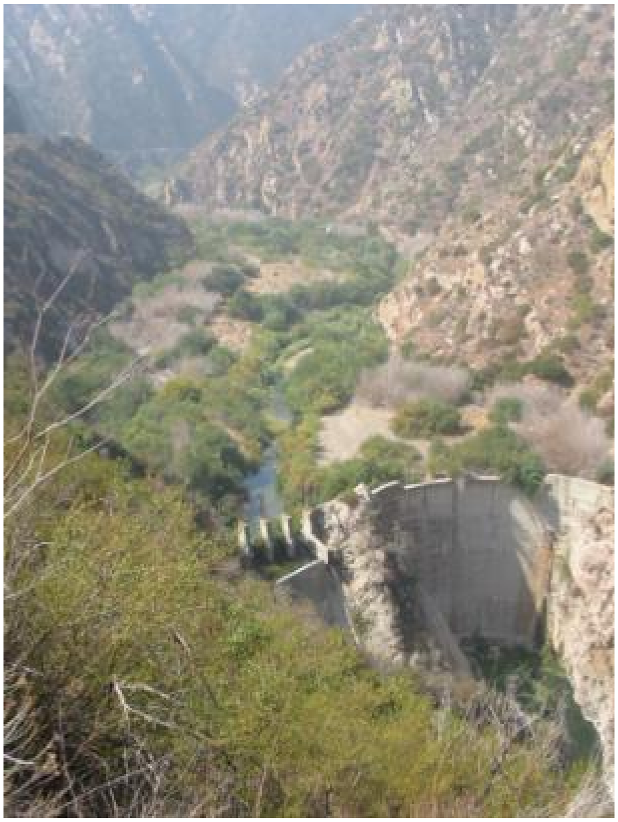
Malibu Creek Ecosystem Restoration Study

Los Angeles and Ventura Counties, California

Appendix O

Coastal Engineering



U.S. Army Corps of Engineers
Los Angeles District

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1.0 INTRODUCTION

1.1 Purpose and Scope

This coastal engineering appendix describes the technical aspects of the Malibu Creek watershed feasibility study in relation to coastal engineering. The purpose of this appendix is to conduct an analysis of the existing conditions and of the proposed alternatives for plan formulation. Evaluation of the project includes an analysis of baseline conditions, technical design and potential design impacts on shoreline processes.

1.2 Beneficial Use of Beach Compatible Sediments

The purpose of removing Rindge Dam is to restore the ecosystem and natural sediment transport both within the watershed and the littoral system. Natural forces would deposit sediment at the mouth of Malibu Creek and would enter the littoral system. Placement of beach quality sediment should be utilized to restore natural sediment transport patterns and magnitude within the littoral system. The study authority also states that sediment from the dam removal should be used "…in the interest of shore protection, storm damage reduction, and other purposes along the shores of Southern California from Point Mugu to the San Pedro Breakwater and nearby areas within Ventura County and Los Angeles County, California."

1.3 Placement Alternatives

To accomplish the aspects stated in the study authority, beach quality material should be placed within the littoral zone in an area, in absence of Rindge Dam, that the sediments would naturally be deposited. Three options exist to provide nourishment; natural sediment transport through Malibu Creek, direct placement on Malibu beaches, or nearshore placement of sediment within the littoral zone. In this coastal engineering appendix, only beach and nearshore placement options will be considered. For information on the natural transport option, see the **Appendix B – Hydraulics, Hydrology, and Sedimentation**.

2.0 BACKGROUND INFORMATION

2.1 Geographic and Physical Setting

The Malibu Creek watershed is located approximately 30 mi west of downtown Los Angeles, CA. Malibu Creek runs approximately 10 mi from Malibou Lake to Malibu Lagoon. The mouth of Malibu Creek is located between the Ventura/Los Angeles County line and the mouth of Topanga Canyon, where the shoreline is generally in an east-west alignment. The shoreline is typically narrow and backed by the steep Santa Monica Mountains. Near the western end, the coastline is characterized by narrow beaches interspersed with rocky outcrops backed by high cliff terraces. South of Sunset Boulevard, the cliff backshore is predominate through Santa Monica whereupon the shoreline opens into the broad expense of the Los Angeles Basin which represents the ancient path of the Los Angeles River prior to its diversion into the Los Angeles Harbor area.

The Santa Monica Mountains vary in width from 3 to 15 miles with summit elevations varying from 1,000 to 3,000 feet. The region consists of igneous, metamorphic and sedimentary rocks varying in age from Triassic to Holocene eras. The igneous and metamorphic rocks include granites, intrusive and extrusive volcanics and slates. The sediments include unconsolidated alluvium of Pleistocene and Holocene age and consolidated rocks described as sandstones, conglomerates and shales, mostly of Tertiary age.

The coastline west of Santa Monica may be characterized as being made up of a succession of narrow crescent beaches bordered by resistant rocky headlands. The headlands are typically formed as long western legs with short northeast trending re-entrants in response to the westerly prevailing wave incidence. Narrow crescent beaches occur principally at the mouths of streams and are often held in place by bedrock exposures or boulder forms at the stream mouths (Thompson, 1988). From Sequit Point to Trancas Canyon, the beach is narrow and backed by a sea cliff about 50 feet high. Three rocky headlands interrupt the reach. The wide Trancas and Zuma Beaches extend for about 4 miles from Lechuza Point to the basaltic outcrop of Point Dume. This wide beach disappears at the Point and reappears immediately downdrift from the promontory as a narrow feature backed by Modele shale cliffs which lead to the narrow Escondido Beach. Between Latigo Canyon and Malibu Beach, the beach is narrow and bedrock is often exposed. The sandy shoreline is widest at Malibu Creek with the Malibu Colony sand spit forming a barrier beach at what was once a relatively large tidal lagoon. East of Malibu Creek the beach gradually diminishes in width to a narrow to non-existent condition between Las Flores and Topanga Canyons as the rugged mountain slope rise abruptly from the shore. An aberrant wider beach occurs at the Topanga Canyon Creek mouth but the short section of sandy shore immediately reverts to a narrow strand littered with boulders, cobble and other debris to Santa Ynez Canyon (Sunset Boulevard). The beach is non-existent at Sunset Point and gradually widens to Temescal Canyon whereupon the effects of the Santa Monica Breakwaters and Will Rogers Beach Groin field system are apparent. Along this reach, the beach is backed by a palisade which was cut into the Santa Monica Plain by marine erosion prior to the last emergence of the coast. The beaches south of Sunset Boulevard and Temescal Canyon are essentially man altered resulting from a series of beach fills and shoreline structure improvements.

2.2 Coastal Processes

2.2.1 Tides and Water Levels

Tides at Malibu are mixed semi-diurnal with a diurnal inequality. Typically, a lunar day consists of 2 high and 2 low tides each of different magnitude. The lower low normally follows the higher high by about 7 to 8 hours, whereas the next higher-high (through lower-high and higher-low waters) follows in about 17 hours. Tidal characteristics at Santa Monica Pier are applicable for the study area which has a length of record of more than 80 years. The average tidal range is about 3.8 ft, with the mean of the higher high water 5.4 ft above the mean lower low water. **Table 2.2-1** shows the tidal datums of the Santa Monica gauge referenced to the standard station datum.

Storm surge is the sea level rise induced by barometric pressure depletion and strong wind stress acting on the water surface. In the southern California coastal zone, due to its narrow continental shelf, storm surges rarely exceed 3 ft, with average heights below 1 ft for two to six days (USACE, 1991). The winter storm of January 17, 1988 produced the record low barometric pressure at the Los Angeles Harbor gage. Measured water level at the gage during this event was 0.7 ft above predicted astronomical levels (NOAA, 1988).

Wave set-up is the local increase in water surface elevation generated by wave breaking and only occurs within the surf zone. This water level change is a function of beach slope, breaking wave height and angle. In general, steeper beach slopes generate larger wave set-ups. The order of magnitude of wave set-up is about 10 percent of the breaking wave height.

