative to existing backshore toe location

$E_{backshore}$ = Backshore erosion at time t

$Offset_{geometric}$ = Horizontal distance from backshore toe to crest (i.e. bluff crest relative to toe)

E_{storm} = Erosion potentially caused by a large storm (for dunes, calculated for a 100-year event)

An average storm hazard distance was calculated for each of the study reaches using storm set-back distances from PWA (2009) and Revell et al (2011). The previous studies did not consider beach width or management actions, so the potential storm erosion was modified by:

- adjusting by the change in beach width (a wider beach shifts the hazard zone seaward)
- capping the hazard distance to 100 ft to account for storms having finite duration (FEMA, 2005) and the ability of sand transport to mitigate local erosion extremes with the storm hazard distance based on the standard deviation of storm-based erosion rates. This erosion distance limit was most appropriate for the narrower beaches in south Ocean Beach, Daly City, and Pacifica where the erosion modeling was applied.
- reducing the potential storm erosion hazard distance by 50% for scenarios with offshore reefs, based on the presumption that the reefs would reduce incident waves. The storm hazard distance was not eliminated for armored shores (e.g., with seawalls and revetments) to allow for extensive wave overtopping that may occur after erosion of the beach and the increased potential for the structure to fail from scour and larger waves associated with beach loss.

Landslide Hazard Zones

Large, complex, rotational landslides characterize the Daly City shoreline. Terrestrial processes (e.g., groundwater levels, geology, landslides, land use) rather than coastal processes, largely drive the landslides in these areas, although coastal erosion at the toe of the bluffs maintains favorable conditions for landslides. Applying a simple erosion model driven by beach width would not address the main factors causing erosion in this area. A different method, based on coastal hazard mapping in Oregon for landslide-backed shorelines (Marra, 1995), was applied to landslide-prone reaches.

Ten representative transects were geomorphically interpreted to measure block failure widths, which averaged 312 ± 77 ft. To delineate the hazard zones, the active bluff edge was buffered by 389 feet and 701 feet to produce hazard zones representing one and two landslide block failures, including one standard deviation to represent uncertainties. The first block failure width inland of the active bluff edge is the high hazard zone (used to represent the 2050 hazard zone) and the second block failure width represents the moderate hazard zone (used to represent the 2100 hazard zone). Although the landslide hazard zones will be the same for all scenarios, sand placement would provide for a wider beach, which will provide some economic benefit. Beach widths were tracked using similar methods applied at other reaches.

4.4 EXISTING COASTAL ARMOR

In 2005, a statewide coastal armor GIS database was developed for the CCC using a combination of oblique aerial images from the California Coastal Records Photo website (www.californiacoastline.org) and georeferenced orthoimages (Dare, 2005). The database contains 1,807 polylines that represent coastal armor types including alongshore structures – bluff walls, infill, revetments, bulkheads, and seawalls – and other structures – breakwaters, groins, and jetties. The bluff walls were classified as either mid-bluff or upper-bluff walls. Other attributes in the database include structure material, comments, image source, source date, and county. The accuracy of the database attributes depends on the investigator's ability to visually identify structure types and materials from oblique photos. The linear representations of the structures are along a single California shoreline[11] and do not represent the actual alignment of structures in three-dimensional space.

For this Plan, ESA updated the Dare (2005) geodatabase using California Coastal Records photos taken in 2010 (ESA PWA, 2012). Additionally, the representative polylines were moved from the single shoreline (as they are in the Dare [2005] database) to their actual cross-shore locations by heads-up digitizing the alignment using 2010 National Agriculture Imagery Program (NAIP) orthoimagery. Revetments were digitized in a separate polygon shapefile to capture their two-dimensional surface extent visible at the time the photo was taken. A field visit was completed in December 2011 to ground truth the changes since 2005 and note additional changes since 2010. All discrepancies between recorded and observed attributes were corrected in the final version of the geodatabase. The field visit did not use quantitative methods (GPS points or surveying) to confirm locations or elevations of armoring. These data were included in the GIS deliverable to the CRSMP Project Team in February 2012.

For the purposes of this Plan, the presence of coastal armor helps inform how active that erosion may be at a location. The following types of coastal armor were defined and quantified by reach (Table 9) to assist in identifying critical erosion areas along the SFLC shoreline.

- Seawall – A wall that sits on the beach and does not extend all the way to the top of the bluff (that would be considered an upper bluff wall).
- Mid Bluff Wall – A wall that sits at an elevation above the beach but does not reach the top of the bluff.

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[11] The shoreline used for this database is believed to be the NOAA medium shoreline (1:100,000).

- Upper Bluff Wall – A wall that may or may not start on the beach but extends to the top of the bluff. Includes walls set on the top edge of the bluff.
- Revetment – A facing of erosion-resistant material (e.g., stone, concrete) built to protect a scarp, embankment, or shore structure against erosion by wave action or currents. Revetments were classified using polygons because the size of the revetments can vary significantly from one revetment to the next and even within a single revetment. The objective was to avoid classifying piles of rocks that were not intentionally placed as armoring. But it is not always obvious which rock piles were revetments and which were natural.

Table 9: Coastal armor in the littoral cell reaches

Reach #	Reach	Reach Length*	Length Unarmored	Length of Shore-Parallel Armoring, by type (feet)				
		(feet)	(feet)	revetment	upper bluff wall	mid bluff wall	seawall	levee
1	Baker Beach	8,300	7,100	0	332	571	1,737	0
2	China Beach	1,100	400	0	332	434	547	0
3	Pt Lobos	8,000	4,350	310	100	691	625	0
4	North Ocean Beach	5,600	0	0	0	886	5,055	0
5	Middle Ocean Beach	10,500	7,050	0	0	0	3,676	0
6	South Ocean Beach	7,500	4,900	2730	236	428	103	0
7	Fort Funston	2,500	2,500	0	0	0	0	0
8	Daly City	14,700	12,480	2,220	0	2,499	0	0
9	Mussel Rock	1,800	1,330	470	0	301	0	0
10	Manor District	6,900	3,800	2,790	188	758	0	0
11	Beach Boulevard	5,200	550	3,110	430	0	3,024	0
12	Sharp Park	4,000	800	1,400	0	0	0	3200
13	Hidden Cove	3,200	3,200	0	0	0	0	0
14	Rockaway Cove	2,700	1,360	1,340	0	0	200	0
15	Linda Mar	7,500	6,350	0	0	0	1,142	0
16	Shelter Cove	3,000	2,883	0	0	0	117	0
	Totals	92,500	62,053	14,370	1,618	6,569	16,228	3200
	Estimated % of Shoreline*		67	16	2	7	18	3

* The length of reach not necessarily the sum of all armored and unarmored lengths because of the geometry of the seawalls and bluff walls (not always shore parallel, and sometimes present in the same location). Therefore, percentages are overestimates.

4.5 REGIONAL CRITICAL EROSION HOTSPOTS

Information from the geomorphic analysis, habitat assessment, and outreach meetings was combined to develop a list of critical erosion hotspots along the SFLC coastline (Table 10). Nine locations in the region were identified – two in San Francisco, two in Daly City, and five in Pacifica. Although these are termed ‘critical’, the regional nature of sediment transport in the ocean and land management should be considered holistically to understand that other locations also could benefit from a targeted erosion mitigation treatment.

Table 10: SFLC critical-erosion hotspots

REACH #	REACH	HOTSPOT
1	Baker	
2	China	
3	Pt. Lobos	
4	NOB	
5	MOB	●
6	SOB	●
7	Ft. Funston	
8	Daly City (north to south)	
8.1	Upper	
8.2	Middle	●
8.3	Lower (Landfill)	●
9	Mussel Rock	
10	Manor District	●
11	Beach Boulevard	●
12	Sharp Park	●
13	Hidden Cove	
14	Rockaway Cove	●
15	Linda Mar	●
16	Shelter Cove	

4.6 INFRASTRUCTURE AND HABITAT ZONES CURRENTLY AT RISK

The nine critical erosion hotspots occur in heavily urbanized and recreational areas. Quantifying the existing risks in these hotspots establishes a baseline to develop strategies relevant to each location. To that end, the intricate network of coastal roads, pipelines, trails, and other utilities from San Francisco to Pacifica were overlaid on the most recent coastal hazard zone map to determine what elements of the infrastructure are at risk (Table 11). The number and type of parcels affected in the existing hazard zone were also compiled. In addition, habitat zones as defined by GGNRA and special-species zones provided by GGNRA and other sources were noted if any portion fell within the coastal hazard zone.

Table 11: Infrastructure, habitat, and species currently at risk

Reach #	Reach	Parcel Type (#) Commercial	Government	Residential	Unknown Vacant Land	Streets (ft)	Trails (ft)	Pipelines (ft)	Pump stations (#)	Outfalls (#)	Sewer (ft)	Habitat	Species*
5	MOB	0	2	0	0	5,591	10,577	2,787	0	0	6,249	Beach; dune grass	Snowy plover
6	SOB	0	5	0	0							Beach; dune grass; dune sagewort; dune	Bank swallow
8	Daly City												
8.2	Middle	7	35	814	22	25216	0	2191	0	0	0	Beach	
8.3	Lower (Landfill)	0	1	0	0	N/A	N/A	N/A	N/A	N/A	N/A	Beach	
10	Manor District	1	18	57	8	2,463	4,548	1,527	0	1	3,671	Beach	
11	Beach Boulevard	5	17	31	5	375	1,653	355	0	7	129	Beach	
12	Sharp Park	0	2	0	0	0	3,355	495	0	0	0	Beach; freshwater pond	*
14	Rockaway Cove	3	1	0	2	886	630	452	0	1	18	Beach	
15	Linda Mar	1	14	1	4	588	1,424	954	0	0	3,111	Beach; dunes	Snowy plover

* additional special status species are present in many of the reaches, such as red-legged frog and San Francisco garter snake in Sharp Park in the vicinity of Laguna Salada in the Sharp Park Golf Course and GGNRA Mori Point unit. Their habitats of residence, however, are not immediately at risk in the critical erosion hotspots although this is expected to change in the coming decades.

CHAPTER 5. ADDRESSING EROSION LOCATIONS

5.1 MEASURES AND ALTERNATIVES

A management measure is a feature or an activity that can be implemented at a specific geographic site to address one or more planning objectives. Management measures are the building blocks of alternative plans and are categorized as non-structural and structural. Non-structural measures reduce risk by modifying the characteristics of the buildings and structures that are subject to the effects of erosion or modifying the behavior of people living in or near potential erosional areas. Structural measures reduce risk by modifying the characteristics of the erosion. With regard to coastal erosion, they are often employed to reduce or refocus wave energy, direct water away from damageable property, or protect infrastructure. The following measures are deemed appropriate for erosion response in the SFLC, but there are others that might be appropriate in specific areas.

- No Action – Allow natural processes to occur without intervention. The shoreline, backshore, and bluffs (or dunes) are allowed to erode unimpeded except where armoring already exists. As sea level rises, shoreline erosion is predicted to occur at a higher rate than backshore erosion, even where unarmored, resulting in a beach that narrows over time, depending on the maximum estimated bluff erosion rate. Where armoring exists, the beach width decreases over time because the backshore cannot move landward.
- Sand Placement – Move the shoreline seaward by placing sand imported from other locations onto the foreshore. The amount of placed sand depends on the beach length and the sand placement width (50 or 100 feet, depending on the reach and scenario). Sand placements are triggered whenever the beach reaches a specified "minimum beach width".
- Sand Placement with Artificial Reefs – The sand placement component of this measure is treated in the same manner as described in Sand Placement. Offshore reefs have successfully demonstrated the ability to widen the beach through the formation of a salient (a landform that extends out beyond its surroundings) along the beach behind the reef (Mead 2009, Black 2001). Eventually the beach reaches a new, wider equilibrium. Another benefit of offshore reefs is wave sheltering. Future erosion rates are expected to decrease because of the added protection provided through wave dissipation at the reef. There are limited data with which to quantify the extent that offshore reefs would change shoreline movement rates, especially with sea level rise. Multi-purpose reefs have been used in other parts of the world and are being considered in California. A reef constructed in Santa Monica Bay did not perform well and was removed. The poor performance was associated with the reef being too small to adequately affect incident waves (Leidersdorf et. at., 2011). Reef construction is being studied for a location called "Oil Piers" in Ventura County, but it is not certain when installation will occur.
- Hold the Line – This measure consists of coastal armoring, including maintaining existing armoring (e.g., seawalls, revetments) where it currently exists. With continued shoreline erosion and the additional impact of sea level rise, the beach will continue to narrow. Some hazard still remains behind the structures because of high-velocity flooding and the potential for failure during major erosion (e.g., a 100-year event). For the purpose of this analysis, the presence of a structure is assumed to reduce the landward extent of the coastal hazard zone by 50%. This value was

selected to reflect the increased loading on the structure and potential for overtopping that produces flooding. Infrastructure was selected using one of two criteria: 1) construction and maintenance originate from public sources such as the federal, state or local government, or 2) construction is recent enough to be considering sea level rise and occurred with the approval of the CCC (e.g., Lands End in Pacifica).

- <u>Managed retreat</u> – This measure reduces impacts by moving development away from sensitive and vulnerable coastal lands. The activities for the measure may entail rerouting roads and utilities, removing public and private buildings, and relocating landfills to establish a buffer zone between the ocean and terrestrial development. This measure is different from the No Action measure because it may combine other approaches, such as short-term sand placement and armoring, to allow communities time to conduct a deliberate movement out of the hazard zone. Overall, this is a non-structural measure. The measure is also considered a 'Strategy' in describing the Alternatives below.

Table 12 summarizes where the measures could be appropriate within the SFLC. Reaches that are not critical erosion hotspots, highlighted in gray, are not discussed further.

Table 12: Summary of measures

Reach	Measure				
	(A) No Action[1]	(B) Sand Placement	(C) Sand Placement with Artificial Reefs	(D) Armor[2]	(E) Managed Realignment
Baker	●				
China	●				
Pt. Lobos	●				
NOB	●				
MOB	●	●		●	●
SOB	●	●	●		●
Ft. Funston	●				
Daly City (north to south)					
1. Upper	●				
2. Middle	●	●	●		●
3. Lower (Landfill)				●	●
Manor District		●	●	●	●
Beach Boulevard		●	●	●	●
Sharp Park	●	●	●	●	●
Hidden Cove	●				
Rockaway Cove	●	●		●	●
Linda Mar	●	●			●
Shelter Cove	●				

● – a primary measure for use in the alternatives

1 – allow natural processes without intervention
2 – maintain armor such as sea walls or revetments, to "hold the line" against erosion of backshore.

An alternative plan is a set of one or more management measures functioning together to address one or more objectives. Alternatives should be in compliance with existing statutes, administrative regulations, and common law or include proposals for changes as appropriate. A limited number of alternatives were developed for critical areas of concern. In addition, the scope of the project focuses on measures that are alternatives to shoreline armor, when reasonable, as directed by the CSMW objectives (Section 1.2). Table 13 presents a detailed description of the alternatives for the critical areas of concern. There are four alternatives:

- Beach Nourishment – this alternative solely uses the Sand Placement measure (Measure B) for the length of the reach with varying amounts of initial sand placement. A minimum beach width triggers a new placement. Backshores have differing treatments specific to the reach, such as being erodible or holding a particular line at existing armor.
- Beach Nourishment and Multi-purpose Reefs – this alternative solely uses the Sand Placement with Artificial Reefs measure (Measure C) for the length of the reach.
- Armor – this alternative uses the Hold the Line measure (Measure D) for the length of the reach. This could entail addition of armor in places where it currently does not exist.
- Hybrids with Managed Realignment Strategy – this alternative uses a combination of the measures to accomplish the goal of mitigating coastal erosion. Portions of a reach (called Subreach in the subsequent tables) are treated with different measures, and the sum of the measures equals the whole reach length.

Table 13: Detailed Description of Alternatives for Shore Reaches

Reach	Alternative 1 Beach Nourishment	Alternative 2 Beach Nourishment and Multi-purpose Reefs	Alternative 3 Armor	Alternative 4 Hybrids with Managed Realignment Strategy: Subreach 4(i)	Alternative 4 Hybrids with Managed Realignment Strategy: Subreach 4(ii)
MOB	"Sand Placement" Within a Managed Realignment Strategy: USACE to pump 1.5 Mcy of sand every ~20 years to widen beach by 50'. Do not allow erosion at the backshore.*	N/A	N/A	"Hold the Line" At seawall locations through maintenance. Other areas in reach receive treatment in Subreach 4(ii).	"No Action": Allow erosion
SOB	"Sand Placement" Within a Managed Realignment Strategy: USACE to pump 0.5 Mcy every ~20 years to widen beach by 50'. Erodible up to 150 feet.*	"Sand Placement with Artificial Reefs" Within a Managed Realignment Strategy: 50' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Erodible up to 150 feet. Offshore reef added.	N/A	"No Action" Allow erosion	N/A
Daly City, section 2 (middle)	"Sand Placement" Within a Managed Realignment Strategy: 50' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore still allowed to erode.	"Sand Placement with Artificial Reefs" Within a Managed Realignment Strategy: 50' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode. Offshore reef added.	N/A	"No Action" Allow erosion	N/A
Daly City, section 3 (lower)	N/A	N/A	"Hold the Line" At the current backshore position	"Managed Realignment": Allow erosion after removal of landfill	N/A
Manor District	"Sand Placement" Within a Managed Realignment Strategy: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode.	"Sand Placement with Artificial Reefs" Within a Managed Realignment Strategy: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode. Offshore reef added.	"Hold the Line" At the seawall and add armor where it currently does not exist.	"Hold the Line" At selected seawall locations through maintenance. Other areas in reach receive treatment in Subreach 4(ii).	"Sand Placement": 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Allow backshore to erode.