Table 2.2-1 - Tidal Datums for Santa Monica, CA, 1983-2001 Epoch (NOAA, 2016)

Station: 9410840, Santa Monica, CA	**T.M.:** 120
Status: Accepted (Apr 17 2003)	**Epoch**: 1983-2001
Units: Feet	**Datum:** STND

Datum	Value (ft)	Description
MHHW	7.87	Mean Higher-High Water
MHW	7.13	Mean High Water
MTL	5.25	Mean Tide Level
MSL	5.23	Mean Sea Level
DTL	5.16	Mean Diurnal Tide Level
MLW	3.37	Mean Low Water
MLLW	2.44	Mean Lower-Low Water
NAVD88	2.63	North American Vertical Datum of 1988
STND	0	Station Datum
GT	5.43	Great Diurnal Range
MN	3.76	Mean Range of Tide
DHQ	0.74	Mean Diurnal High Water Inequality
DLQ	0.93	Mean Diurnal Low Water Inequality
HWI	5.19	Greenwich High Water Interval (in hours)
LWI	11.26	Greenwich Low Water Interval (in hours)
Maximum	10.94	Highest Observed Water Level
Max Date & Time	11/30/1982 7:54	Highest Observed Water Level Date and Time
Minimum	-0.4	Lowest Observed Water Level
Min Date & Time	12/17/1933 15:42	Lowest Observed Water Level Date and Time
HAT	9.71	Highest Astronomical Tide
HAT Date & Time	12/2/1990 16:12	HAT Date and Time
LAT	0.47	Lowest Astronomical Tide
LAT Date & Time	1/1/1987 0:00	LAT Date and Time

Positive departures from the astronomical tides can occur during strong El Niño Southern Oscillation (ENSO) events. These meteorological anomalies are characterized by low atmospheric pressures and persistent onshore winds. Tidal data from 1905 through 1983 indicates seven of these episodes (1914, 1930-1931, 1941, 1957-1959, 1982-1983 and 1997-1998, 2015-2016). Lessor ENSO events in the 2000's include 2009-2010 (NOAA, 2015). Cursory analysis of these data suggests an average return period of 14 years with 0.2 ft tidal departures lasting for 2 to 3 years. The added probability of experiencing more severe winter storms during El Nino periods increases the likelihood of coincident storm waves and higher water elevations. The record water level of 8.35 ft MLLW, observed at San Diego in January 1983 includes an estimated 0.8 ft of surge and seasonal level rise (Flick and Cayan, 1984). The highest observed tide at the Santa Monica Pier tide gage was 7.08 ft above NAVD 88, or about 7.3 ft above MLLW of the 1983-2001 tidal epoch.

2.2.2 Sea Level Change

The sea level rise in the southern California region associated with ocean thermal expansion and the meltwater generated from continental glaciers and the Antarctic ice sheet is estimated to be 0.1 to 0.2 ft in a time span of 25 years (Church et al., 2004; USACE, 1991). This correlates to an approximate potential increase of 0.004 to 0.008 ft of mean sea level elevation per year. However, the past trends at Santa Monica suggest the actual rate is on the low end of this estimate as shown by **Figure 2.2-1**, which provides a historic rate of sea level change to be 0.0043±0.0011 ft/yr for the period between 1933 and 2016 (NOAA, 2016).

The U.S. Army Corps of Engineers (USACE) considers potential relative sea level change in every feasibility study undertaken in the coastal zone. ER-1100-2-8162 (USACE, 2013) provides a guideline to determine the potential sea level changes to consider. A sensitivity analysis should be conducted to determine what effect, if any, changes in sea level would have on plan evaluation and selection. The sea level increase scenarios can be described by:

$$E(t_1) - E(t_2) = 0.0017(t_2 - t_1) + b({t_2}^2 - {t_1}^2) \quad (1)$$

where $E(t)$ is the eustatic sea level change, t_1 is the time between the project's start date and 1992, t_2 is the time between a future date of interest and 1992 and b is a constant that changes depending on the rate of sea level rise considered; 0, $2.71\text{x}10^{-5}$ and $1.13\text{x}10^{-4}$ for low (historic), intermediate and high respectively. The projected relative sea level change, based on the local observations at Santa Monica, is shown in **Figure 2.2-2**. Over a 50-year (life of project) time span, approximately 2075, the low, mid and high scenario would produce a mean sea level rise of 0.4, 1.01 and 2.95 ft from the 1992 sea level, respectively.

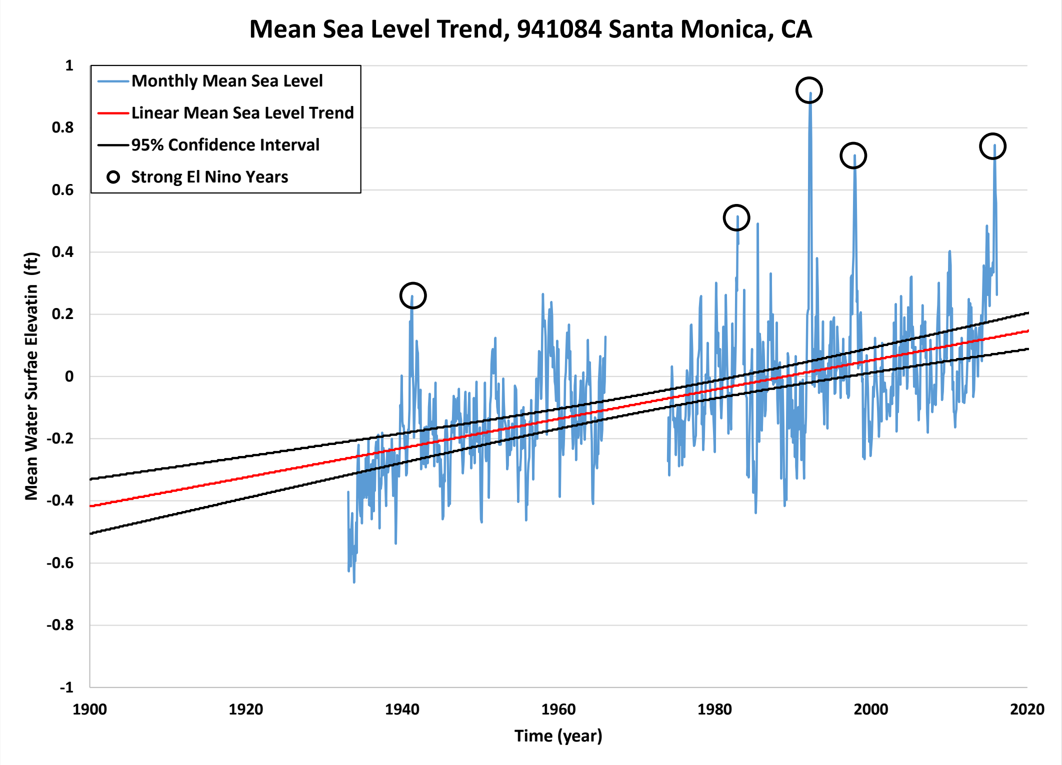

Figure 2.2-1 - Sea Level Trend for Santa Monica, CA

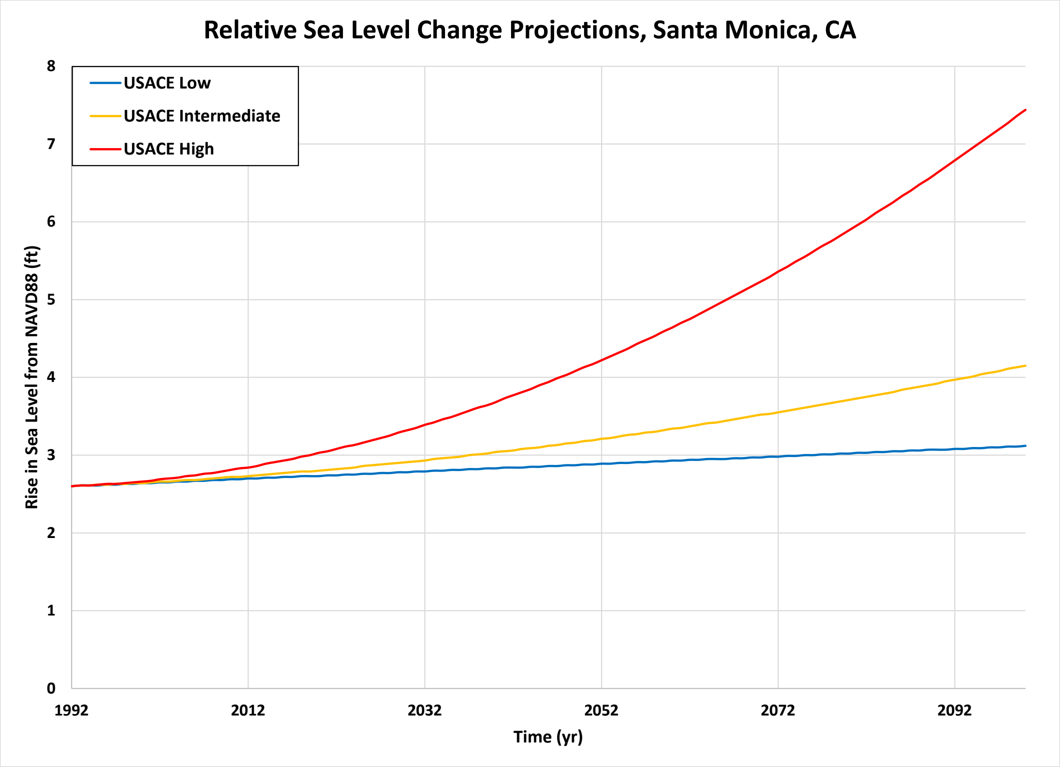

Figure 2.2-2 - Sea Level Change Scenarios from NAVD88 reference

The actual project site of Rindge dam will not be directly affected by sea level rise. Malibu Lagoon will experience a natural rise in sea level, but since the amount of incoming sediment from Malibu Creek will not change, there will be no deviation from the natural sea level rise process over time. To visualize the effect of natural sea level rise on the lagoon, **Figure 2.2-3** shows the new elevation of mean sea level for the three estimated rates in 2075. This figure only shows the increase of still water level and not the natural retreat of the shoreline as stated by the Bruun Rule (Bruun, 1962) which would be approximately 6 ft, 18 ft and 57 ft for the low, intermediate, and high sea level rise scenarios, respectively.

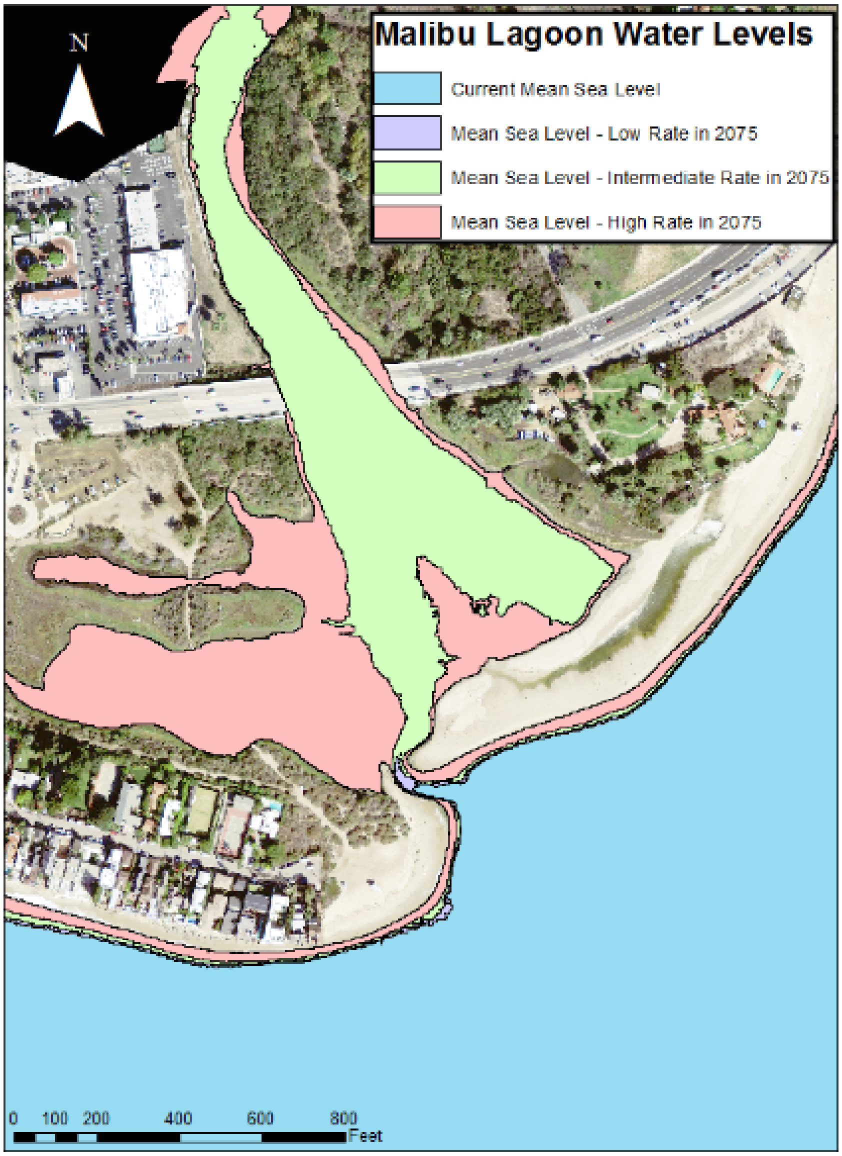

Figure 2.2-3: Sea Level Rise Effect of Malibu Lagoon

2.2.3 Waves

The study area is somewhat sheltered from deep water ocean waves by the effect of the shoreline projections at Point Dume to the west and the Palos Verdes Peninsula to the south. As a result, the area is primarily exposed to a wave window bounded on the north by Santa Rosa Island and on the south by Catalina Island. **Figure 2.2-4** shows the exposure window to be between 265° and 180°. Wind waves and swell, which comprise the prevailing and storm climates at the Malibu shoreline, are produced by six basic meteorological patterns. These include extra tropical storm swells in the northern hemisphere (north or northwest swell), wind swells generated by northwest winds in the outer coastal waters (wind swell), westerly (west sea) and southeasterly (southeast sea) local seas, storm swells of tropical storms and hurricanes off the Mexican coast, and southerly swells originating in the southern hemisphere (south swell). Among these waves generated by the six meteorological patterns, the south swells in summer and the west sea in winter impact the Malibu shoreline most. These waves transform from deep water to shallow water and break in the surf zone generating an eastward alongshore current that transports sediment along the Malibu shoreline.

Wave setup and setdown along the beach profile varies from a minimum near the wave breaker location and a maximum at the shoreline. Linear wave theory predicts maximum setdown of about 4 to 5 percent of wave height along a plane beach and a slightly higher setup along the shore. Surf beats or infragravity waves are thought to be the result of non-linear transformation of energy across the surfzone. This phenomenon is not precisely understood but is generally observed with a magnitude of one to several feet during severe wave events (USACE, 1993).

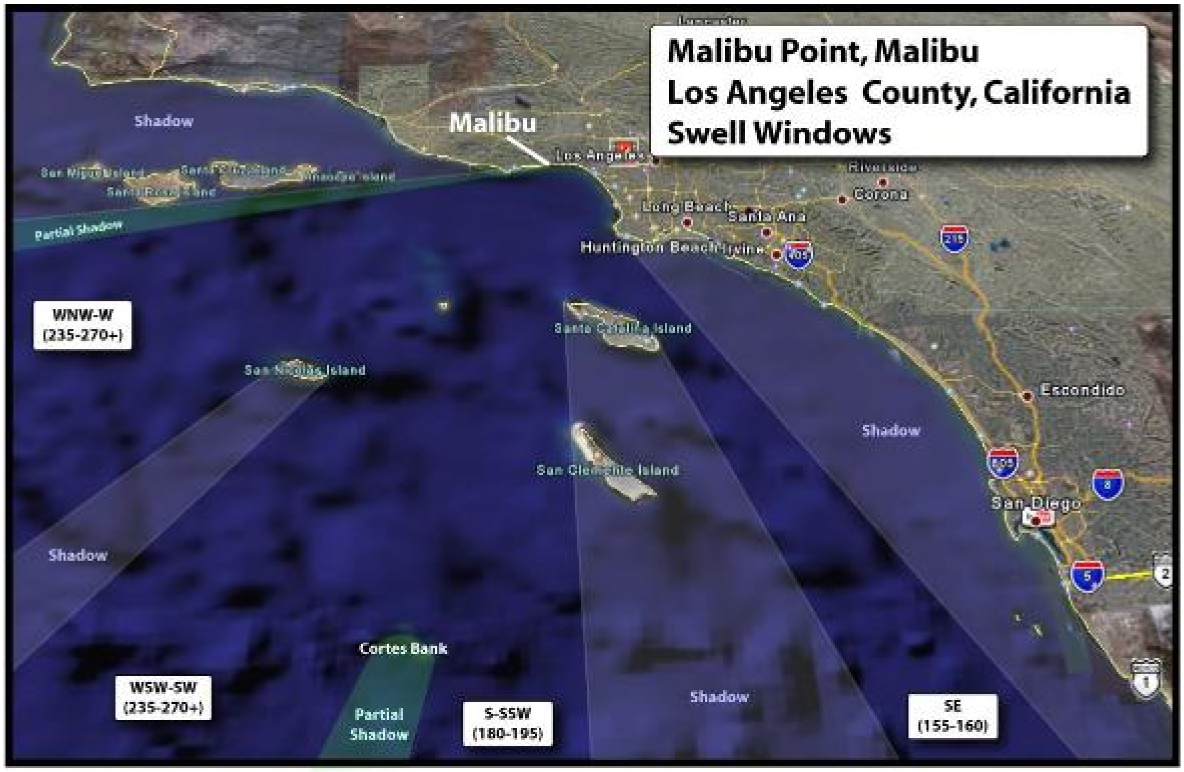

Figure 2.2-4: Swell window for Malibu, CA (Write, 2008)

Wave observations were made through a comprehensive Coastal Data Information Program (CDIP) funded by USACE, the State of California, NOAA's National Data Buoy Center and other public agencies. For this study, the Santa Monica Bay (CDIP 028) buoy is used for wave data inputs which has a nearly constant record dating back to 2000 and records 30 minute significant wave height, peak period, peak direction and water surface temperature. This stationary buoy lies approximately 12 miles due south of the study area and is in a water depth of approximately 1,190 feet, which can be considered deep water. In this context, water is defined as deep if the bottom bathymetry has little or no effect on wave propagation; typically 700 ft is sufficient for deep water.