Reach	Alternative 1 Beach Nourishment	Alternative 2 Beach Nourishment and Multi-purpose Reefs	Alternative 3 Armor	Alternative 4 Hybrids with Managed Realignment Strategy Subreach 4(i)	Alternative 4 Hybrids with Managed Realignment Strategy Subreach 4(ii)
Beach Boulevard	“Sand Placement”: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at backshore.	“Sand Placement with Artificial Reefs”: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at backshore. Offshore reef added.	“Hold the Line” At the seawall and add armor where it currently does not exist.	“Hold the Line” At selected seawall locations through maintenance. Other areas in reach receive treatment in Subreach 4(ii).	“Sand Placement”: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode.
Sharp Park[1]	“Sand Placement” Within a Managed Realignment Strategy: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode.	“Sand Placement with Artificial Reefs” Within a Managed Realignment Strategy: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore still allowed to erode. Offshore reef added.	“Hold the Line” At the levee and revetment	“No Action” Allow erosion	N/A
Rockaway Cove	“Sand Placement”: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at the backshore.	N/A	N/A	“Hold the Line” At the seawall and revetment locations through maintenance. Other areas in reach receive treatment in Subreach 4(ii).	“No Action” Allow erosion
Linda Mar	“Sand Placement” Within a Managed Realignment Strategy: 100' of sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore erodible.	N/A	N/A	“No Action” Allow erosion	N/A

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* - Sand placement approach at MOB and SOB is consistent with the OBMP

1 – The Sharp Park Golf Course is in the Sharp Park reach.

In summary, the measures and alternatives are a spectrum of possibilities balanced among no action and hard and soft structures (sand placement is considered a soft structure) along the shoreline. This is shown graphically (Figure 11): measures occupy the edges along the spectra and alternatives are inward from the edges to reflect the combination of individual measures. For example, Measure C (Sand Placement with Artificial Reefs) is a balance between hard and soft treatments but Alternative 2 (Beach Nourishment with Multi-purpose Reefs) combines Measure C with no action in some locations, which moves Circle 2 towards the No Action vertex of the Conceptual Solution Space. The Hybrids are a special case as they vary by reach. As a result, Circle 4 occupies space in the diagram that covers all proposed possibilities.

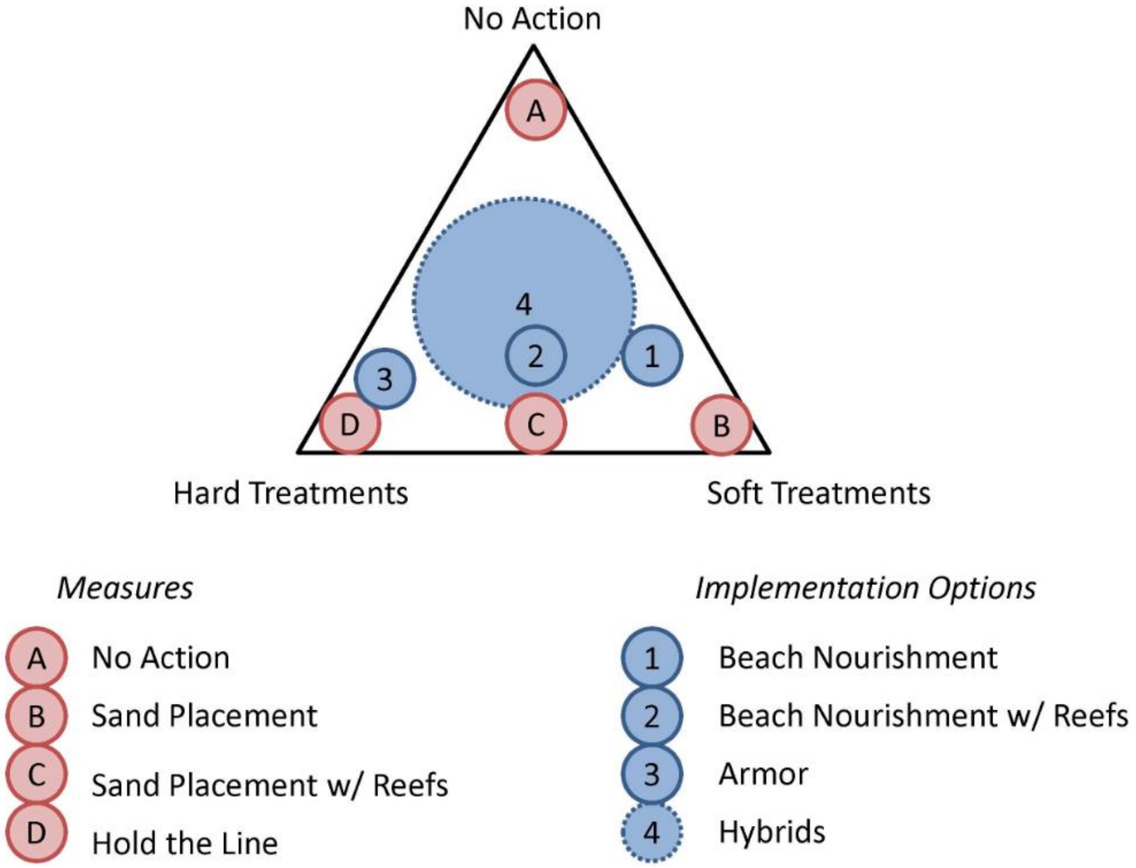


Figure 11: Conceptual Solution Space

5.2 Application of Alternatives to Critical Erosion Hotspots

The success of an alternative will be determined by the criteria set by the communities and agencies involved in sediment management. Those criteria can consider property, infrastructure, ecology, ecosystem services, funding, recreation, and other community values. Therefore, the application of the alternatives explored below is a preliminary step toward understanding sediment management activities in this area.

In addition to beach width, the property and infrastructure at risk changes in response to the alternative (Table 14). The hazard zones associated with each alternative were overlaid with existing infrastructure and tabulated. The armor alternative shows the least amount of risk from a strictly ‘built environment’ perspective of parcels, streets, trails, sewers, pipelines, and outfalls. Property and infrastructure can be still at risk under alternatives that use sand placement with or without reefs but with the added benefit of a beach environment. The hybrid alternative that varies in action by reach also creates beach environments with property and infrastructure at risk.

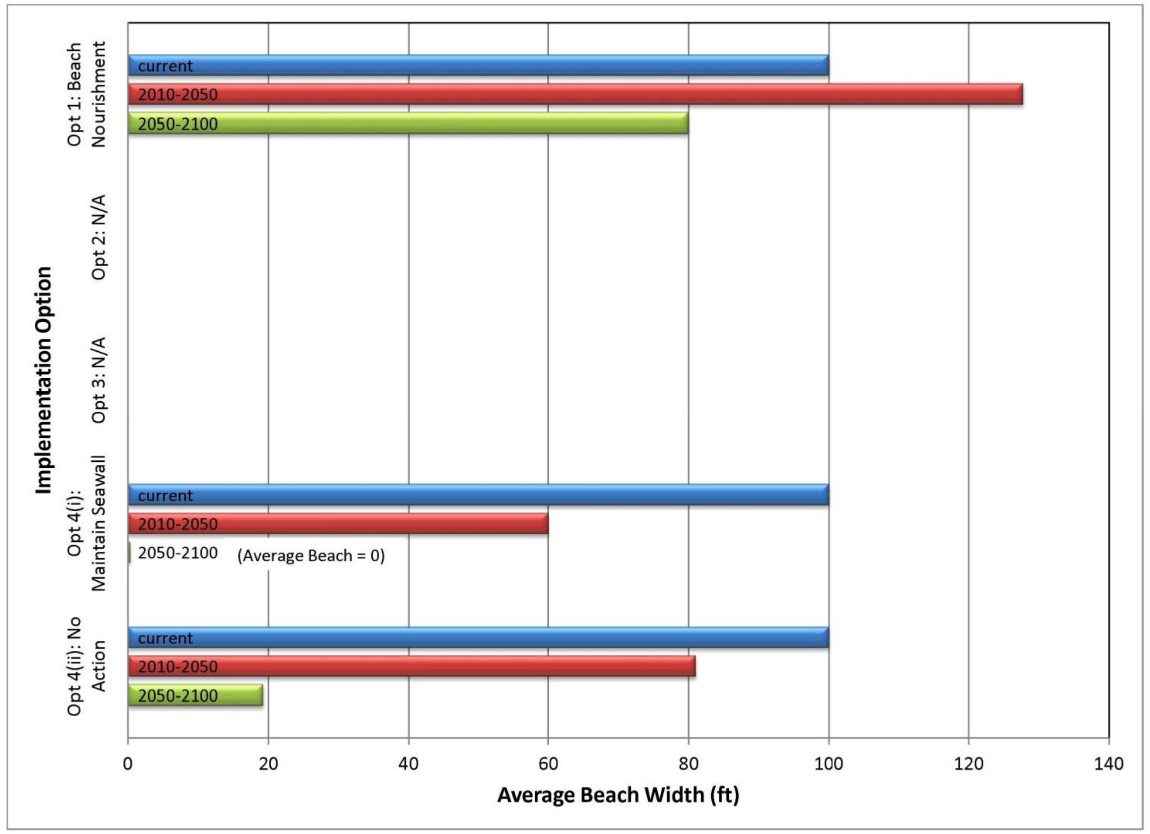
Figure 12 through Figure 20 present tables and figures summarizing sand placement frequencies (when appropriate), average beach widths for the management scenarios, and the economic calculations described in Section 6. The application of the alternatives for each reach can be put in context with the final erosion hazard zones shown in Appendix B Detailed Coastal Hazard Maps. In general, average beach widths are largest in the mid-century timeframe from active sand placement activities before sea level rise begins to accelerate. The frequency of sand placement increases through the century because of increasing sea level rise. When a reef is co-located with sand placements, the frequency of placement decreases, and the average beach width is generally larger. Average beach width is smallest for scenarios that involve maintaining shore armor (seawalls, revetments, and levees), although other benefits, such as infrastructure protection, are not seen by focusing solely on average beach width. Because scenarios that incorporate managed retreat will require a more robust analysis that involves community input, average beach widths were not calculated when this measure is used in the management scenarios.

Table 14: Infrastructure at Risk under different Alternatives

		Parcel Type (#)									
Reach	Alternative	Commercial	Governmental	Residential	Unknown Vacant Land	Streets (ft)	Trails (ft)	Pipelines (ft)	Sewer (ft)	# Pump stations	# Outfalls
5	1	0	2	0	0	6,743	10,577	4,258		0	0
	2	–	–	–	–	–	–	–		–	–
	3	–	–	–	–	–	–	–		–	–
	4	0	2	0	0	11,717	10,577	7,046		0	0
6	1	0	5	0	0	729	346	1,513	8,228	0	2
	2	–	–	–	–	0	293	1,195	–	0	2
	3	–	–	–	–	–	–	–	–	–	–
	4	0	5	0	0	5,580	525	4,450	11,891	0	2
8.2		9	36	1,388	23	58,503	0	2386	0	0	0
8.3	–										
10	1	1	18	65	9	2,793	4,867	1,710	4,224	0	3
	2	1	18	60	8	2,741	4,821	1,969	4,104	0	3
	3	0	0	0	0	0	0	183	0	0	2
	4	1	19	55	7	2,463	4,548	1,710	3,649	0	3
11	1	5	17	31	5	375	1,653	943	729	0	9
	2	5	17	31	5	375	1,653	587	729	0	9
	3	0	0	0	0	0	0	0	0	0	0
	4	5	20	41	6	3,205	2,373	943	3,510	0	10
12	1	0	2	0	0	0	3,552	1,341	0	0	2
	2	0	2	0	0	0	3,425	1,371	0	0	2
	3	0	2	0	0	0	3,959	2,033	0	0	2
	4	0	2	0	0	0	3,361	1,341	0	0	2
14	1	3	1	0	4	886	630	652	18	0	3
	2	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–
	4	3	1	0	4	1,036	1,249	652	781	0	5
15	1	1	14	1	8	588	1,424	2,324	3,111	1	7
	2	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–
	4	2	15	6	9	3,914	4,025	2,324	6,129	3	7

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, USACE to pump 1.5 M cy every 20 years to widen beach by 50'. Do not allow erosion at the backshore.*	2	5	2010, 2030, 2051, 2072, 2093
2	N/A for this reach	N/A	N/A	N/A	N/A
3	N/A for this reach	N/A	N/A	N/A	N/A
4(i)	Hold the Line	At the seawall locations through maintenance.	0.57	N/A	N/A
4(ii)	No Action	Allow erosion	1.43	N/A	N/A

* - Sand placement approach at MOB and SOB is consistent with the Ocean Beach Master Plan



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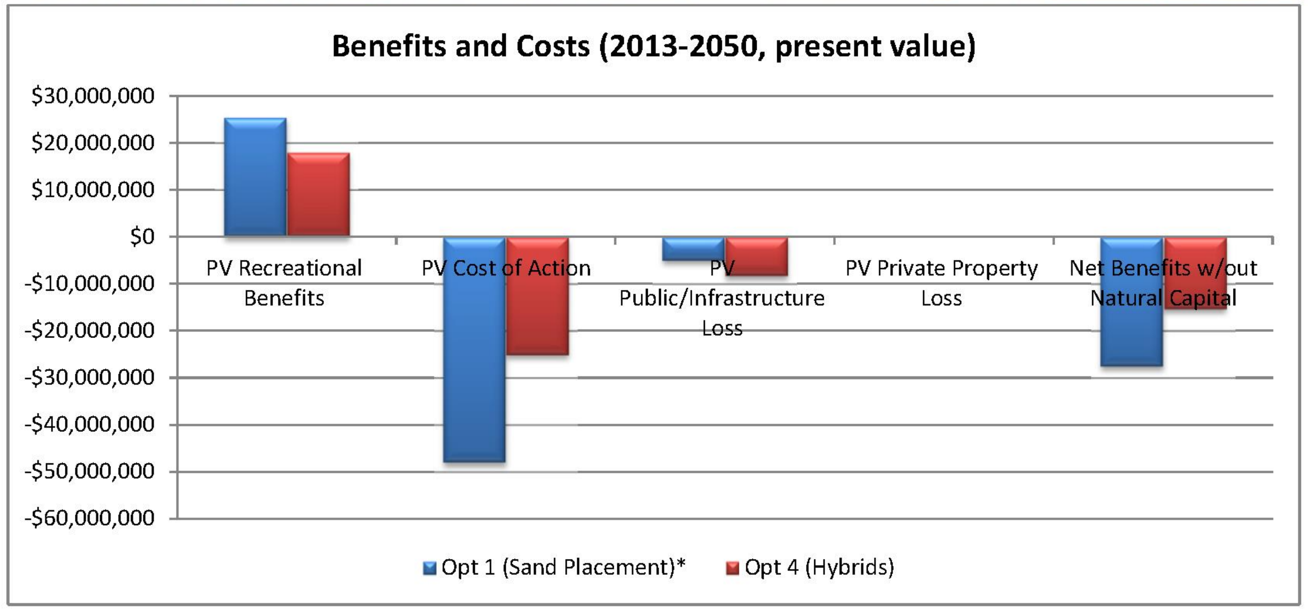


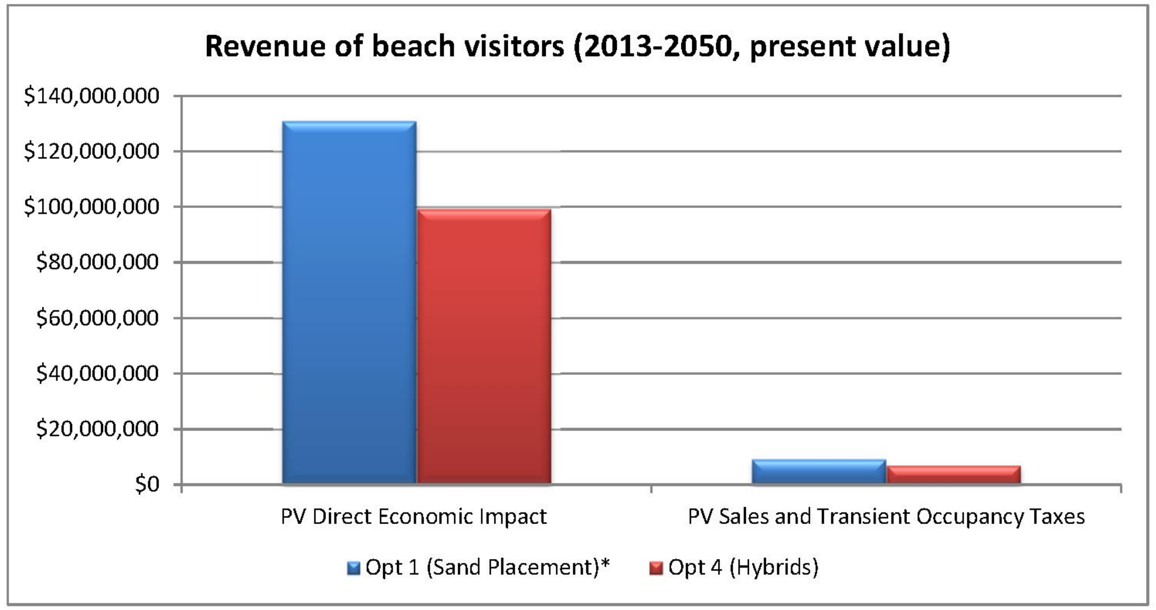
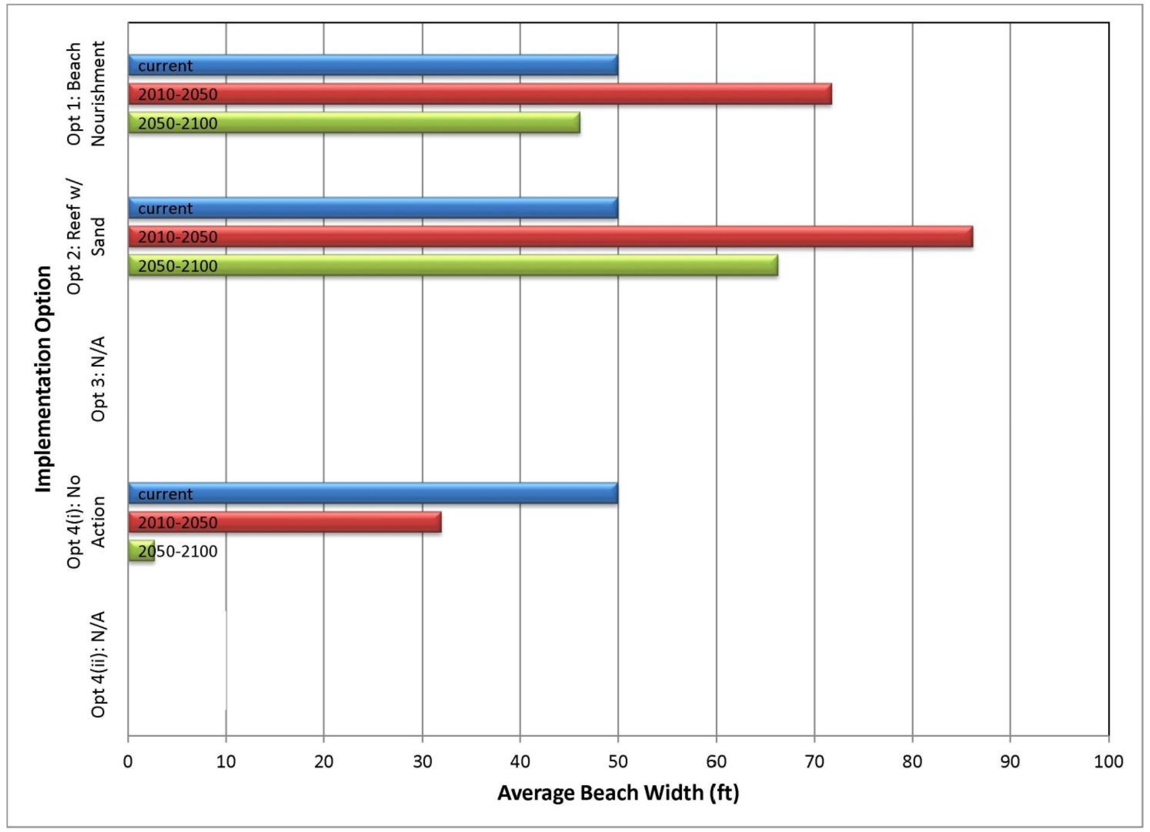


Figure 12: Middle Ocean Beach Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, USACE to pump 0.5 M cy every 20 years to widen beach by 50'. Erodible up to 150 feet.*	1.43	5	2010, 2030, 2051, 2072, 2093**
2	Sand Placement with Artificial Reef	Within a Managed Realignment Strategy, 50' sand placement the first year, and then every time the beach width falls below the minimum beach width. Erodible up to 150 feet. Offshore reef added.	1.43 (sand), 1.07 (reef)	5	2010, 2034, 2055, 2076, 2097**
3	N/A for this reach	N/A	N/A	N/A	N/A
4(i)	No Action	Allow erosion	1.43	N/A	N/A
4(ii)	N/A for this reach	N/A	N/A	N/A	N/A

* - Sand placement approach at MOB and SOB is consistent with the Ocean Beach Master Plan (OBMP)

**- The frequency of sand placement was determined by the OBMP resulting in an identical number of placements but a wider beach when an artificial reef is employed.



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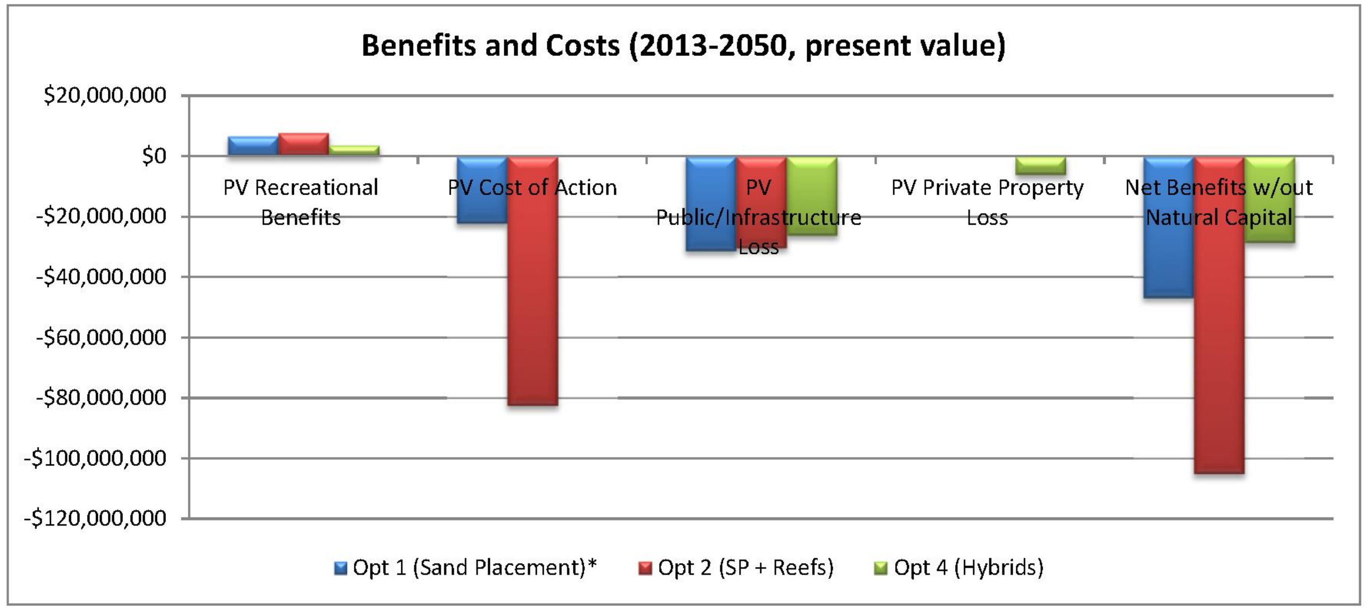


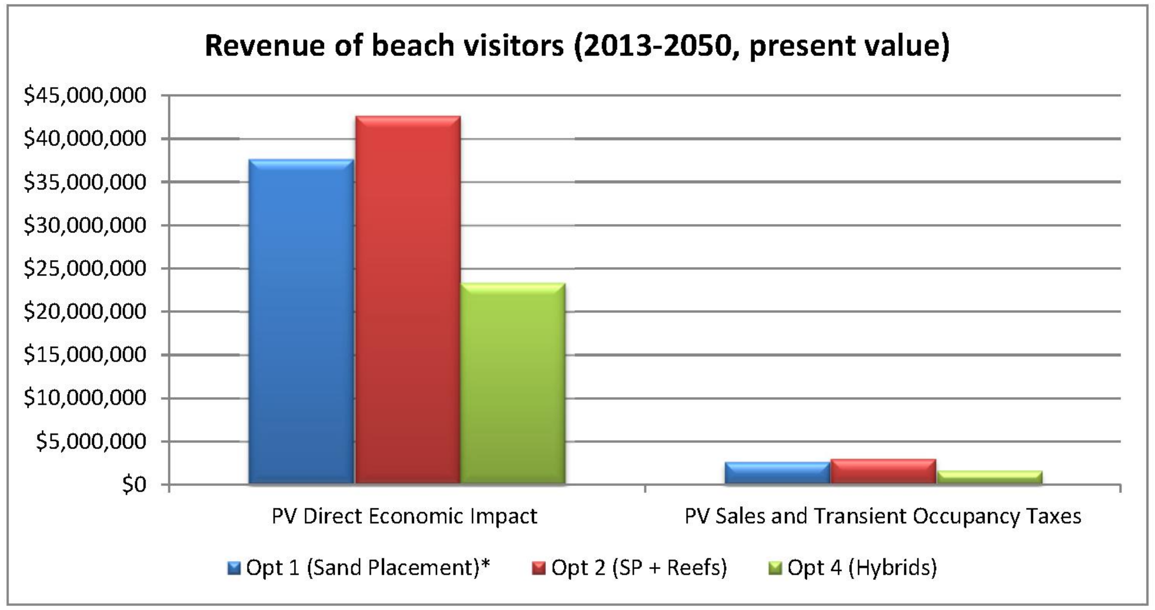
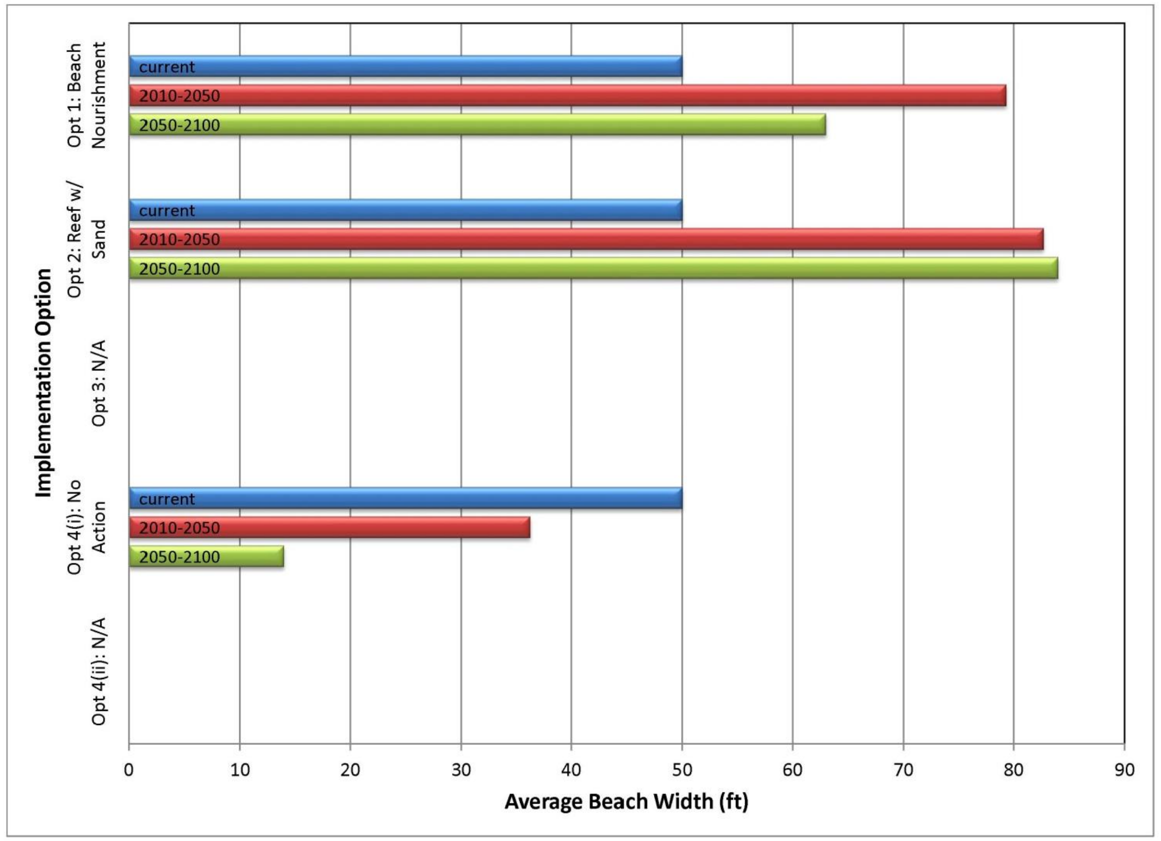


Figure 13: South Ocean Beach Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, 50' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore still allowed to erode.	2.79	9	2010, 2020, 2031, 2042, 2053, 2064, 2075, 2086, 2097
2	Sand Placement with Artificial Reef	Within a Managed Realignment Strategy, 50' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode. Offshore reef added.	2.79	6	2010, 2031, 2050, 2065, 2078, 2090
3	N/A for this reach	N/A	N/A	N/A	N/A
4(i)	No Action	Allow erosion	2.79	N/A	N/A
4(ii)	N/A for this reach	N/A	N/A	N/A	N/A



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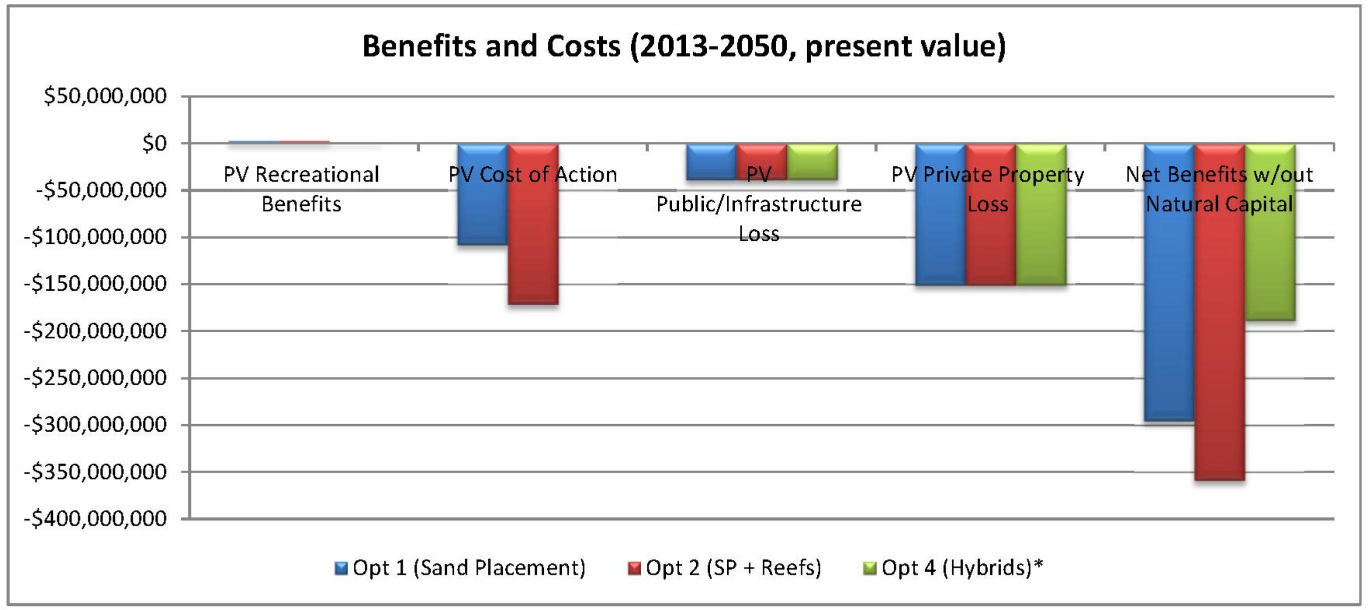


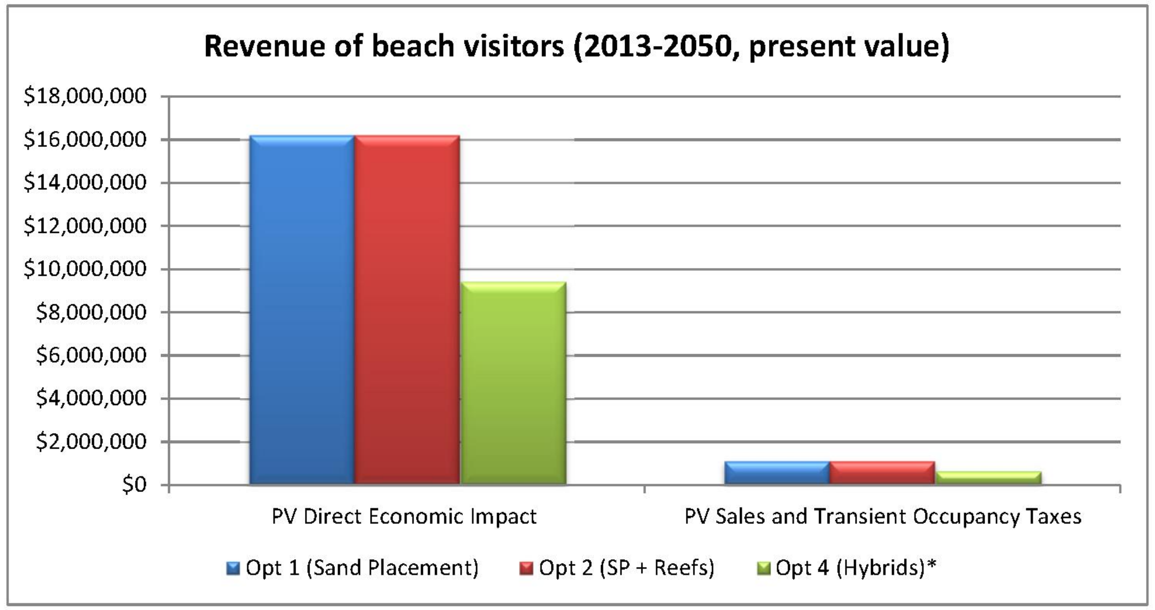
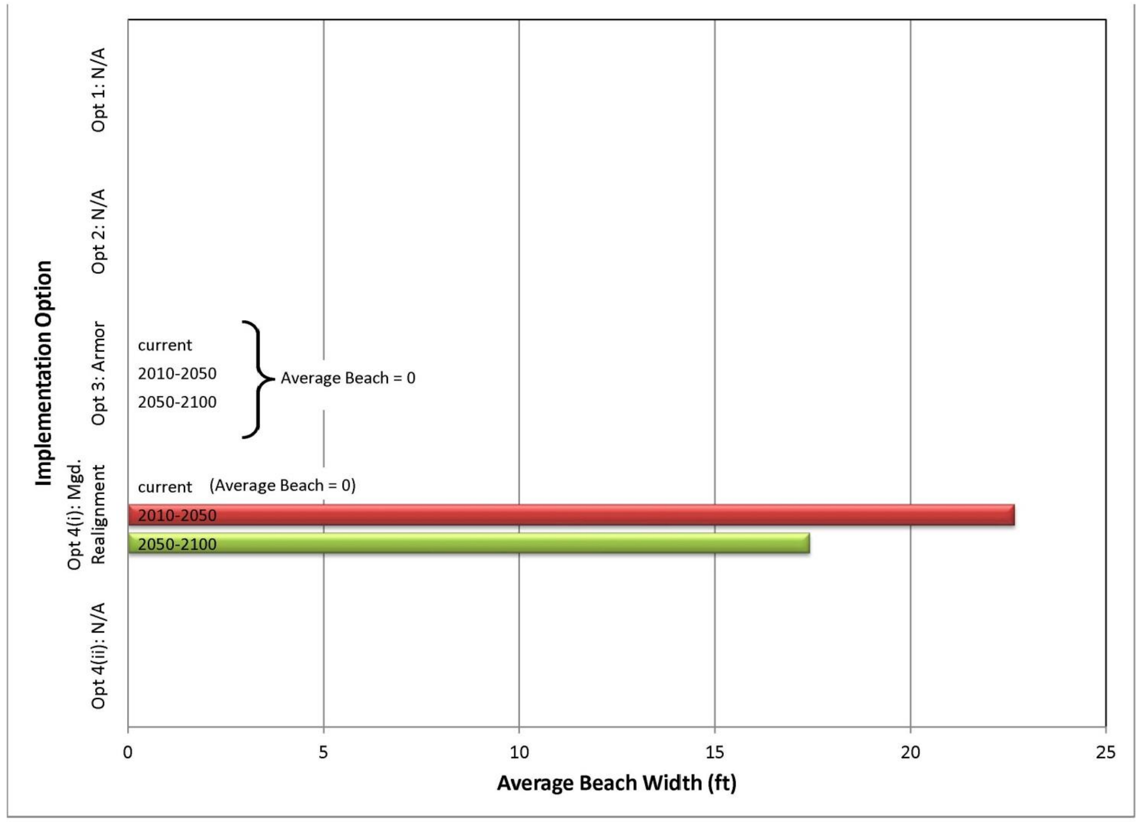