Figure 2.2-5 and **Figure 2.2-6** show a wave and period rose for the length of record. The widths and colors of the bands show the magnitude of either wave height (**Figure 2.2-5**) or period (**Figure 2.2-6**) while the lengths provide the frequency of occurrence of each event. **Figure 2.2-7** and **Figure 2.2-8** show more detailed information regarding the wave record. The joint probability is shown in the bottom left plot with a color that signifies the frequency of occurrence. Throughout the time of record, the largest wave was 15 ft with an associated 14 second period and a 262° meteorological direction. The typical conditions show a significant wave height of 2.75 ft, a 14 second period and a direction from the south.

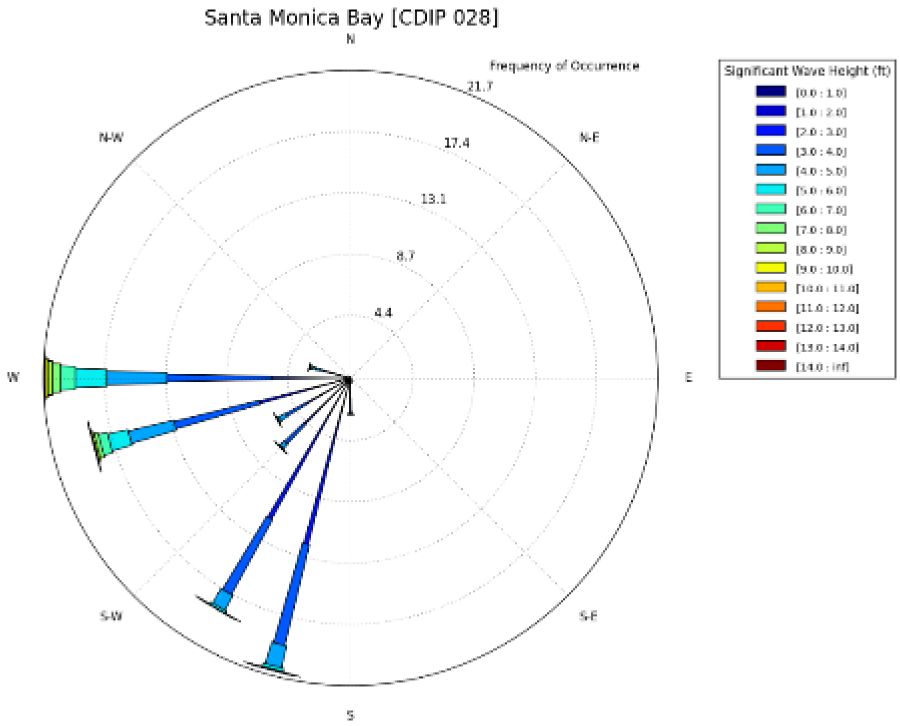

Figure 2.2-5: Wave rose for Santa Monica Bay (CDIP, 2015)

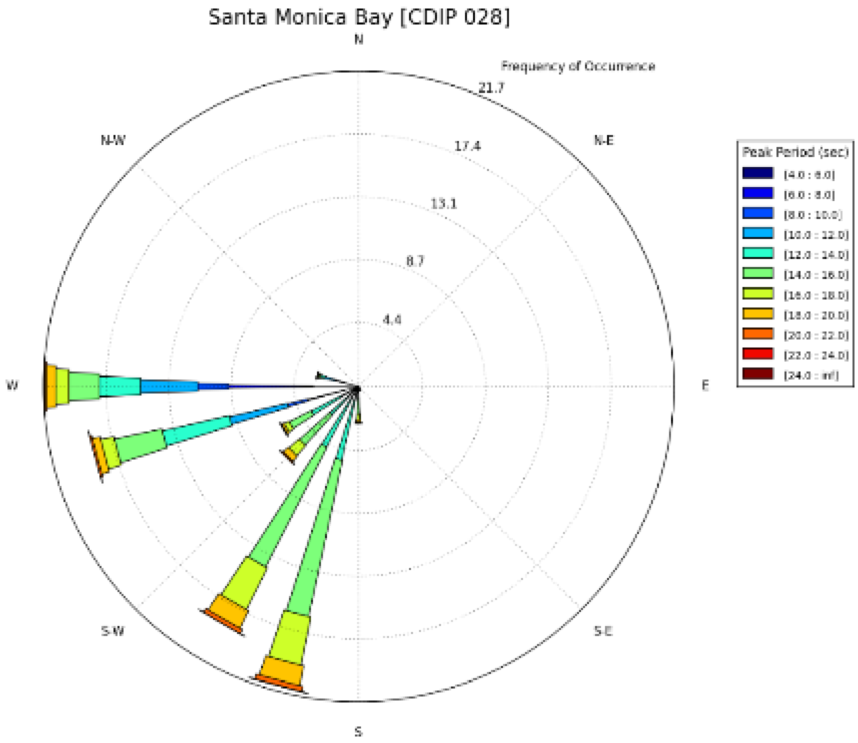

Figure 2.2-6: Period rose for Santa Monica Bay (CDIP, 2015)

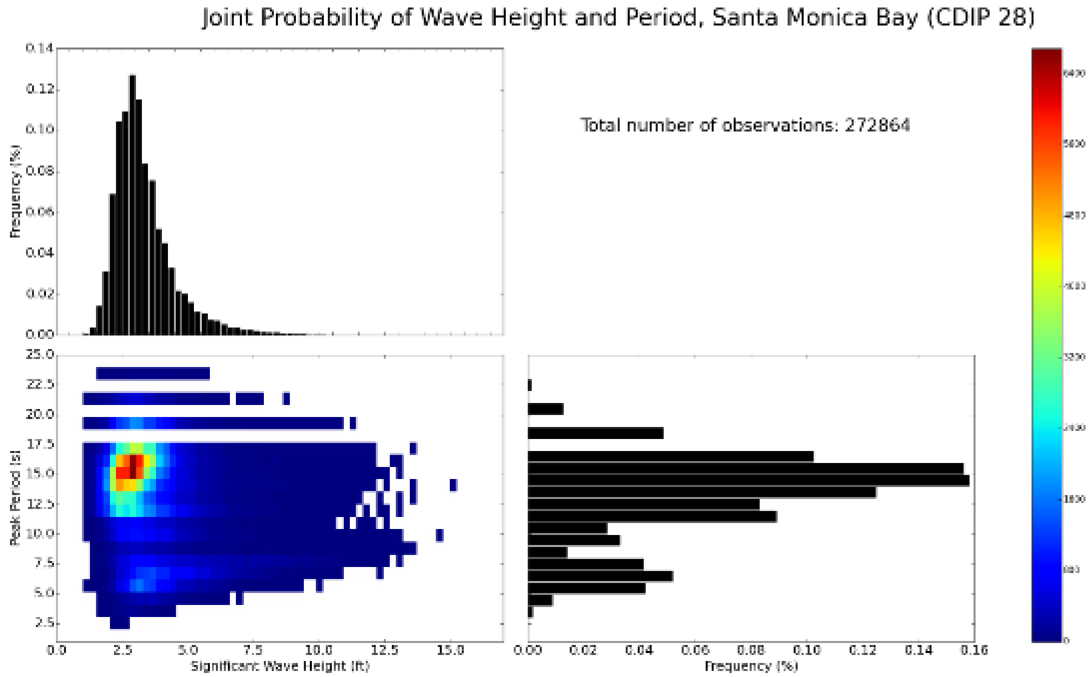

Figure 2.2-7: Wave height and period joint probability for Santa Monica Bay (CDIP, 2015)