Figure 14: Daly City, Section 2 Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	N/A for this reach	N/A	N/A	N/A	N/A
2	N/A for this reach	N/A	N/A	N/A	N/A
3	Hold the Line	At the current backshore position	0.45	N/A	N/A
4(i)	Managed Realignment	Allow erosion after removal of landfill	0.45	N/A	N/A
4(ii)	N/A for this reach	N/A	N/A	N/A	N/A



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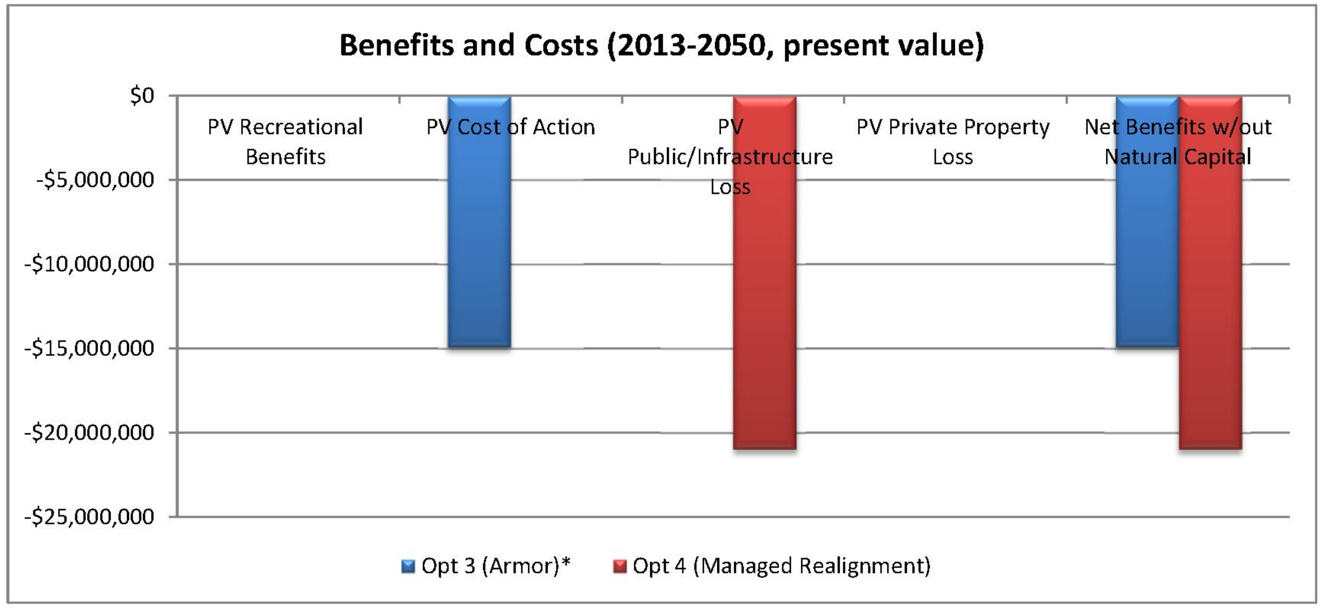
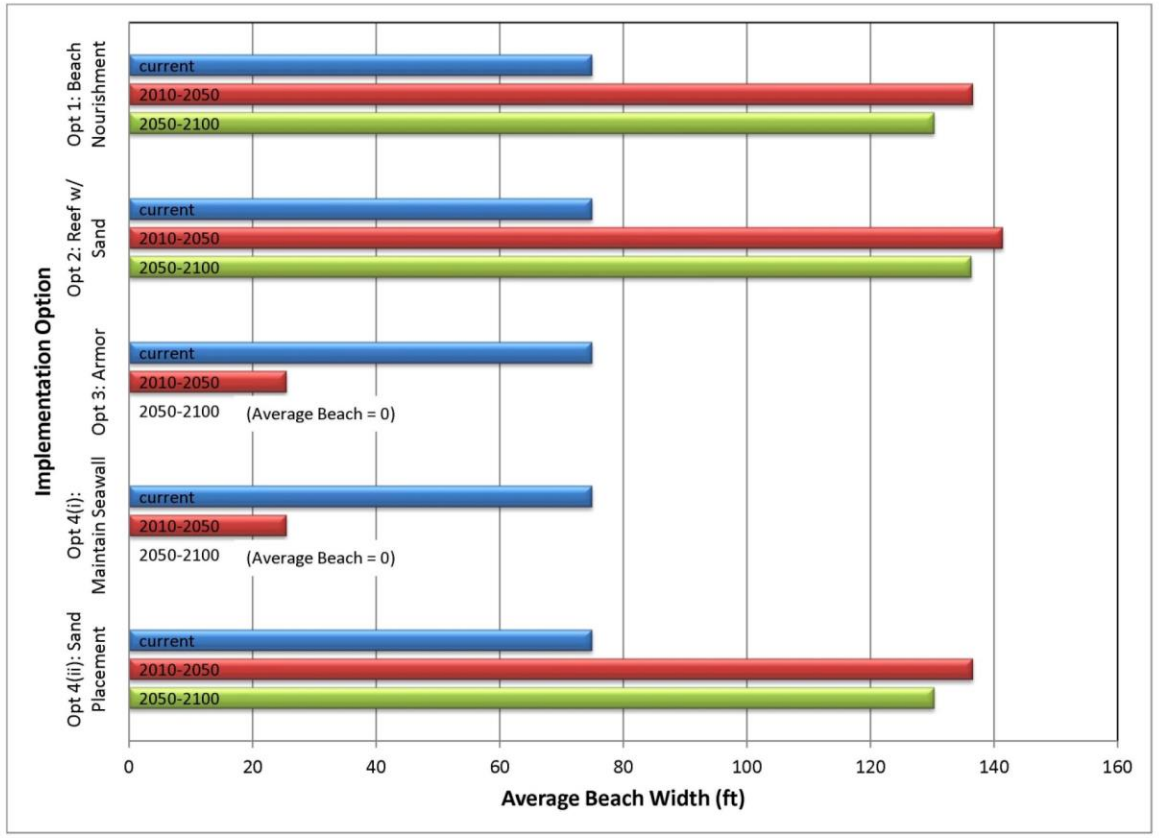


Figure 15: Results Summary: Daly City, Section 3 Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, 100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode	1.18	7	2010, 2025, 2042, 2057, 2071, 2085, 2098
2	Sand Placement with Artificial Reef	Within a Managed Realignment Strategy, 100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode. Offshore reef added	1.18 (sand), 0.79 (reef)	4	2010, 2043, 2072, 2096
3	Hold the Line	At the seawall, including addition of armor where it currently does not exist.	1.18	N/A	N/A
4(i)	Hold the Line	At selected seawall/revetment locations through maintenance.	0.38/0.17	N/A	N/A
4(ii)	Sand Placement	100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Allow backshore to erode.	0.76	7	2010, 2025, 2042, 2057, 2071, 2085, 2098



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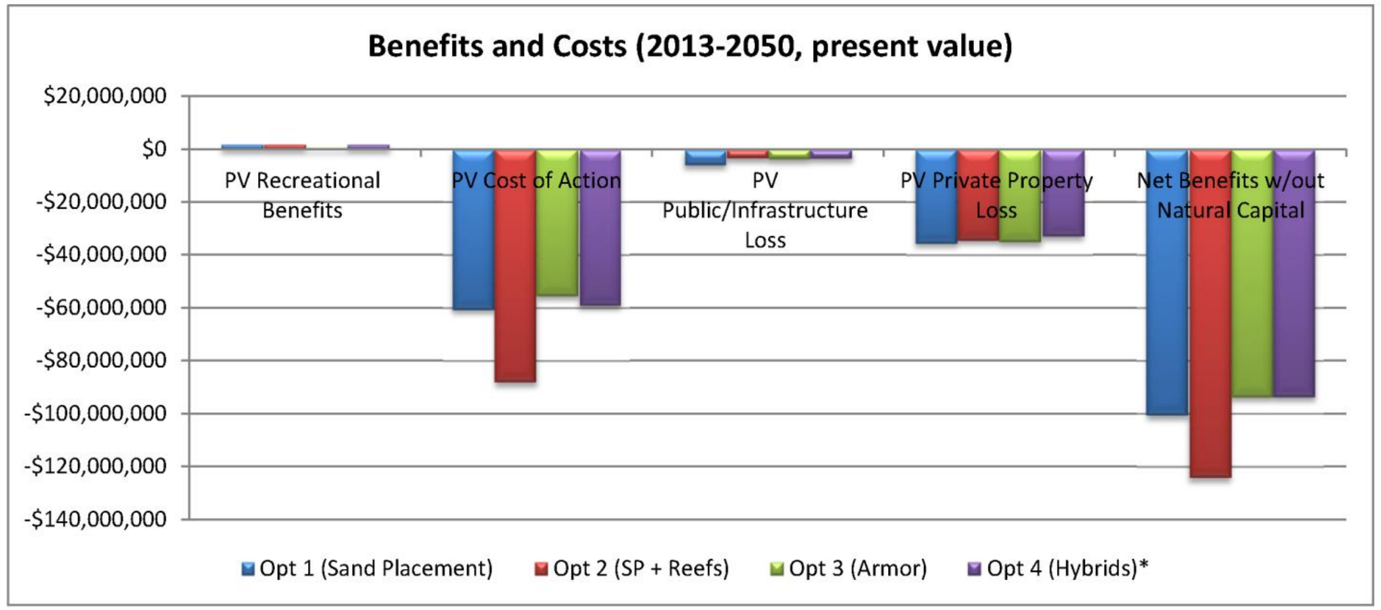


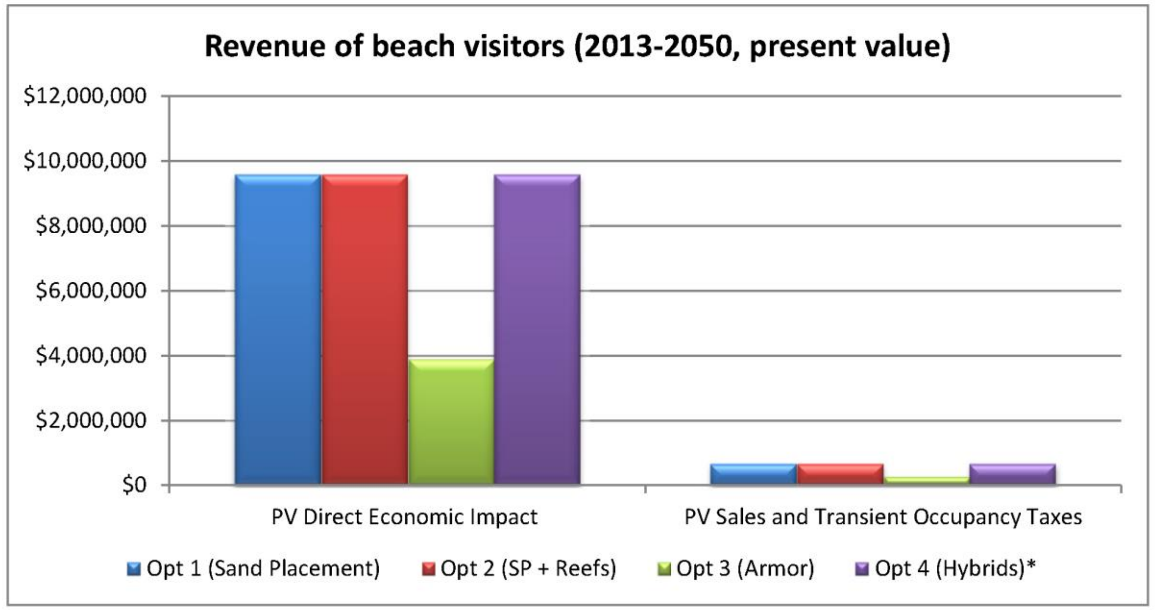
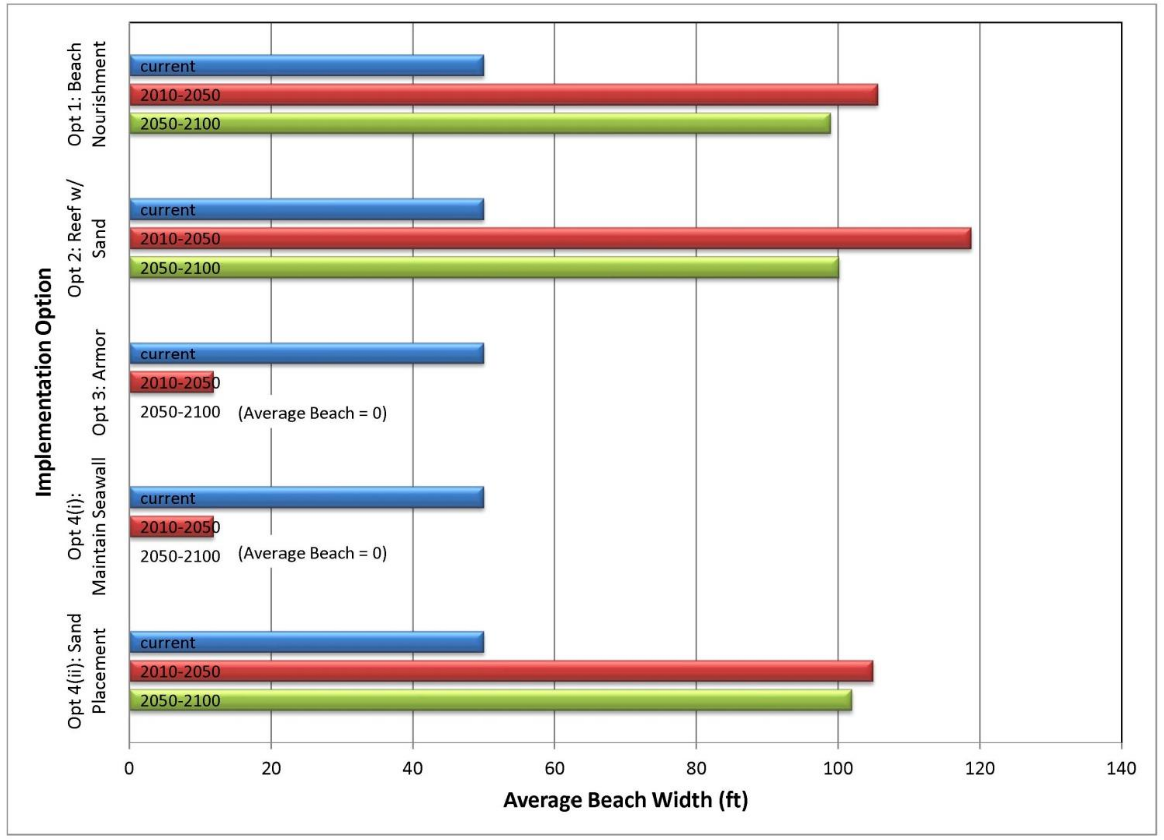


Figure 16: Results Summary: Manor District Summary

Option	Measure	Description	Length	Sand Placements	
			mile	# by 2100	years
1	Sand Placement	100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at backshore.	0.99	8	2010, 2024, 2039, 2052, 2065, 2077, 2088, 2099
2	Sand Placement with Artificial Reef	100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at backshore. Offshore reef added.	0.99 (sand), 0.66 (reef)	4	2010, 2039, 2063, 2083
3	Hold the Line	At the seawall, including addition of armor where it currently does not exist.	0.99	N/A	N/A
4(i)	Hold the Line	At selected seawall locations through maintenance.	0.52	N/A	N/A
4(ii)	Sand Placement	100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode.	0.49	8	2010, 2024, 2039, 2052, 2065, 2077, 2088, 2099