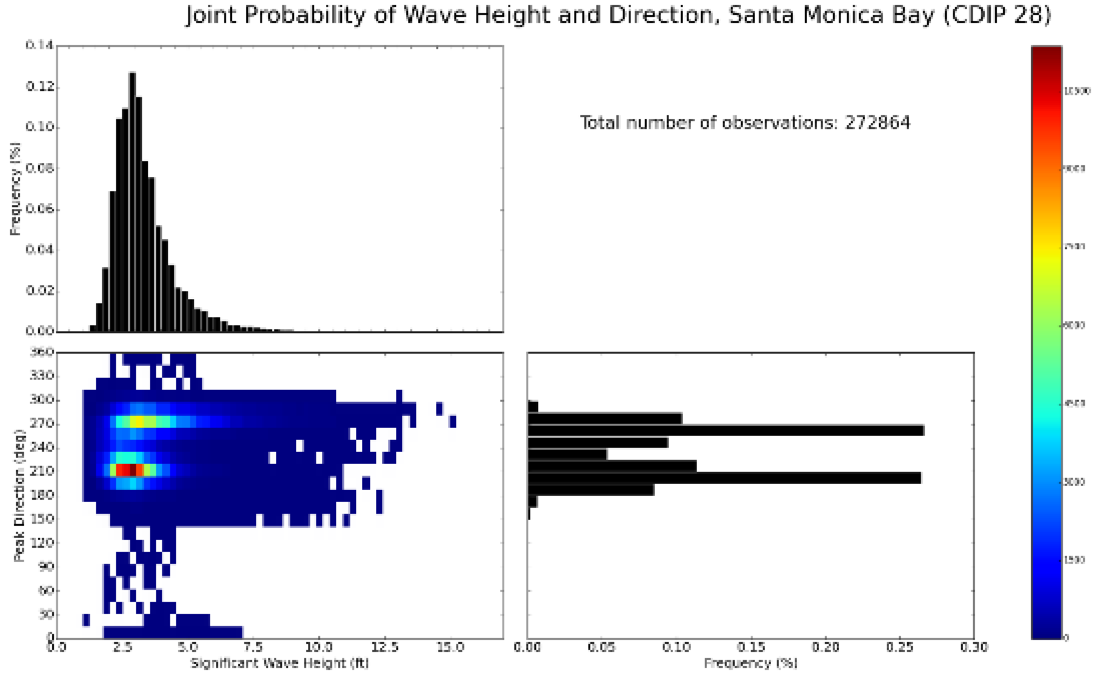

Figure 2.2-8: Wave height and direction joint probability for Santa Monica Bay (CDIP, 2015)

Although the wave parameters are of the utmost importance in engineering analysis, the above figures do not suggest the conditions at the site on a year by year basis. To easily see the change in wave climate from one year to the next, the annual energy index (E_r) is used. The annual energy index can be found by first calculating the wave power per wave, P, integrating the wave power over the entire year to find the total energy per wave, then indexing this parameter:

$$P \sim H_S^2 T_P$$

$$E = \int P\,dt$$

$$E_r = \frac{E}{1000}$$

The annual energy index for the Santa Monica Buoy is shown in **Figure 2.2-9**. It can be seen that the wave climate is relatively small in the early part of the 2000’s then increases in 2010 and returns to lower energy in the final years of record. Although a complete enough wave record does not exist, this pattern is normal for the Southern California Bight and the peak usually correspond to an ENSO event.

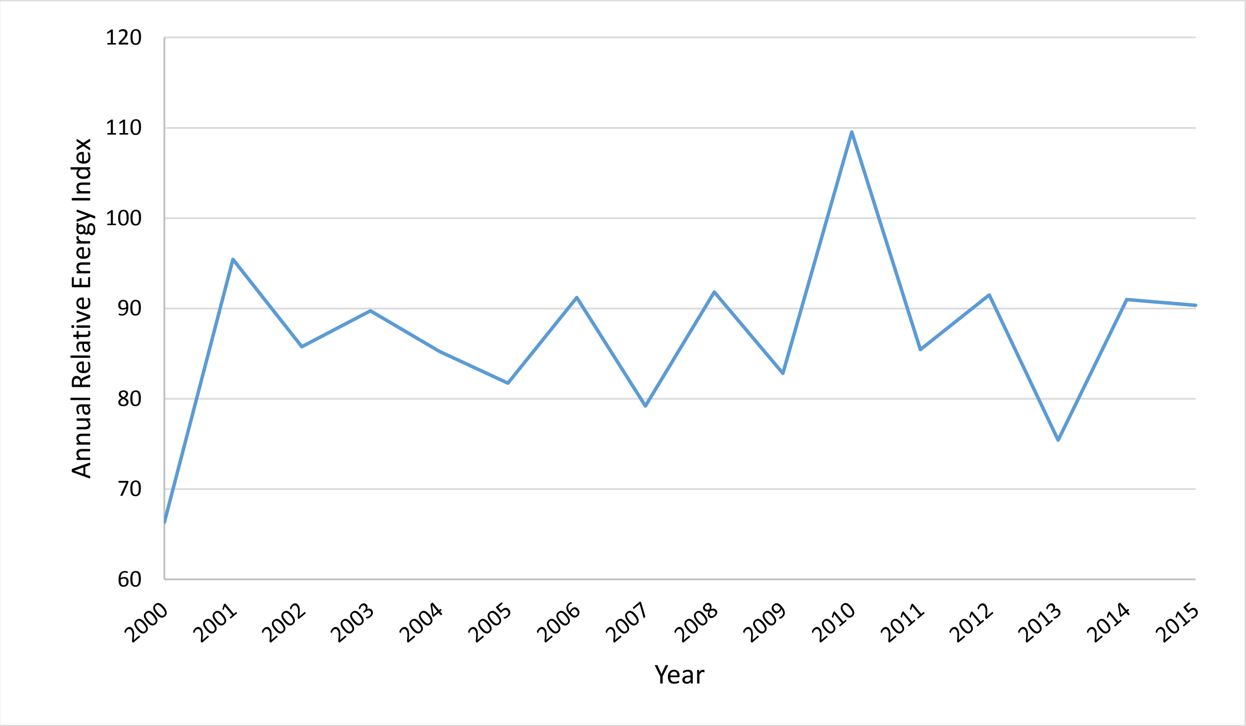

Figure 2.2-9: Annual energy index near Malibu

2.2.4 Shoreline History

Shoreline changes within the study area are almost entirely due to the effects of sediment supply deficiencies, development encroachment, shoreline structure construction and artificial beach nourishment that has occurred since the early 1900's. Areas west of Sunset Boulevard have been strongly influenced by roadway and private structures encroachment whereas the shoreline east of Sunset Boulevard has been advanced seaward through regular construction of groins, offshore breakwaters, storm drains and periodic placement of beach fills. Aerial oblique photographs flown over the Malibu coastline in 1924 show that the beaches were narrow and in many cases not much different than today. However, between 1924 and the late 1940's the shoreline was altered by construction of the Pacific Coast Highway and numerous private residences seaward of the road's right-of-way. The road between Carbon Beach and Sunset Boulevard was widened in the 1930's and realigned in the 1940's to the present day configuration. Also in the late 1940's the portions of the State Highway at what is now Malibu Road and Malibu Cove Colony Road was rerouted inland because of persistent landslide and/or storm damage problems. For the past 70 years, an undocumented volume of material has been deposited in the littoral zone during construction and as part of recurring slide and debris basin maintenance practices to keep the thoroughfare clear. As a result, the shoreline east of Las Flores Beach has been gradually altered to a cobble beach through years of accumulated and dumped material (Thompson, 1993). The shoreline has also been almost continuously fortified with seawalls and revetments over time to protect the private residences.

The limited beach profile data west of Topanga Canyon suggests that most of the beach areas have not altered much from their relatively narrow and sediment limited condition before 1928 which has been legally defined as the last time of natural shoreline. Because the thin beaches are heavily dependent on fluvial discharge, it is believed that the shoreline recedes in response to low sediment yield years and recovers temporarily after episodes of higher rainfall and stream flow. This section of the shore is cross-shore dominant as winter conditions typically erode the thin veneers of sand and severe storms temporarily cause scour down to the general bedrock shelf elevation of 0 to +2 ft, MLLW. Shoreline recession is limited by existing development, road right-of-ways and resistant bluffs. Limited data suggests that the lower lying road fills at Corral, Las Tunas and Castellemmare experience episodes of slope sloughing during severe storm incidents. Between 1971 and 1989, it is estimated that an annual average retreat of about 1 foot per year occurred along these sections. For a further more detailed shoreline history see Hapke et al. (2006) and Orme et al. (2011).

2.2.5 Alongshore Transport

Littoral transport of sand along the Santa Monica cell and Dume subcell is mainly influenced by the wave climate, material source, and the extent of manmade alterations since the turn of the century. Longshore currents in the coastal zone are driven primarily by waves impinging on the shoreline at oblique angles. The orientation of the Malibu coastline is southerly. Consequently, wave energy entering this area transports material in an easterly net direction nearly all year at all locations. Several segments in this reach, mostly west of Point Dume, can experience transport reversal during swell events generated from the southern hemisphere, but this is rare and quickly returns to an eastward direction. The calculated range of annual net littoral transport rate for this cell is about 150,000 to 250,000 yd^3 in an easterly direction (USACE, 1994).