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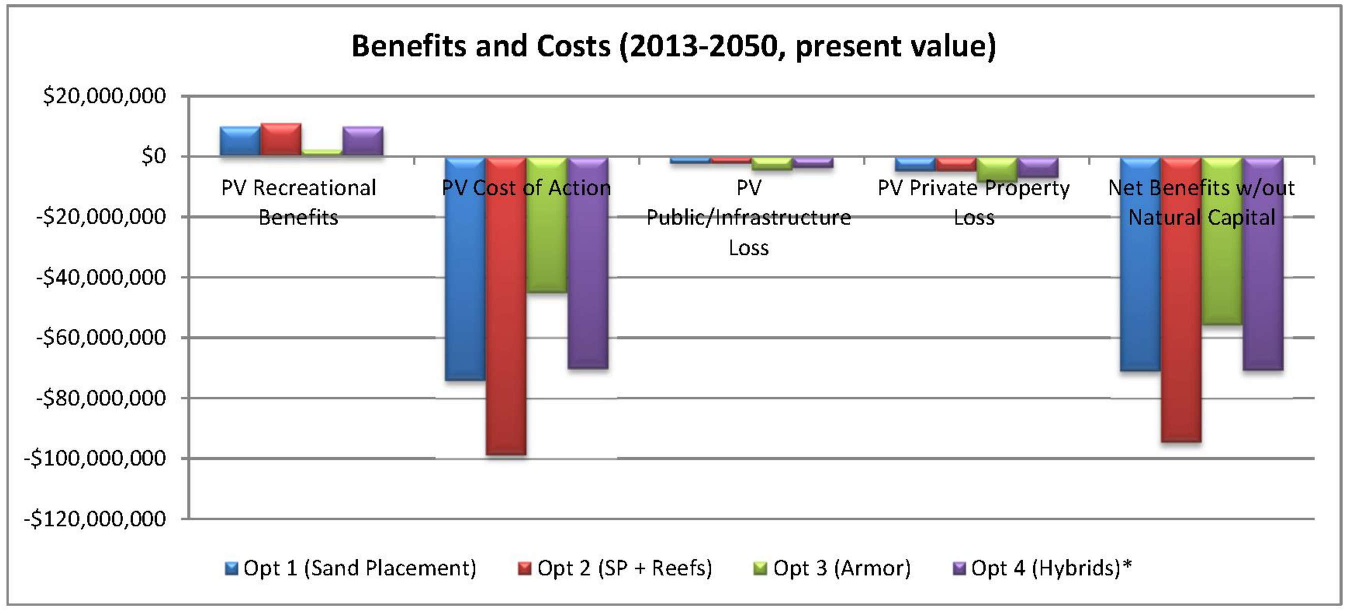


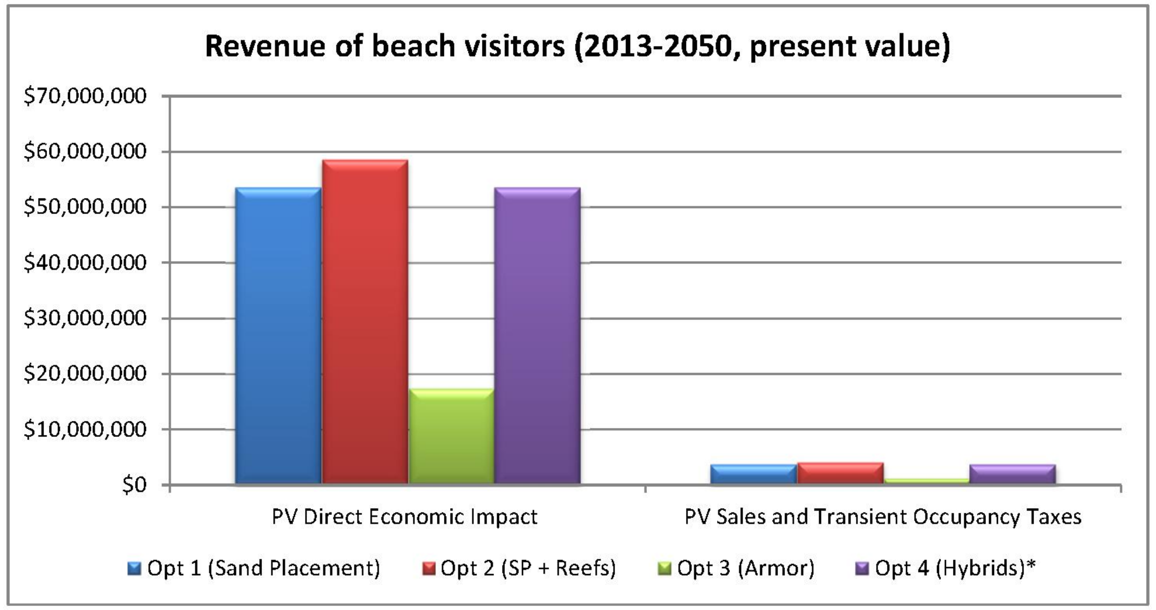
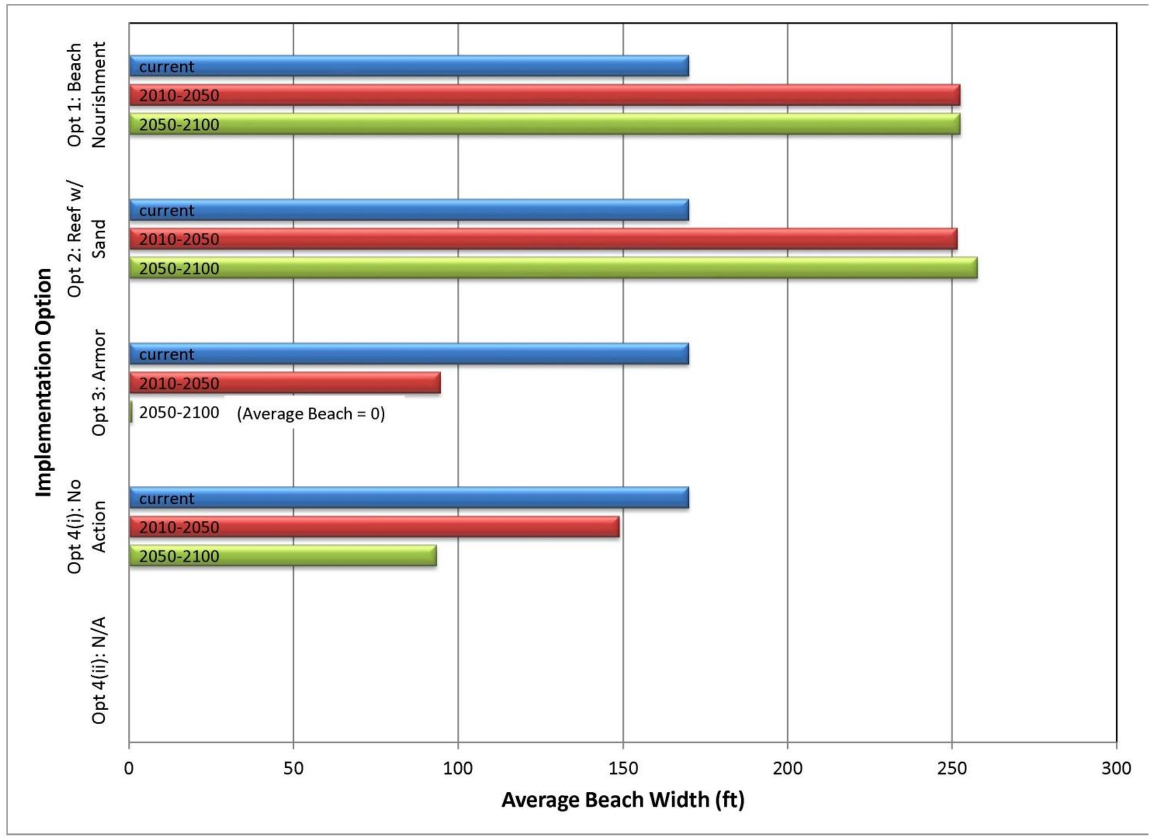


Figure 17: Results Summary: Beach Boulevard Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, 100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore allowed to erode.	0.64	6	2010, 2025, 2044, 2061, 2076, 2090
2	Sand Placement with Artificial Reef	Within a Managed Realignment Strategy, 100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore still allowed to erode. Offshore reef added.	0.64 (sand), 0.42 (reef)	4	2010, 2040, 2070, 2093
3	Hold the Line	Hold the line at the levee/revetment	0.63/0.6	N/A	N/A
4(i)	No Action	Allow erosion	N/A	N/A	N/A
4(ii)	N/A for this reach	N/A	N/A	N/A	N/A



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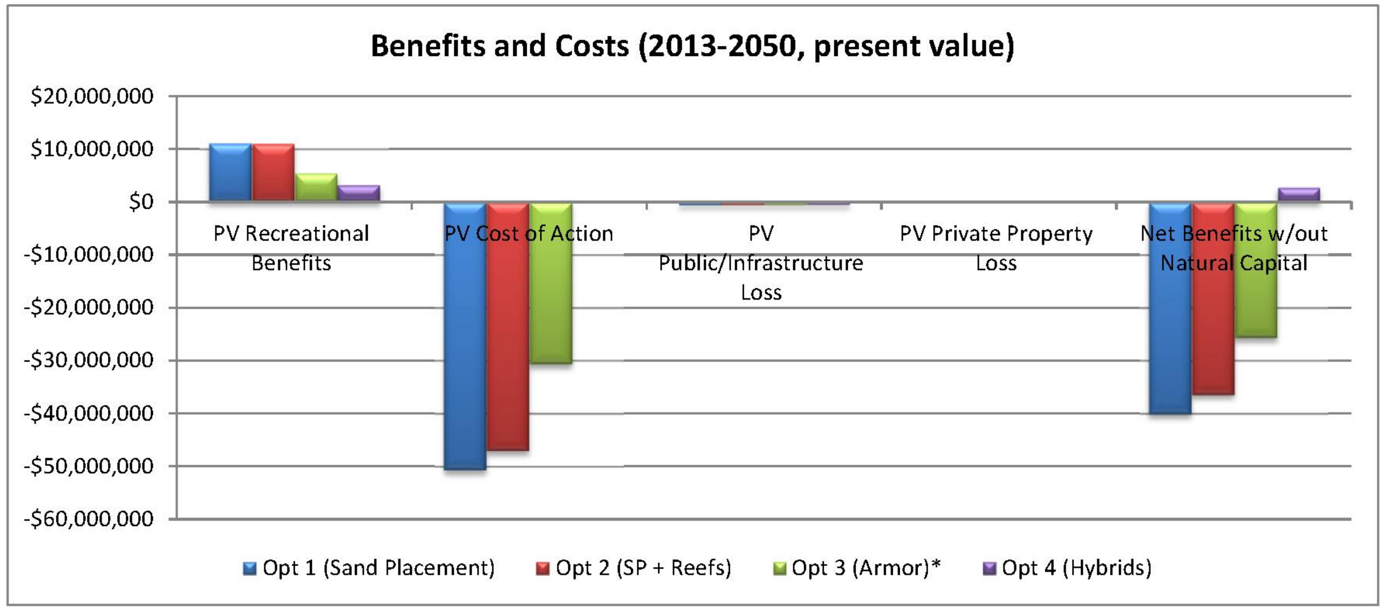


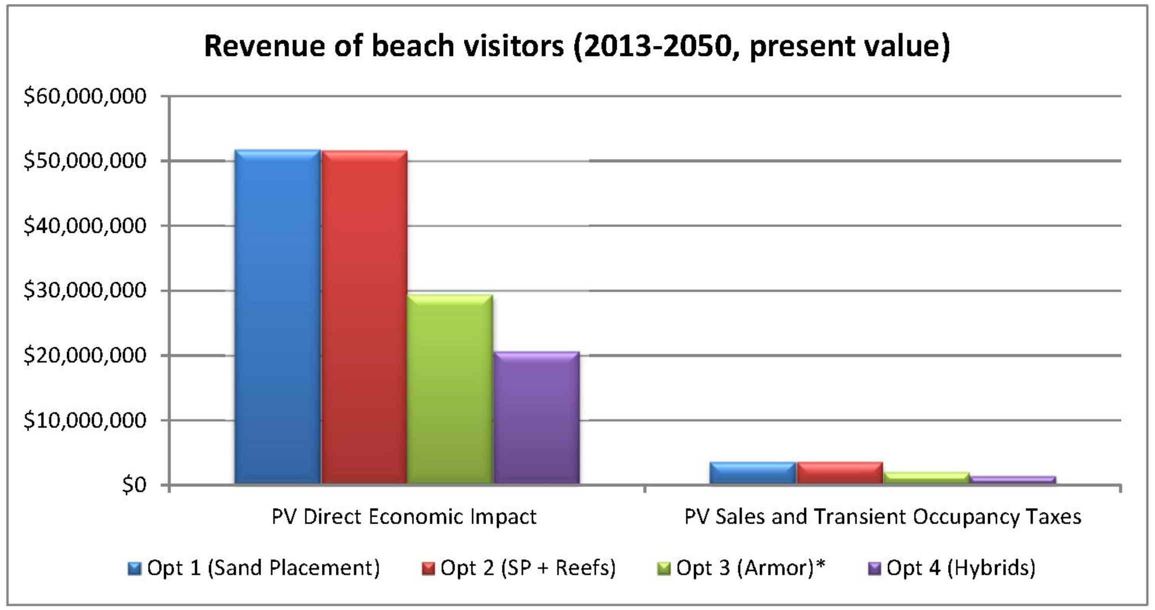
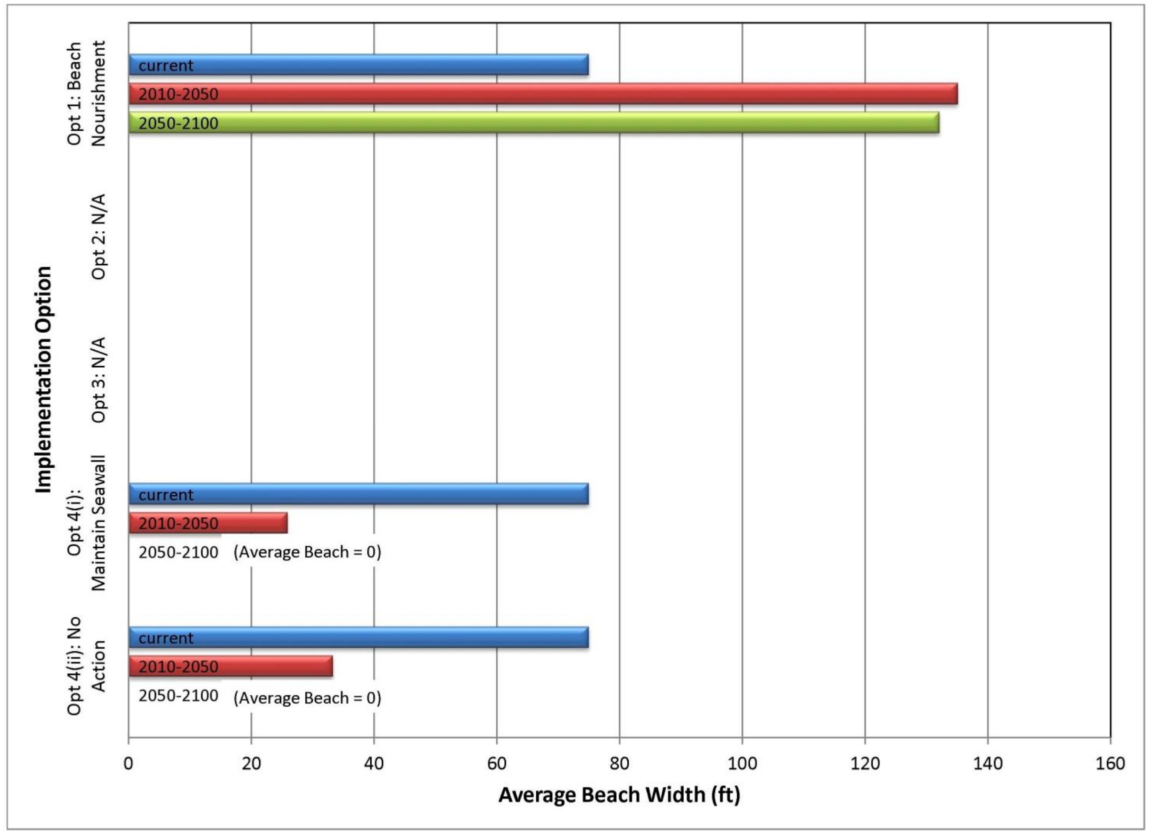


Figure 18: Results Summary: Sharp Park Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Hold the line at the backshore.	0.35	7	2010, 2025, 2041, 2055, 2068, 2081, 2093
2	N/A for this reach	N/A	N/A	N/A	N/A
3	N/A for this reach	N/A	N/A	N/A	N/A
4(i)	Hold the Line	At the seawall/ revetment locations through maintenance.	0.23/0.04	N/A	N/A
4(ii)	No Action	Allow erosion	0.08	N/A	N/A



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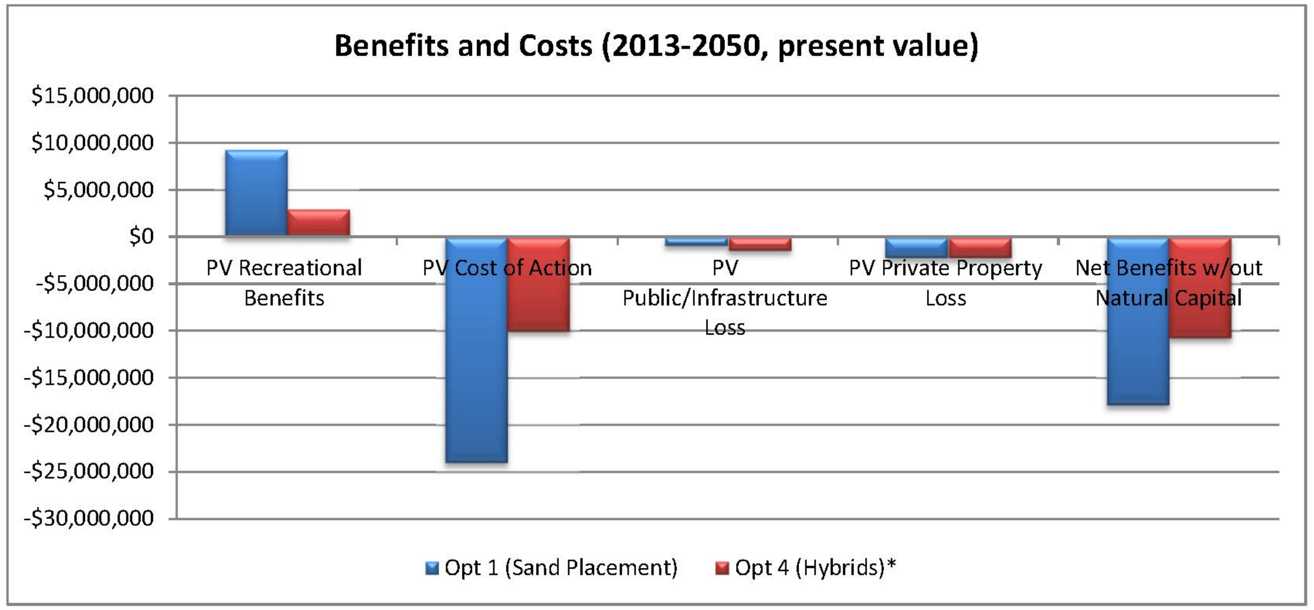


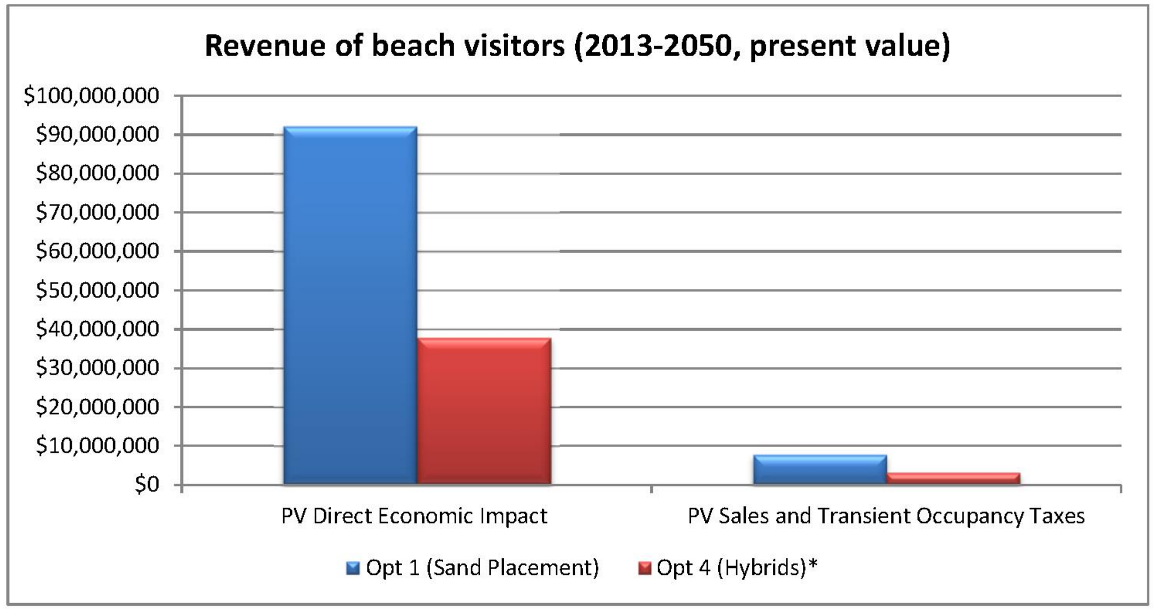
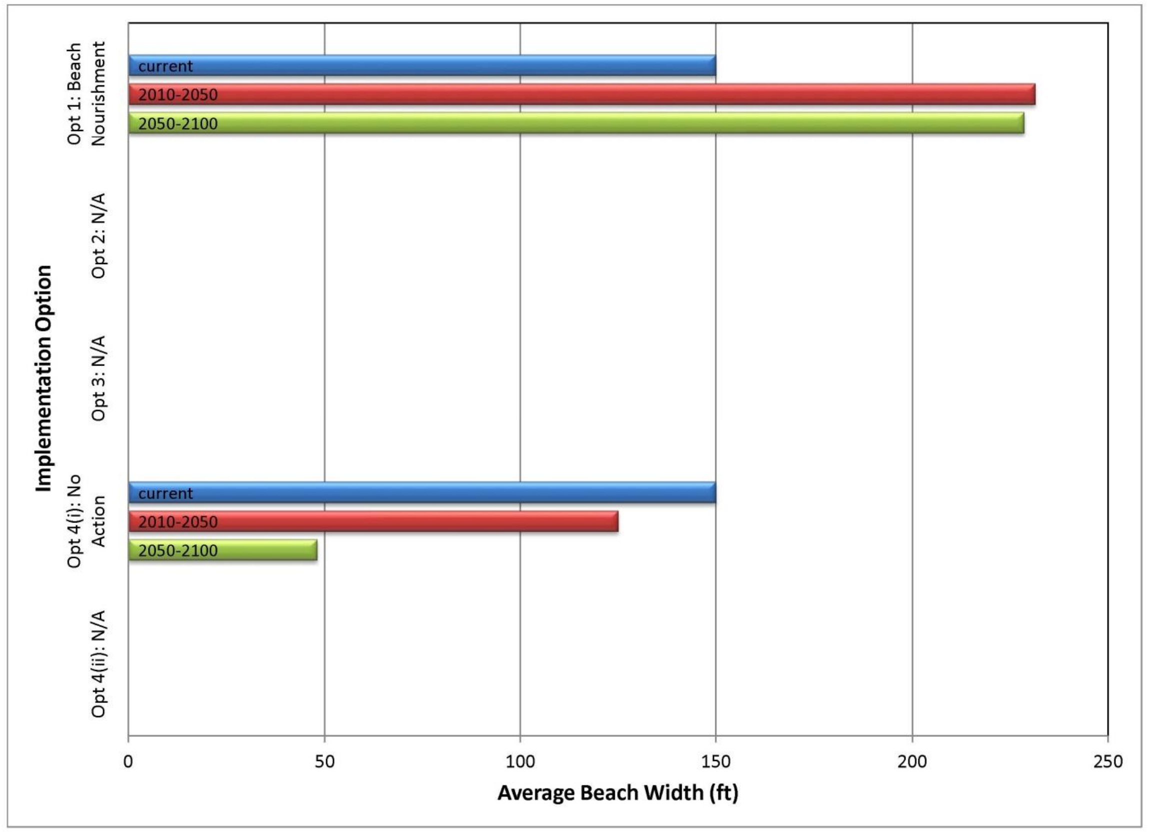


Figure 19: Results Summary: Rockaway Cove Summary

Option	Measure	Description	Length	Sand Placements	
			mile	*# by 2100*	*years*
1	Sand Placement	Within a Managed Realignment Strategy, 100' sand placement the first year, and then every time the beach width falls below the minimum beach width. Backshore erodible.	0.68	4	2010, 2036, 2063, 2085
2	N/A for this reach	N/A	N/A	N/A	N/A
3	N/A for this reach	N/A	N/A	N/A	N/A
4(i)	No Action	Allow erosion	0.68	N/A	N/A
4(ii)	N/A for this reach	N/A	N/A	N/A	N/A



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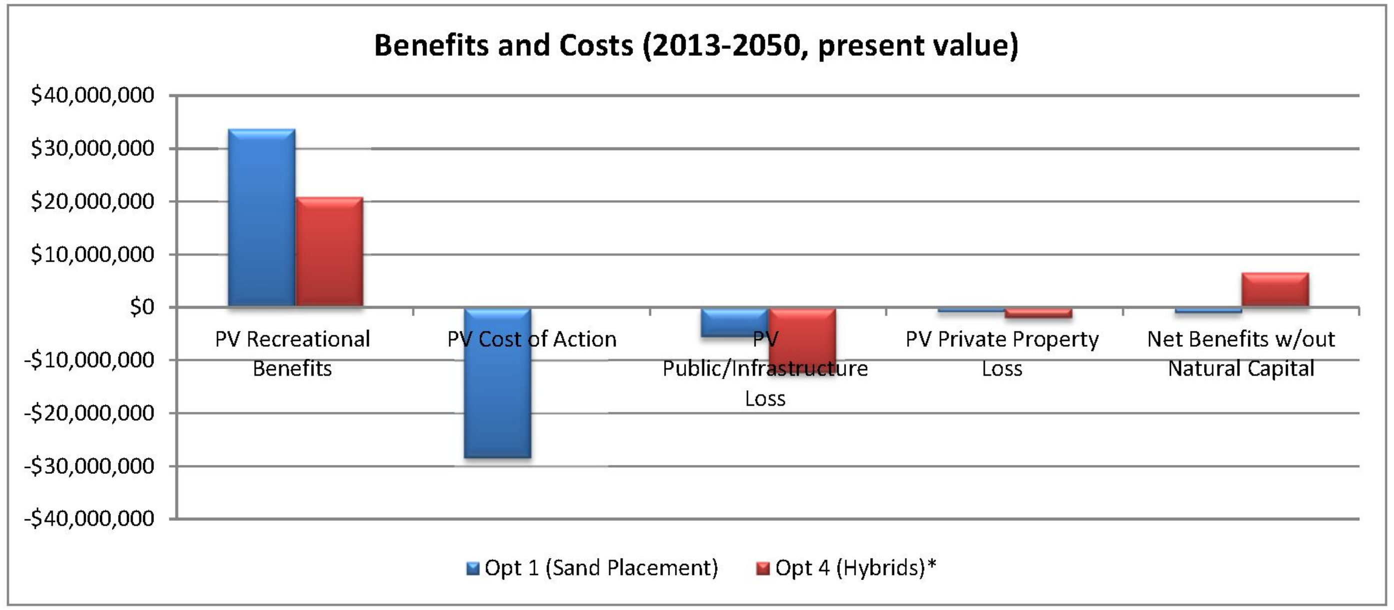

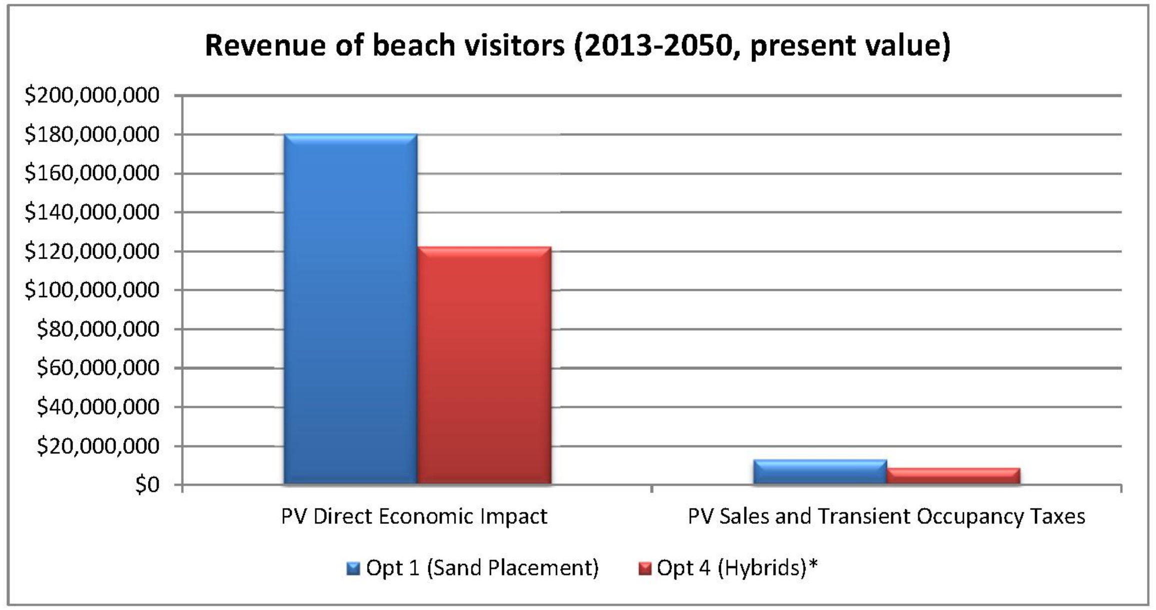

Figure 20: Results Summary: Linda Mar Summary

5.3 POTENTIAL SAND SOURCES

For eight of the reaches, placing up to a total of approximately 10 million yd^3 of sand directly onto beaches is recommended. Of the limited opportunities for beach-compatible sand in the region, the most promising sources are:

5.3.1 Maintenance dredging of the MSC

The USACE maintains the MSC through the Bar offshore of the Golden Gate (**Error! Reference source not found.**Figure 21). The MSC, which is approximately 26,000 feet long and 2,600 feet wide with a federally-authorized depth of 55 ft (MLLW), has yielded an average of 325,000 yd^3 of clean sand per year since 2000 (Table 15). The sand is placed either at the authorized ocean site on the south lobe of the Bar (SF-8) or at the Ocean Beach Demonstration Site (OBDS) in the nearshore off of the seriously eroding stretch of Ocean Beach south of Sloat Boulevard. The sediment is 90–95% fine to coarse sand (0.1-0.5 mm). Based on the success of the OBDS, a permanent placement site (SF-17) is in the process of being designated as the primary location for the placement of sand dredged from the MSC. Other sand that meets USEPA's regulations for beneficial use could also be placed there.

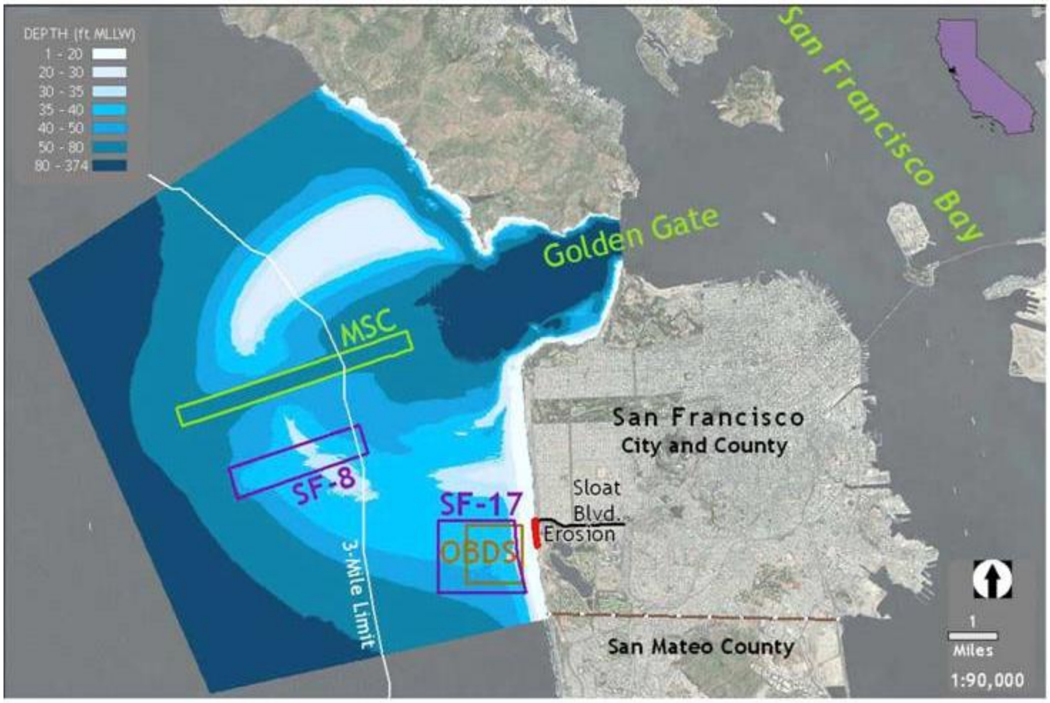

Figure 21: Main Ship Channel, San Francisco Bar

Table 15: Recent MSC Dredged Volumes

Year	Volume (yd^3)	Placement Site
2000	666,662	SF-8
2001	78,013	SF-8
2002	132,088	SF-8
2003	378,153	SF-8
2004	232,893	SF-8
2005	410,657	OBDS
2006	381,810	OBDS
2007	325,079	OBDS
2008	200,313	SF-8
2009	288,304	OBDS
2010	450,614	OBDS
2011	7,336	SF-8
2011	332,198	OBDS
2012	187,650	OBDS
2013	476,108	SF-8
SF–8 Total	2,171,566	
OBDS Total	2,376,312	
Avg.	324,848	

Because of the proximity of Ocean Beach to the MSC, the dredged sediment is most appropriately used along the San Francisco coastline. To that end, the OBMP recommends directly pumping sand dredged from the MSC onshore to MOB and SOB.

There is also the option of back-passing the sediment by trucking or pumping it from Pt. Lobos and NOB to the two southern sections of Ocean Beach.

5.3.2 Offshore dredge locations

Preliminary data from the California Seafloor Mapping Program was provided to ESA PWA by the USGS in February 2012. Some of those data include bed sediment characterization offshore of the southern half of the SFLC and sediment thickness along the counties of San Mateo, San Francisco, and Marin. Those data, when combined with quantified surface grain-size distributions from the USGS and Moss Landing Marine Laboratories, indicate offshore areas that might be able to supply sand for beach and nearshore placement. The sediment on the shelf immediately west of Daly City and Pacifica is characterized as mostly unconsolidated fine sand with a thickness of up to 10 feet. Even thicker deposits of sediment (more than 15 feet thick) are found to the west of Point San Pedro in water depths deeper than 90 feet (NAVD88). To the north, a large, coarse sediment deposit called the San Andreas graben[12] has been identified near the Marin Headlands although the grain sizes within the deposit still need to be quantified (S. Johnson, pers. comm., USGS). Figure 22 shows the general areas that can be explored in more detail to determine offshore grain size compatibility. Issues regarding sand removal from the MBNMS will need to be considered.