2.2.6 Cross Shore Transport

Cross-shore currents exist throughout the study reach, particularly at times of high surf. These currents tend to concentrate at creek mouths and structures, but can occur anywhere along the shoreline in the form of rip currents which result in return flows that form complex circulation cells. To date, information is limited on the quantification of these currents and their effect on sediment transport. Consequently, their significance to the long-term sediment budget and coastal processes of the study area is unclear. In theory, cross-shore transport acts from the limit of the shore berm to the depth of closure. The closure depth is directly proportional to the breaking wave height. It can be assumed that no sediment, or a negligible amount, will be transferred from the surf zone to the offshore. To determine the depth of closure, four equations that estimate the closure depth were applied to the wave statistics and an average was found to be 23 ft (Birkemeier, 1985; Hallermeier, 1981) as shown in **Table 2.2-2** using data from a Wave Information Studies (WIS) buoy, 83098.

Table 2.2-2 - Depth of closure calculation

Equation	d_c (ft)
Hallermeier (1981), eq. 2	28.8
Hallermeier (1981), eq. 6	20.4
Birkemeier (1985), eq. 2	21.9
Birkemeier (1985), eq. 3	21.5
Average	**23.2**

Beaches west of Sunset Boulevard generally experience winter retreat followed by summer recovery. Because of the sediment limited conditions, the more narrow beaches can be stripped of sandy material leaving cobbles and rocky outcrops. More severe and temporal storm losses vary throughout the area. Wave action in Malibu can result in as much as 80 feet of horizontal retreat and a 10 foot vertical drop in profile elevation (Hale, 1977). Other anecdotal evidence indicates that the January 1983 storm lowered the beach elevation by at least 16 ft to an elevation of 2 ft below mean lower low water at Malibu Colony (Doyle, 1993), about 10 ft at Castellemmare near Gladstones 4 Fish (Lee, 1993), and similarly at Venice Beach. Typical horizontal retreats in Santa Monica Bay ranged from 100 to 150 feet during the severe 1983 storms with complete recovery (Lee, 1993). This indicates no material is lost to deeper water during high surf events.

2.2.7 Sediment Budget

Sediment budget for the nearshore study area is not well understood due primarily to the lack of coastal process data west of Topanga Canyon and the history of frequent shoreline modifications that have occurred in Santa Monica Bay since the early 1900s. However, the limited volumetric changes computed between the shoreline segments by the USACE in 1948 and the energy flux for longshore sediment drift calculated provide a reasonable estimate of sediment budget for the shoreline reach between Point Dume and the Santa Monica city limit. It was estimated that sediment input to this study area is 120,000 yd^3/yr from the net output of the updrift littoral cell. Updrift is defined as against the natural flow of sediment and downdrift is with the flow of sediment. Additional annual sediment sources contributing to this littoral cell include 90,000 yd^3 of fluvial transported material, 40,000 yd^3 from beach erosion updrift of the study area, and 15,000 yd^3 of artificial fill, which results in a total of an additional 145,000 yd^3/yr. Because no sediment loss is estimated, the net sediment transport out of this cell is 265,000 yd^3/yr. The calculated range of annual net littoral transport rate for this cell is about 150,000 to 250,000 yd^3 (USACE, 1994). After 1920, CALTRANS and Los Angeles County constructed many debris basins to control sediment transport in the study area. This has resulted in the interception of about 46,000 yd^3/yr coarse sediment that otherwise would have been transported to the littoral transport zone as described above. This reduces the annual sediment supply from 145,000 yd^3/yr to about 100,000 yd^3/yr as of present.

3.0 BENEFICIAL USE PLACEMENT FORMULATION

3.1 Planning Constraints and Considerations

Beneficial reuse of dredged or excavated materials and the restoration of a “natural” supply of sediments from the Malibu Creek watershed to the coastal littoral zone is an opportunity of the project. Sediments impounded upstream of Rindge Dam would have naturally washed down to the ocean if the dam was never constructed. The sand fraction, and larger sediments, would supply the littoral cell with material. Fine sediments would have dispersed and settled in the offshore. Alongshore currents resulting from approaching waves would distribute the material both updrift to the west but predominantly downdrift to the east to nourish beaches between Malibu and Santa Monica. Fluvial sediment transport modeling of existing and future no-action conditions show the dam to no longer impound sediments and predicts future sediments yield to the coast unaffected by the presence of the dam. However, a deficit of sand to the shoreline has accrued during the period when the dam reservoir was capturing sediments. This can be partially remedied by placement of the sand rich sediment layer excavated from the reservoir into the littoral zone. The placement of sediments on the beach or in the littoral zone has many considerations which include:

- The placement is beneficial; for recreation, habitat and/or reduction of coastal storm damages.
- Sediments are compatible from both benthic and aesthetic accounts.
- Access and constructability.
- Impacts to neighborhoods and business.
- Impacts to benthic habitat.
- Impacts to traffic.
- Impacts to recreation; beach use, parking, surfing.
- Costs.

3.1.1 Available Quantity of Sand Rich Sediments

Appendix D - Geotechnical Engineering characterizes sediments to be removed from the reservoir into three layers: approximately 210,000 yd^3 of a gravel-rich material on the surface, 340,000 yd^3 of a sand-rich layer in the middle, and 230,000 yd^3 of silt and clay in the bottom layer. The middle layer is considered for beneficial use in beach nourishment. The bulk composition of the middle layer is 73% sand, 5% gravel and 22% fine. This layer is also utilized in the reservoir for construction of access ramps and staging pads. The net quantity available for beach fill is estimated at 276,000 yd^3 with the same gradation breakdown mentioned above. A more rigorous analysis of sediment grain size will need to be performed before any material can be placed within the littoral zone. All modeling assumes that the excavated material is of beach quality.

3.1.2 Scheduling of Removal and Placement

Weather, traffic limitations, construction productivity and recreational beach use are all drivers of a schedule for placing sediments along the shoreline. Excavation of the reservoir in Malibu Creek is confined to the dry season, generally from 1 April to 15 October, for safety and habitat protection reasons. Recreational beach use prevents beach closure or beach access restrictions during the high use summer season between Memorial Day and Labor Day; generally 15 April to 15 September. Hence, the only overlap when sediments could be transported directly from the reservoir excavation site to a beach placement site is two weeks in April and one month from mid-

September to mid-October. An additional schedule constraint is the traffic limitation on Malibu Canyon Road. Due to these limitations, and assuming the inclusion of a temporary sediment stockpile area, results in the following production schedule of the sand-rich layer available for beach or nearshore placement, shown in **Table 3.1-1**.

Table 3.1-1: Timeframe for beach or nearshore placement of material and approximate quantities

Time	Quantity (yd^3)
Year 2	54,000
Year 3	127,000
Year 4	96,000

3.1.3 Need for Temporary Stockpile and Staging Area(s)

A need for temporary stockpile area(s) arise due to the scheduling conflict when excavation from the reservoir site can occur and when sediment placement at the beach can occur, as described above. These areas will need to be large enough to hold 75 to 100 thousand cubic yards. Upland stockpiles will only be required if a beach placement alternative is considered. In addition, temporary construction easements and staging areas will be required for any placement alternatives. These temporary construction areas are described elsewhere in this report, however, restrictions associated with these temporary construction sites will also drive the placement production and methodology.

3.2 <u>Methods of Delivery for Placement of Sediments in the Littoral Zone</u>

3.2.1 Mechanical Delivery (Truck)

Delivery to the shore could be accomplished by individual truck trips from the site to the receiver beach. The sediment will be dumped at a staging area then conventional earth moving equipment, such as dozer and front-end loader, will move the sediment to a designated area and finally grade the sub-aerial beach profile. The fill is built on a section-by-section basis with an average length of 20 ft. The daily production rate depends on the distance between the dam site or storage area and receiver beach.

3.2.2 Nearshore Delivery

Delivery can also be accomplished by dumping the sediment into the nearshore environment. If the sediment is landward of the depth of closure, the sand will remain within the littoral zone and ultimately result in sand accretion along the Malibu coast. A barge can be loaded at a nearby port or marina and transported by water to the nearshore zone placement site and then dumped at a depth shallower than the depth of closure, 23 ft. A typical barge can hold 1,500 yd^3 and thus can be filled by 75 20 yd^3 trucks. Actual production rate depends on distance between the dam site and port as well as the port and the nearshore zone.

3.3 Littoral Zone Placement

3.3.1 Beach Fill Alternatives

A single beach nourishment locations will be considered as disposal options for excavated material from the removal of Rindge Dam as seen in **Figure 3.3-1**, east of Malibu Lagoon. Other sites have been considered and ruled out due to a lack of access and room for a staging area. As material is placed on the beach, the wave action will disperse the sediment. This dispersion will be modeled by a shoreline change model to show the extent of influence of the nourished sediment. The disposal site can contain approximately 100,000 yd³, but since the delivery rate will only be around 1,000 yd³/day, the areas will never fill and the sediment will be transported by the longshore current before the area will reach a maximum capacity. The site has limited access for delivery and required earth working equipment and construction in such a small area will be challenging, but not impossible.