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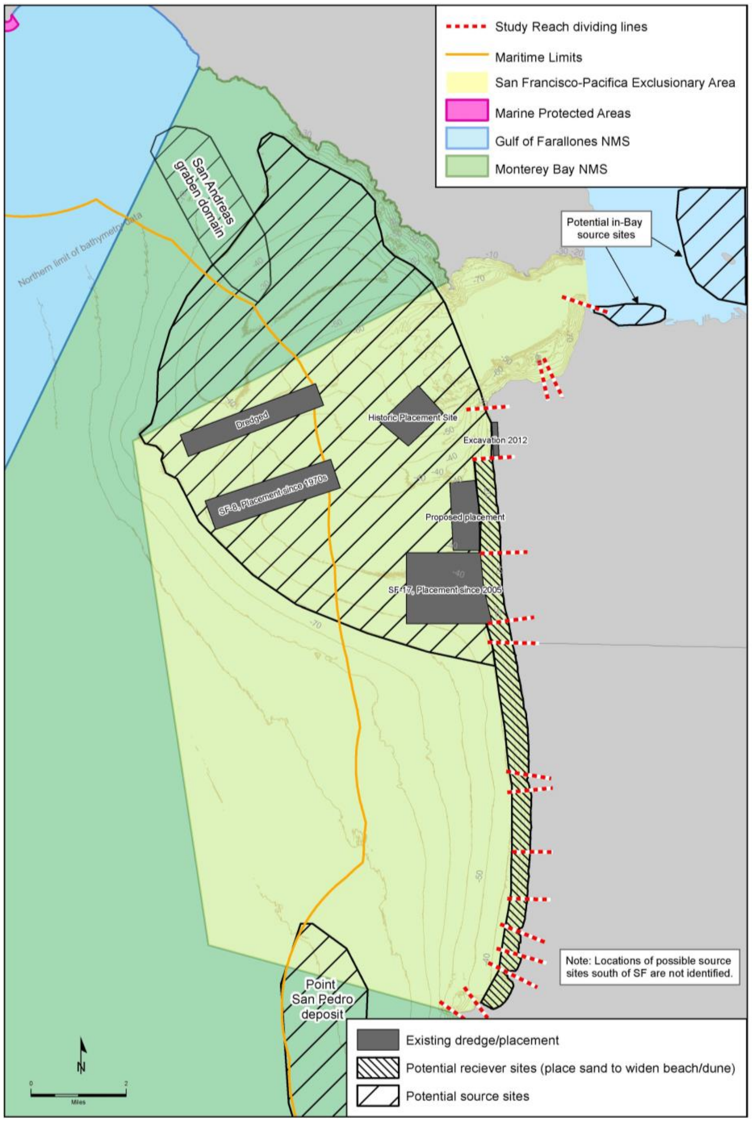
[12] Graben – An elongated, trenchlike, structural form bounded by parallel normal faults created when the block that forms the trench floor moves downward relative to blocks that form the sides.



Sources: ESA PWA (Figure, Reaches); NOAA (Maritime Limits, NMS); CDFG (Marine Protected Areas); USGS (Bathymetry).

NMS = National Marine Sanctuary

Bathymetry in ft NAVD88 (not shown below 100 ft)

Graben domain and Point San Pedro deposit locations estimated from CSMP (S. Johnson, pers. Comm).

Figure 22: Coastal reaches, potential sand sources, and potential receiver sites.

5.3.3 Sediment from Caltrans road maintenance in the coastal areas of San Francisco and San Mateo counties

Caltrans maintains several major roadways inside and near the SFLC. Highway 1, in particular, is a vital transportation connection from San Francisco southwards to Pacifica and Half Moon Bay. Along Highway 1 in that area, many roadcuts through unconsolidated sedimentary rocks provide source material from debris that slides onto the roadway. Caltrans is responsible for ensuring that sediment is removed. The frequent road closures and need for the new tunnel-bridge viaduct at Devil’s Slide just south of the SFLC region are examples of how active the coastal cliffs and bluffs can be. Sediment that once flowed to the ocean through small coastal watersheds is now stopped by Highway 1 and other peripheral roads. This sediment contains the natural background grain size distribution as determined from the coastal watershed. Transporting the sediment accumulated on the roadways and in catchment basins to the coast would re-establish the former sediment pathways. For economic reasons, Caltrans has expressed interest in delivering it to the coast and avoiding landfills.

An example of how sediment removed by Caltrans can be re-introduced to the shoreline is found in Marin County at the State Route 1 - Lone Tree Slide Project. After the October 1989 Loma Prieta earthquake, the Lone Tree Slide closed Highway 1 between Muir Beach and Stinson Beach. The road was reopened in June 1991, after more than 750,000 yd^3 of soil and rock were removed from the slide area. More than 200,000 yd^3 of fill were deposited into the ocean, covering rocky and sandy intertidal habitat and sandy subtidal habitat immediately below the repair site (Coastal Commission Coastal Development Permit 1-90-109). Initial deposition and subsequent settling of the fill material resulted in the loss of 5.61 acres of marine habitat. An analysis by Komar (1998) showed that the toe of the fill had become self-armored by a gradual coarsening from fine-grain sediment to cobble under wave action, which minimized negative impacts to water quality. Subsequent rill-type erosion continued to deliver sediment to the nearshore in small steady amounts.

The topography and tectonics of the SFLC and environs provide a unique opportunity to mimic historic and ongoing landslides through an innovative delivery mechanism. The approach used by Caltrans in Marin County can be adapted to the SFLC CRSMP area by identifying an active landslide that extends to the ocean within the SFLC and depositing sediment from the roadways at the head of the landslide. Natural processes would sort and transport the sediment towards the ocean. The reconnection of locally-derived terrestrial sediment sources to the shoreline would have a positive impact to the nearshore sediment budget while supplying Caltrans with a potentially economically feasible solution to roadway maintenance. The periodic delivery of sediment through this approach is similar to the natural geomorphic processes found in the project area of coastal bluffs collapsing into the ocean. In addition to the economic benefits for Caltrans, this approach could minimize negative ecological consequences of sand placement by limiting the area that could be covered by sediment. Water quality concerns, namely turbidity, could complicate this approach, especially if the Monterey Bay National Marine Sanctuary expands to the shoreline (discussed below).

5.3.4 Sediment from GGNRA

Dammed watersheds collect sediment behind the water retention structures. Areas within the jurisdiction of GGNRA have been trapping sediment that otherwise would have been delivered to the coast. This sediment could also be used for sand placement projects while improving storage capacity behind the dams under GGNRA's jurisdiction.

5.3.5 Sediment from inside San Francisco Bay

Commercial sand mining in central San Francisco Bay and in the Carquinez Strait has occurred for decades. The impact that the removal of the sand has on the San Francisco ebb tide delta is controversial with BCDC, the State Lands Commission, USGS, and others working to quantify those impacts. Setting the controversy aside, the CSMW and BCDC are developing an RSMP for inside San Francisco Bay that would provide guidance on the availability of sediment for use on beaches in the SFLC. Some potential areas near the mouth of the Bay are noted in Figure 22.

5.3.6 Sediment from outside the region

The CSMW is supporting the completion of a CRSMP for the Eureka Littoral Cell in Humboldt County, CA. The primary sediment management issue there is an overabundance of sediment relative to the needs of the local communities and habitats. One supply opportunity for the SFLC beaches is to import sediment from the northern part of the state on barges for sand placement activities.

5.3.7 Sediment from backshore erosion –

Sediment is delivered to the beaches during erosion of the bluffs backing the beaches. The contribution can be estimated by the volume of sand that is coarse enough to remain on the shoreface. Between 1971 and 1992, the linear dune system at Ocean Beach seaward of the Great Highway is estimated to have delivered approximately 14,000 yd^3/yr of sand to the beach via erosion, but subtracting wind-blown transport inland yielded a net contribution of less than 5,000 yd^3/yr (Battalio and Trivedi, 1996). The bluffs in Daly City provide large volumes of fine to medium sand with some coarser sands, pebbles, and cobble. The bluffs in Pacifica also provide sand through erosion, although many of these are now armored. The amount of beach-sized sand delivered from the Daly City and Pacifica bluffs is considered small, perhaps being approximately 10% of the total bluff volume (Limber et al, 2008). However, the process of breaking down and transporting talus from bluff erosion dissipates wave energy that could otherwise induce more rapid shore recession. Hence the focus on grain size alone under predicts the "buffering" effect that backshore erosion has on the rate of shore migration and beach persistence.

CHAPTER 6. ECONOMICS AND FUNDING

This chapter discusses (1) the economic benefits derived from beaches in the SFLC and (2) how different policy scenarios will alter these benefits. Economics plays an important role in decision-making when choosing between coastal sediment management options. This analysis provides background on the important economic considerations for beaches and coastal armoring choices, but is not a complete analysis because of limited data sources. Still, this economic analysis can assist policy-makers by helping narrow policy options. Estimated costs of each option are given followed by a summary of the top options for funding.

6.1 ECONOMIC ANALYSIS

The economic analysis estimated the benefits of beach recreation under different scenarios as well as the impacts on property behind the beach when storms and coastal erosion lead to a loss of land, buildings, roads, and infrastructure (e.g., Pacifica). The benefits of beach recreation were estimated using the Coastal Sediment Benefits Assessment Tool (CSBAT)[13] model, which has been employed in other CRSMPs. In essence, increasing or decreasing beach width increases or decreases economic value in two ways: 1) numerous studies show that visitors prefer wider beaches up to about 250-300 ft; 2) in cases where beaches are crowded, wider beaches reduce overcrowding.

6.1.1 Analysis of Assets at Risk in Developed Coastal Areas

Coastal erosion places land, structures, and infrastructure (‘assets’) at risk to physical and economic damages. GIS-based spatial analysis techniques were employed to evaluate the impact that different sediment management options would have on such assets in the SFLC. The GIS data represented the best publically available data at the time the analysis was conducted.

To simplify the presentation of results, damages were broken into three categories: private property (e.g., residential homes, commercial establishments), public property (e.g., parks, post offices) and public infrastructure (e.g., sewers, streets). The following assumptions were used when translating erosion inputs to damage functions:

- Developed public parcels and private parcels face a complete loss of structure and land value when within an erosion hazard zone;
- Public infrastructure face a complete loss of structure and land value when within an erosion hazard zone; and
- Undeveloped public parcel and private parcel losses are a function of the fraction of parcel (i.e., the ratio of parcel surface area at risk to total parcel surface area) within the erosion hazard zone.

To estimate losses, the base value was estimated for all assets that were identified to be at risk from beach or bluff erosion. Values for private and public parcels were obtained from assessor data from the County of San Mateo and the City and County of San Francisco. Assessor data is recorded for tax purposes, and public properties are in

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[13] For more detail visit http://www.dbw.ca.gov/csmw/csbat.aspx.

many cases exempt from property taxes. As a result, public lands and public structures are often recorded as having no value (i.e., $0). Because the assessor data did not include attributes for the structures at risk, the value of such public structures could not be inferred. However, most public land identified at risk is undeveloped, and in certain cases the land has been purchased by land trusts or various government entities, indicating an economic value. To estimate the value of this undeveloped public land, past sales transactions were analyzed for identified at-risk parcels embedded in the assessor data, while also including proximate parcels, such as Mori Point. Based on this analysis, an average value of $10 per square foot in 2010 dollars was estimated.

To adjust the value of the assets, the following factors were applied:

- A discount rate of 4 percent was applied to all assets at risk.
- A constant depreciation factor of 25 percent was applied for all structures at risk. This is consistent with how USACE uses depreciation replacement values, and in line with past guidance provided by USACE. The underlying rationale for using a constant depreciation factor is that most structures reach a state where the annual maintenance spending and the annual rate of depreciation are equal. This is especially the case for projects where the planning horizon is greater than 20–25 years, as is the case in this analysis.
- A two percent annualized increase was applied to property value (from 2013 to 2050), representing the annualized percent maximum increase in assessed property value outlined in Proposition 13.
- This analysis does not account for changes in construction costs for public infrastructure over the period of analysis because the USACE Civil Works Construction Cost Index only goes to 2025.

6.1.2 Findings

The benefits of some recreation types, costs of the sediment-management options, and loss of public and private property were totaled to quantify the net benefits without the inclusion of natural capital for each reach. In addition, the revenue of beach visitors from spending assumptions and expected sales and occupancy taxes were tabulated. Larger beaches consistently generate higher revenue from beach visitors across all the reaches, but the balance of the net benefits is sensitive to the chosen coastal-management option. When large investments are needed to sustain sand placement or reefs, the benefits become more negative when compared to maintaining hard structures already in place. If new hard structures were constructed, which is not proposed for any reach, construction and maintenance costs would be expected to increase the negative net benefits substantially.

6.2 POSSIBLE FUNDING SOURCES

This section provides a brief overview of some of the existing state and federal funding sources as well as potential sources for local revenue streams to implement future coastal erosion mitigation projects for the CRSMP. A more detailed assessment can be found in Appendix E.

In 2002, the California Department of Boating and Waterways (now Division of Boating and Waterways [CDBW] within State Parks) and the State Coastal Conservancy (SCC) estimated the cost[14] to protect and restore California's beaches. They found that:

> The State of California needs to invest $120 million in one-time beach nourishment costs and $27 million in annual beach maintenance costs. These projects would directly replenish 24 miles of heavily-used public beaches and collaterally benefit more than twice that length due to alongshore sand transport. Through cost-sharing partnerships with the U.S. Army Corps of Engineers, federal funding for these shoreline projects could reduce the state's burden to $42 million (65% reduction) and $13.5 million (50% reduction) for restoration and maintenance costs, respectively (CDBW and SCC 2002, p. xvii).

This summary of known options is provided as an initial overview for review by community and agency managers who may choose to undertake projects. Further research would be needed to determine applicability of a potential source for a given project and the optimum mixture of revenue streams and funding sources. Successful implementation of the CRSMP will require a combination of local, state, and federal funding sources and the coordination of applicable agencies to develop funding plans further. The relative contribution of each source will reflect the prevailing political climate and the state of the economy and budgetary constraints, priorities, and opportunities working within each individual funding and revenue source.

At this time, the most promising potential funding sources include Geologic Hazard Abatement District assessments, the CDBW Public Beach Restoration Program, the USACE Continuing Authorities Program, and increasing the transient occupancy and local sales taxes (Table 16). Further exploration of these potential sources is recommended when a project is being considered.

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[14] Note that costs estimated in 2002 will be larger today because of inflation. For example, assuming environmental conditions are static (for the purposes of analysis) total one-time beach nourishment costs have increased from $120 million in 2002 to approximately $156 million in 2013.

Table 16: Top Funding Sources and Revenue Measures

Ranking	Top Funding Source or Revenue Measure (Increase in)	Feasibility/Factors to Consider
1	Geologic Hazard Abatement Districts	• Used elsewhere for coastal erosion projects • Formation must be abandoned if more than 50% of property owners object • Funds can be raised through supplemental property assessments collected on property tax bills
2	California Division of Boating and Waterways Public Beach Restoration Program	• Little competition for funding in Northern California, • Funding inconsistent • Each project requires budgeting
3	U.S. Army Corps of Engineers Continuing Authorities Program	• Continued funding subject to political climate • Only certain authority sections would apply to Region
4	Transient Occupancy Tax	• Funds can be dedicated to a particular use (specialty taxes) or for general use, with different voter approval thresholds. • Consistent and substantial funds • More politically feasible, as fees are generally placed on nonresidents
5	Sales Tax	• Consistent and substantial funds • 2/3 vote approval required for funds to be dedicated to coastal protection as a specialty tax

Provide guidance and management needed to accomplish coastal restoration activities?

CHAPTER 7. GOVERNANCE

7.1 GOVERNANCE – DEFINITION AND PURPOSE

7.1.1 Definition of Governance

Generally, “governance” refers to processes of interaction and decision-making among relevant entities involved in a collective problem or goal. In the context of this Plan, a governance structure will provide a framework for decision-making by local, regional, state, and federal entities on actions and activities relevant to regional sediment management and coastal restoration in or affecting the San Francisco Littoral Cell. The governance structure will also provide opportunities for citizens to provide input and will maintain accountability to the public and transparency in decision-making.

7.1.2 Why Governance is Important for the SFLC CRSMP

Governance is particularly relevant for CRSMPs because of the regional nature of sediment transport, and consequently the need to manage sediment from a regional perspective. Sediment does not stay within existing jurisdictional boundaries, and therefore a new structure must be identified to ensure efficient coordination and use of funding and staff resources, and to clarity roles and responsibilities regarding regional-level decision-making among municipalities and agencies with coastal jurisdiction. A clear governance structure will support information sharing; collaboration on studies and projects; education, outreach, and engagement of stakeholders and the interested public; sharing of resources and efforts to pursue and secure funding; keeping the SFLC CRSMP updated and relevant, and transparency and accountability around region-wide decision-making.

Effective governance will also help ensure that the potential benefits of the SFLC CRSMP are better realized. These benefits include protecting habitat, buildings and infrastructure, improving and maintaining safety of public access, operating with efficiencies of scale, access to more funding, coordinated stakeholder engagement, and informing other planning efforts (e.g., Local Coastal Programs, Master Plans).

Agencies with jurisdiction on sediment management in some portion of the SFLC include:

- San Francisco Bay Conservation and Development Commission
- California Coastal Commission
- California Department of Parks and Recreation
- California State Lands Commission
- City of Daly City
- City of Pacifica
- City and County of San Francisco
    - Public Utilities Commission
    - Department of Public Works
- Golden Gate National Recreation Area (NPS)
- San Mateo County
- US Army Corps of Engineers, San Francisco District

7.1.3 Keys to Success

Successful governance around coastal regional sediment management depends on other factors as well. Steps should be taken to pursue these success factors where possible and appropriate. Key success factors include:

- Securing broad support for the SFLC CRSMP is critical to the governance formation process. Potential participating agencies must see the benefit and value of the Plan to their constituents before they will be willing to engage in discussions about governance in a meaningful way.
- The governance structure will need to be characterized by strong leadership and committed participation to promote appropriate actions at the regional level.
- The governance approach will need to be resource efficient with minimal added overhead or operating costs. Many of the jurisdictions and agencies in the SFLC are limited in the funding and staff that they can bring to a governance structure.
- Regional efforts to manage sediment must not impede the sediment management efforts of local jurisdictions and individual agencies.
- Coastal regional sediment management planning in the SFLC will need to be closely coordinated and integrated with other related planning efforts, such as relevant General Plans, Local Coastal Plans, the San Mateo County Sea Level Rise Vulnerability Assessment, Ocean Beach Master Plan, and the San Francisco Bay CRSMP.
- All interested parties need to come together early in the governance development process to ensure the range of interests and priorities is considered.