Figure 3.3-1: Proposed beach placement location

Figure 3.3-2 show a representative profile for a beach placement option. The solid black line represents the initial placement with a berm height at +10 ft MLLW.

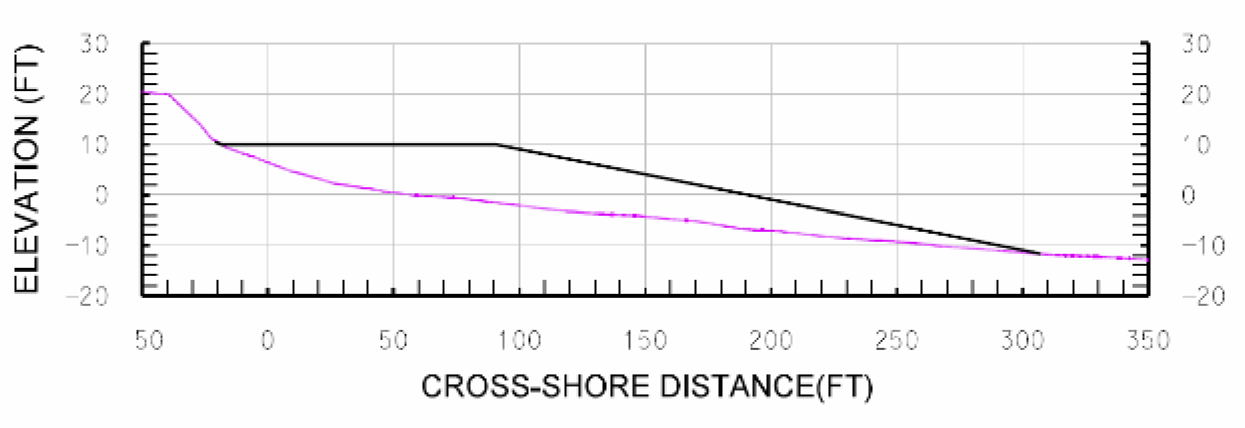

Figure 3.3-2: Representative beach placement profile. Pink line shows the natural bathymetry and the solid shows the proposed placement profile

3.3.2 Nearshore Placement Alternatives

Another suitable placement option would be nearshore placement by barge. The placement location would need to be within the limits of the depth of closure to ensure all material is retained within the littoral zone. A single area is identified as an acceptable nearshore placement sites and is shown in **Figure 3.3-3**. This area falls within the depth of closure and would not directly impact the nearby submerged rubble field as seen in the nearshore habitat survey described in the **Appendix J - Habitat Evaluation**. The placement area can hold approximately 100,000 yd³ of sediment with a height of the artificial berm no more than three feet above the natural bathymetry. Nearshore placement would not be limited by the October to December timeframe proposed for the beach placement alternatives. Adverse wave conditions may limit placement windows, but the ability to work for the entire year will not impact the project schedule.

Figure 3.3-3: Nearshore placement location

4.0 ANALYSIS OF PLACEMENT ALTERNATES

4.1 Wave Transformation with CMS-Wave

The numerical model CMS-Wave is used to simulate depth-induced wave refraction and shoaling, wave breaking, diffraction, and wave-wave interaction that redistribute and dissipate energy in a growing wave field from the relatively deep-water location in Santa Monica Bay to a nearshore location off of Malibu and the study area. This model was used through the Shoreline Modeling System interface as described in the SMS User Manual (v11.1). The modeling domain is shown **in Figure 4.1-1** . The angle of the model domain was determined by providing a near-constant water depth of 1,200 ft at the input boundary condition, which is a similar depth to the Santa Monica Bay CDIP buoy. Since both locations are in deep water and similar locations, it can be assumed that same wave climate is present at each location.

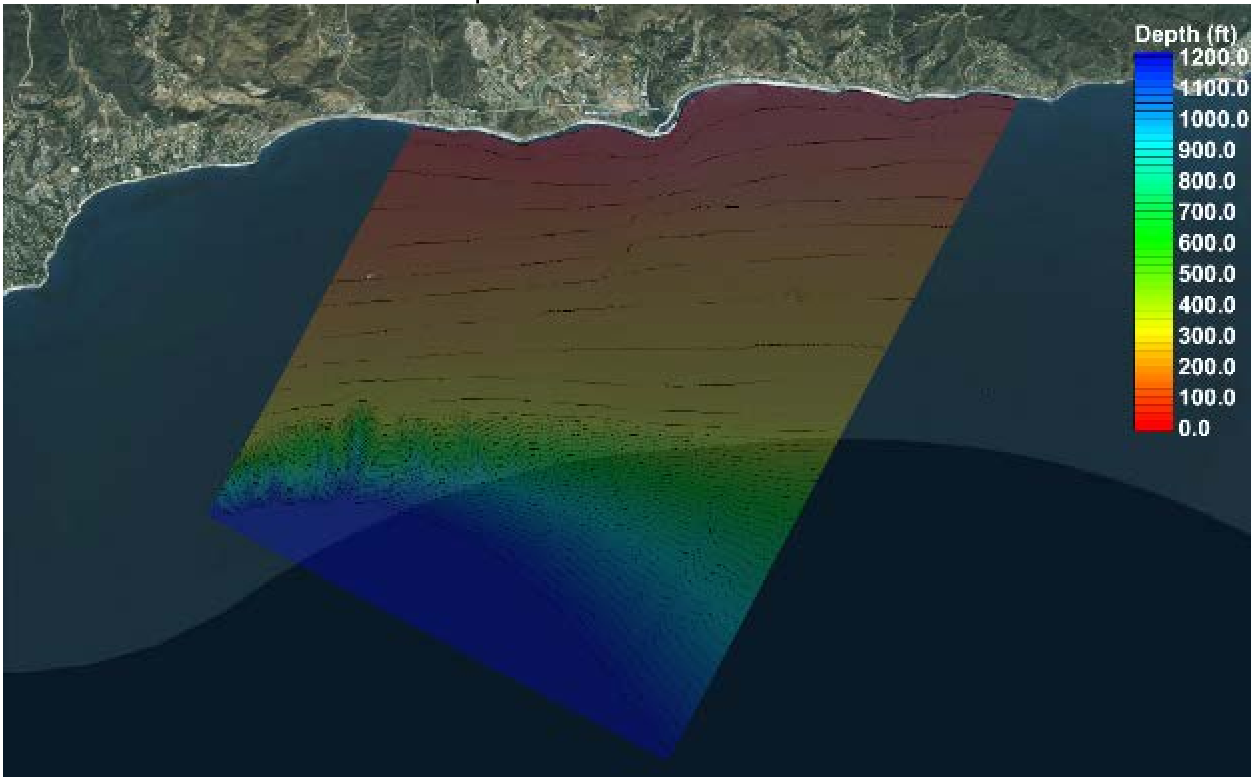

Figure 4.1-1: CMS-Wave model domain

While this wave propagation model has greater capabilities, no wind field was applied and a constant tide level of approximately 3 ft above NAVD88 was modeled, simulating the Mean Tide Level (MTL). The full time series of wave data collected from the CDIP buoy was combined into 3-way joint probability of significant wave height, wave period and meteorological wave direction. Bin sizes were set as 0.5 ft for wave height, 2 seconds for period and 15° for direction. Input wave data produced a total of 651 bins. A sample of the input parameters for the CMS-Wave boundary conditions are shown in **Table 4.1-1**. The model was run in half-plane mode with a variable cell size, which ranges from approximately 165 ft (50 m) at the deep water boundary to 16 ft (5 m) near the shore, and a constant Manning value of 0.03 to simulate bottom friction.

Table 4.1-1: CMS-Wave sample of input boundary conditions

Case	Direction (°)	Wave Height (ft)	Period (s)
0	247.5	1.25	6
1	262.5	1.25	6
		.	
325	262.5	4.75	12
326	277.5	4.75	12
		.	
649	277.5	14.25	10
650	262.5	14.75	14

The output of CMS-Wave is shown in **Figure 4.2-1** and **Figure 4.2-2** for the typical and maximum conditions at the project location. The typical condition was determined from the same 3-way joint probability as shown in **Table 4.1-1** which consisted of the bin with the most number of occurrences. For the typical conditions, the offshore wave parameters are a 2.75 ft significant wave height, a 14 s peak period and 195° peak direction. Waves enter nearly perpendicular to the coast, shoal, enlarge, and break very near the coast. For the maximum conditions the offshore parameters are 14.75 ft wave height, 14 s period and 262° direction. In this case, waves enter with a more shore parallel direction and break further offshore. The color ramp represents the significant wave height and the arrow represent the predominate wave direction.