7.2 GOVERNANCE STRUCTURE OPTIONS FOR THE SLFC REGION

The uniqueness of the physical features, coastal development patterns, and geopolitical structures of the SFLC region requires development of an individualized approach to sediment management that best meets the needs of local jurisdictions and agencies in addressing a diverse and specific set of issues spread throughout the littoral cell. Because of the complexities involved with the SFLC region and the lack of an obvious governance structure model and lead agency, this Plan has identified a range of potential governance options. Additional discussions among local jurisdictions, agencies, and other stakeholders in a collaborative context will be needed to inform an eventual decision by stakeholders on the most appropriate governance structure for the region.

The sections below explore different options for governance of coastal regional sediment management in the SFLC. The options listed are generally organized from lesser to more intensive approaches relative to effort, complexity, and resources required.

6. Status quo
7. Coordinating Network
8. Existing Jurisdiction(s) as the Lead CRSMP Agency
9. Special District, including Geologic Hazard Assessment District
10. Joint Powers Authority

7.2.1 Status Quo – No SFLC CRSMP Coordination

This option could be considered the “no action” alternative, because it would not involve structured coordination efforts being undertaken after the Plan is finalized. This would mean that sediment management projects would continue to be carried out on an individual basis, and communication and coordination across relevant entities would be ad hoc.

Pros:

- Requires minimal effort on the part of local jurisdictions and agencies.

Cons:

- Ongoing and future sediment management challenges would likely be dealt with in an uncoordinated manner by individual entities, often using a case-by-case emergency response approach.
- Solutions implemented under this scenario may not be as cost-efficient or as resilient over time as those considered within a regional context.
- It is less likely that recommendations for collaborative planning processes or new sediment management measures from the SFLC CRSMP would be implemented.
- Some state and federal funding entities would not look favorably on proposed projects within the littoral cell when considering allocation of their scarce resources.
- There would be no formal agreements, formal public outreach, or stakeholder engagement processes to support sediment management. Although the Plan would be readily available, decision-makers may not be aware of its existence and potential uses and benefits.

7.2.2 Coordinating Network

With the creation of a Coordinating Network, sediment management efforts would likely continue to take place at the level of individual local jurisdictions and agencies in the SFLC, but it would facilitate advantages for these entities through coordination for key purposes. Examples might include sharing information, pursuing joint studies, and stakeholder outreach and engagement. To achieve this, the involved agencies and jurisdictions would establish the Coordinating Network to facilitate effective coordination and communication. The focus of the Network would be on joint problem solving (rather than power sharing).

In essence, the Coordinating Network can be viewed as an early step on the path to greater levels of regional collaboration and commitment. Characteristics of the Network could include:

- *Participation*: Participating in a Coordinating Network would be open to all interested local jurisdictions or agencies, although it would not be mandatory.
- *Roles and responsibilities*: The commitment of time and resources on the part of the participating agencies would be relatively low, and their responsibilities would be limited to actively coordinate on a consistent basis, such as by participating in bi-monthly or quarterly meetings or conference calls. The actual participants would be staff from the participating entities who already have coastal protection or sediment management as part of their job responsibilities. Participating in the Network would help them accomplish their jobs more effectively. Leadership in terms of convening

and organizing meetings could be assigned on a rotating basis to share this burden and promote multiple perspectives. In addition to meetings, the Network could also serve as a regional online resource for sediment management and sea-level rise data and other information.

- *Scope*: The focus of the Network would be on coordinating to both a) help address issues that each agency is dealing with individually, and b) support coordinated approaches to sediment management where it makes sense. Discussions would focus on information sharing but could also extend to participating in joint studies or collaborating on stakeholder education or outreach.

To be sustainable, the Coordinating Network would require some level of commitment from the participating entities. These commitments would be identified in a collaborative agreement that could be formalized through a memorandum of understanding (MOU) or memorandum of agreement (MOA), which would specify key terms such as who may participate, roles and responsibilities, resource contributions, and scope of work.

Pros:

- A Coordinating Network would provide the benefits of increased regional coordination without adding significant administrative costs or resource requirements.
- The Coordinating Network concept is scalable. It could begin with a relatively modest commitment from participants and grow in scope and resources if participants see the benefit in doing so.
- A Coordinating Network would not threaten perceptions of jurisdictional authority.

Cons:

- Because the Coordinating Network would mainly focus on information sharing and coordination, it would not be effective for cross-jurisdictional decision-making (e.g., identification and prioritization of regional projects).

7.2.3 Existing Jurisdiction(s) as Lead CRSMP Agency

Another option builds on the Coordinating Network idea but expands it with stronger leadership, commitment of resources, and broadening the types of issues that could be addressed at a regional level. In particular, this option would involve identifying one or more lead jurisdictions or agencies to assume a formal leadership role in addressing sediment management issues. A lead agency would have the ability to enter into contracts, administer funding, oversee staff, and convene key stakeholders and decision-makers. A lead agency would develop and oversee the MOU/MOA, and would also be responsible for coordinating updates to the Plan and pursuing additional staff resources to lead the coordination efforts.

If no single agency or local jurisdiction is willing or able to make a commitment and take on the lead role for sediment management coordination, the responsibilities could be split among multiple agencies and jurisdictions. This could include a chair and lead coordination responsibilities that rotate between participating jurisdictions and agencies.

Other characteristics of this option include:

- *Participation*: Similar to a Coordinating Network, participation under this governance structure would be open to all interested local jurisdictions or agencies.
- *Roles and responsibilities*: The commitment of time and resources would be higher for the lead jurisdiction(s). This could involve the dedication of staff (% FTE) to support a higher level of coordination and collaboration.
- *Scope*: The scope of issues under this structure would be expanded relative to those of a Coordinating Network. With the benefit of more dedicated staff, participating agencies could address additional issues, such as pursuit of joint funding and identification and pursuit of potential projects at the regional level.

Pros:

- This option benefits from having more clearly identified leadership and the associated increased commitment to staffing and other resources.
- Coordinated funding requests that address multiple issues demonstrate to potential funders a commitment to resolving coastal issues through a regional approach.

Cons:

- The SFLC does not have a single agency or local jurisdiction that would be an obvious choice to serve as the lead agency. Authority within the region is shared among various entities, so a more complicated governance committee might be needed.
- Like the Coordinating Network, this option would not be effective for cross-jurisdictional decision-making.

7.2.4 Special District

A more formal and legally-based governance option for implementing the SFLC CRSMP would be to create a special district focused on implementing projects to support coastal regional sediment management. Special districts are a form of local government created by a community or communities to meet a specific need. When residents or landowners want new services or higher levels of existing services, they can form a district to pay for and administer them. Most special districts in California perform a single function such as sewage, water, or fire protection. Multi-function districts, like community services districts, provide two or more services.

Similar to a special district, a Geologic Hazard Assessment District (GHAD) is an independent, state-level public agency that oversees geologic hazard prevention, mitigation, abatement and control. GHADs operate with a focus on the prevention of geologic hazards, with mitigation and abatement also being primary functions. GHADs finance their response and maintenance work through assessments of property owners who own real estate within the boundaries of the designated district. A relevant existing GHAD can be found in Broad Beach in Malibu, where property owners banded together and formed a GHAD to implement a long-term shoreline protection plan consisting of 1) sand nourishment; 2) dune restoration; 3) sand backpassing to prolong nourishment; and 4) retaining existing rock revetment where needed.

Pros:

- If a special district or GHAD were developed and fees assessed, it would provide resources for regional coordination and potentially implementation of coastal regional sediment management projects.

Cons:

- Developing and operating a special district is resource intensive. If the special district's responsibilities are restricted to sediment management and do not make use of synergies with other related programs in the SFLC region, it would require even more resources.
- Residents would need to support being assessed a fee to create and support the special district. Given the region's mixed level of support and proactivity around sediment management, this may not be realistic.

7.2.5 Joint Powers Authority

A final governance option for consideration, and one similar in level of formality and resource intensiveness to a special district, is to use a Joint Powers Authority (JPA) to direct coordination and decision-making among relevant jurisdictions and agencies.

A JPA is an institution whereby two or more public authorities can operate collectively. It can be used where an activity (such as regional sediment management) spans across the boundaries of existing public authorities. A JPA has a separate operating Board of Directors, and the Board can be given any of the powers inherent in all of the participating agencies. In setting up a JPA, the participating authorities must establish which of their powers the new authority will be allowed to exercise. The JPA can employ staff and establish policies independently of the participating authorities. JPAs can be tailored to meet specific needs, and there are many differences among individual JPAs.

1. Leverage or Modify an Existing JPA

Several other CRSMPs in California adopted the approach of modifying an existing JPA to support CRSMP implementation. Selected examples include:

- The San Diego County Association of Government (SANDAG) serves as the governance entity for the San Diego CRSMP. SANDAG comprises 18 cities and county governments and is a forum for decisions on a wide range of issues. SANDAG is governed by a Board of Directors comprising mayors, council members, and county supervisors, as well as advisory members from other entities. In addition to the Board, SANDAG also has a staff of professional planners, engineers, and research specialists. SANDAG has a Shoreline Preservation Working Group with staff members and a Shoreline Preservation Strategy that was adopted in 1993. The Working Group advises SANDAG's Regional Planning Committee on issues related to the Shoreline Preservation Strategy.
- The Beacon Erosion Authority for Clean Oceans and Nourishment (BEACON) is a JPA established in 1986 to address coastal erosion, beach nourishment and clean oceans within the Central California Coast from Point Conception to Point Mugu. BEACON member agencies include the Counties of Santa Barbara and Venture as well as the coastal cities of Santa Barbara, Goleta, Carpinteria, Ventura, Oxnard, and

Port Hueneme. The BEACON Board is made up of two Supervisors from each county and one councilmember from each coastal city. BEACON led the development of a CRSMP for its region, and it was adopted by BEACON's Board of Directors in 2009. It serves as the governance structure for activities associated with the CRSMP.

For the SFLC CRSMP, an existing JPA that could possibly serve to govern coordination and decision-making around the CRSMP is the Association of Bay Area Governments (ABAG). ABAG is the comprehensive regional planning agency and Council of Governments for the nine counties and 101 cities and towns of the San Francisco Bay Region. The region encompasses Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties.

Pros:

- Using a JPA to govern the SFLC CRSMP would create greater consistency of governance approaches across the state.
- Similar to a Special District, a JPA would provide resources for regional coordination and potentially implementation of coastal regional sediment management projects.

Cons:

- It is relatively expensive and time consuming for parties to participate in a JPA.
- Few existing JPAs exist in the SFLC region that might serve this role. ABAG does not appear to be an appropriate candidate for several reasons:
    - ABAG's institutional status is uncertain given its evolving relationship with the Metropolitan Transportation Commission.
    - Sediment management and coastal hazards have not been a major focus of ABAG's scope to date, and ABAG does not have expertise in this area.
    - ABAG has not engaged in other sub-regional planning efforts. The coastal areas of San Francisco, Daly City, and Pacifica constitute a small portion of what has been ABAG's regional purview.

2. Create a New JPA

The other JPA option would be to create a new JPA. This would allow for a tailored and customized governance structure that would focus solely on sediment management.

Pros:

- A newly formed JPA could be designed to fit the needs of the local jurisdictions and stakeholders. It could include staff with sediment management expertise.
- As a legal entity, a new JPA could establish authorities that allow for the agency to play a more involved role in carrying out sediment management projects and planning efforts.
- A new JPA focused only on sediment management could stay focused on that topic and not be distracted by other responsibilities.

Cons:

- Creating a new JPA is resource intensive.
- Participating in the JPA would be relatively expensive and time consuming for local stakeholders.

- Funding and staff time would need to be contributed by local jurisdictions. A new JPA would require an executive director supported by other sediment management-focused staff.

7.3 PRELIMINARY RECOMMENDATIONS

Preliminary recommendations for a governance structure for the SFLC CRSMP, as well as other analyses in this Chapter, should be discussed further by relevant local jurisdictions and agencies. These discussions should examine the governance options identified in this Plan, and participants should be invited to assess the different options against how well they achieve the intended purposes of governance and keys to success described above.

Additional recommendations will be informed by comments received during public review of this Plan.

Preliminary recommendations include:

- If there are concerns about resource commitments, creating a Coordinating Network may be a good first step in advancing governance and coordination for sediment management in the SFLC (this would be formalized through a cooperative agreement [MOU or MOA] between relevant local jurisdictions and agencies). The Coordinating Network could be used as a test case to better understand the governance requirements around sediment management in the SFLC and to assess periodically whether a more formal governance structure is needed.
- To the greatest extent possible, governance for the SFLC CRSMP should be closely linked or coordinated with governance of other relevant structures – especially those established to support: 1) the San Mateo County Sea Level Rise Vulnerability Assessment, 2) implementation of the Ocean Beach Master Plan in San Francisco, and 3) the Bayside CRSMP being led by the San Francisco Bay Conservation and Development Commission.
- Because the cities of Pacifica and Daly City have limited staff and funding resources to support sediment management activities, consider having the Counties of San Mateo and San Francisco (along with relevant federal and state agencies such as GGNRA, as appropriate) serve as eventual lead agencies in a governance structure. The roles and responsibilities of the involved jurisdictions and agencies could be established in the MOU/MOA to account for these resource constraints and make it easier for Pacifica and Daly City to participate.
- A hybrid structure involving a Coordinating Network and a lead agency or agencies may be a good way to address a situation where some local jurisdictions and agencies have more resources and capacity than others, but where all may want to be involved.

CHAPTER 8. RECOMMENDED NEXT STEPS

8.1 DATA GAPS AND ANALYSES

A number of data gaps require further research prior to implementing a regional sediment management plan. In general, a substantial amount of research exists in the SFLC, but the system is complicated and perturbed by human intervention. These complicating factors add uncertainty to the understanding of shore response to beach nourishment and other regional sediment management actions. The shores along Pacifica and Daly City are much less studied, and a wide range of research and analysis is required to develop plans suitable for these areas.

8.1.1 Physical and Biological

- Sand availability for beach nourishment at Daly City and Pacifica
- Sediment supply from watersheds and on the Daly City–Pacifica portion of the shelf
- Sediment thickness and the horizon of underlying hardpan, especially in the reaches between Sharp Park and Middle Ocean Beach.
- Wave conditions and alongshore transport processes south of Ocean Beach
- Comprehensive ecological survey of existing habitats and special species
- Vertical land motion

8.1.2 Economic and Policy

- Infrastructure replacement costs
- Beach attendance and type-of-use records
- The value of beaches from ecology, aesthetics, and community benefits
- Extension of MBNMS would be pertinent to this CRSMP

8.2 SHORT- AND LONG-TERM NEXT STEPS

- Investigate offshore sand deposits for beach nourishment supply
- Analyze sediment transport and complete a sediment budget analysis in the Daly City–Pacifica area to provide more accurate information for sediment management activities
- Investigate the effects of coastal armoring on beaches and bluff erosion
- Investigate the sand content and size of the region’s coastal bluffs
- Evaluate the other contributors to beach valuation, such as ecology and the full range of ecosystem services
- Engage the Daly City and Pacifica communities in a visioning process for their shores investigating coastal hazard mitigation and adaptation strategies

CHAPTER 9. CONCLUSIONS

The development of this CRSMP consolidated existing knowledge, expanded understanding of coastal processes, and revealed several opportunities and challenges to establishing regional sediment management in the San Francisco Littoral Cell.

9.1 COASTAL AND SEDIMENT MANAGEMENT CONCLUSIONS

- Erosion of the Daly City bluffs is probably a primary sediment source for Daly City and Pacifica beaches. The marked narrowing of the Pacifica beaches over the period of record of known shorelines is not fully explained.
- There is a progressive challenge between coastal development and erosion that will be exacerbated by sea level rise and, potentially, the lack of management capabilities. The erosion is a historically natural process in Daly City and Pacifica but appears to have accelerated in the past century for undefined reasons. In San Francisco, the erosion is associated with human activities.
- The state of knowledge in Daly City and Pacifica is limited in many areas where coastal erosion is problematic.
- Regional sediment management may be best accomplished by each of the cities taking the lead in their jurisdiction and cooperating to the extent desirable.
- Northern Daly City and San Francisco could be combined for regional sediment management because:
    - Common land owner (NPS represented by the GGNRA) could take a leadership role in regional sediment management
    - Adjacent to each other with similar geology and geography
    - Sewer systems are linked
- The geography and geology of Daly City poses special challenges to manage coastal hazards; additional effort may be beneficial toward a vision and feasibility of intervention.
- Additional effort is required to develop a consensus in Pacifica. There is interest in finding sediment-management solutions, but no clear direction has been established. The elements required include education, outreach, facilitation, and funding.
- If a regional approach continues to be the goal, the NPS (GGNRA) and NOAA (MBNMS or GFNMS) could take a regional governance role for the entire SFLC region with shared responsibility for the shoreline.

9.2 ALTERNATIVES CONCLUSIONS

- Valuation of the beaches is important to assess the adaptation strategies.
- A substantial amount of infrastructure and property are at risk in Pacifica (170 parcels, 4,300 feet of streets, 11,600 feet of trails, 3,800 feet of pipelines, 6,900 feet of sewers, and 3 outfalls). Sediment management alternatives affect these numbers but sea level rise will increase all of them if no action is taken.
- Armoring results in loss of beaches and continued investment to maintain armoring is significant.
    - Armoring has been constructed along most of the beaches in Pacifica with the exception of Linda Mar where setback occurred for most structures and managed retreat applied in 2005.

  - Because of the loss of beaches, it is assumed the coastal ecology has been adversely affected.
  - One of the benefits of sand placement is to restore beach ecology.
  - Estimated investment in armoring for Pacifica is $131 million through 2050 at present value.
- Reefs have benefits but the costs are large and the incremental benefits are small. Offshore reefs have benefits to maintaining beaches but they are expensive. If sand is not available for placement, they still may be effective as a coastal sediment management tool, however, by retaining transient sediment.
- An adaptation strategy worth more investigation can be found at Manor District where a crenulated shore develops over time with beaches forming between armored hard points. This could result in similar morphology and sediment retention as reefs with the hardened points anchoring the nascent beaches.

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