Figure 4.1-2: Typical conditions of project location (H_s=2.75 ft, T_p=14 s, D_p=195°)

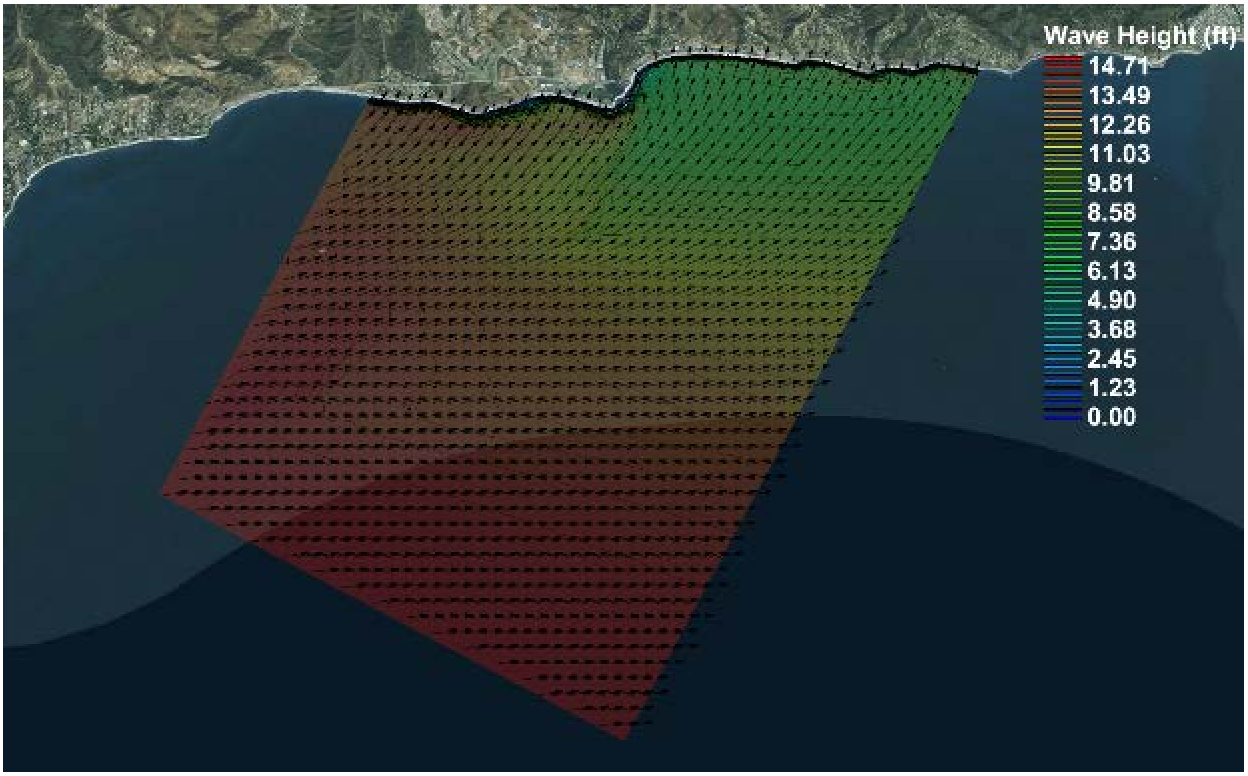

Figure 4.1-3: Maximum recorded wave height conditions at project location (H_s=14.75ft, T_p=14s, D_p=262°)

Regardless of the offshore wave conditions, Santa Monica bay causes refraction of the offshore wave due to the bottom bathymetry, the direction changes to more shore normal but still oblique enough to create a longshore current that travels from west to east.

4.2 Evaluation of Historic Beach Profiles

4.2.1 Beach Profile Surveys

Historical beach profiles along the County's shoreline, shown in **Figure 4.2-1**, have been collected by Los Angeles County since the 1930's to document the shoreline changes within the Los Angeles region. This historical data has been augmented with recent comprehensive beach profile surveys that were conducted as part of the Coast of California Storm and Tidal Wave Study (CCSTWS) program from 2002 to 2005. While the initial survey in 1935, followed by a subsequent survey in 1946, and a post-Hyperion-nourishment survey in 1953 to document large beach fills from the construction of the Hyperion wastewater treatment plant, these surveys only extended as far north and west as Topanga Canyon. Likewise, the three surveys prepared by Coastal Frontiers (1992) between 1989 and 1990 were all east of Topanga Canyon. The earliest survey available to resolve an accurate beach profile in the Malibu area is from 1967. Six surveys conducted under the CCSTWS program between 2002 and 2005 also cover the Malibu area. In addition, profiles were extracted from a DTM based on a 2009 LiDAR/SHOALS survey conducted by USACE (JABLTCX).

Table 4.2-1: Historical and Recent Comprehensive Beach Profile Surveys in Los Angeles County

Survey Period	Survey Region	Number of Transects
Oct-35	From Malaga Cove to Topanga Canyon	256
Nov-46	From Malaga Cove to Topanga Canyon	243
Oct-53	From Malaga Cove to Topanga Canyon	219
May-89	From Malaga Cove to Topanga Canyon	256
Jan-90	From Malaga Cove to Topanga Canyon	256
Jun-90	From Malaga Cove to Topanga Canyon	256
Mar-Jun 02	From Malaga Cove to Leo Carrillo State Beach	437
Jun-03	From Malaga Cove to Leo Carrillo State Beach	81
Nov-03	From Malaga Cove to Leo Carrillo State Beach	81
Jun-04	From Malaga Cove to Leo Carrillo State Beach	81
Oct-Nov 04	From Malaga Cove to Leo Carrillo State Beach	81
May-Jun 05	From Malaga Cove to Leo Carrillo State Beach	437

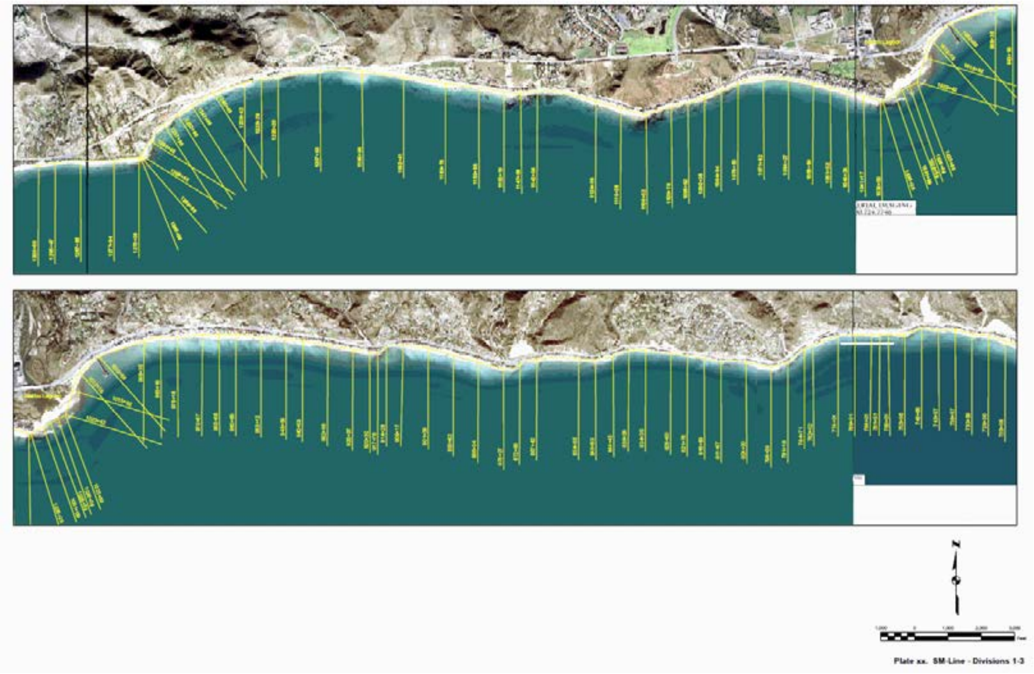

Figure 4.2-1: Malibu transect locations

Two profiles will be shown as representative near the vicinity of Malibu Creek, 953+12 (Malibu Colony) and 1046+38 (Malibu Pier), which represent an areas that may receive sediment. Due to the limited extent of backshore data, the berm locations could only be determined using the 2009 SHOALS dataset. Previous surveys concentrated on the submerged profile and did not extend landward enough to capture adequate resolution to determine the change in berm location. From this LiDAR survey, the berm height was determined to be in the order of 10 ft MLLW. **Figure 4.5** shows the average profile of each transect for surveys shown in **Table 4.2**. Note that only surveys from 1967, 1969, 2002-2005 and 2009 were taken at these locations.

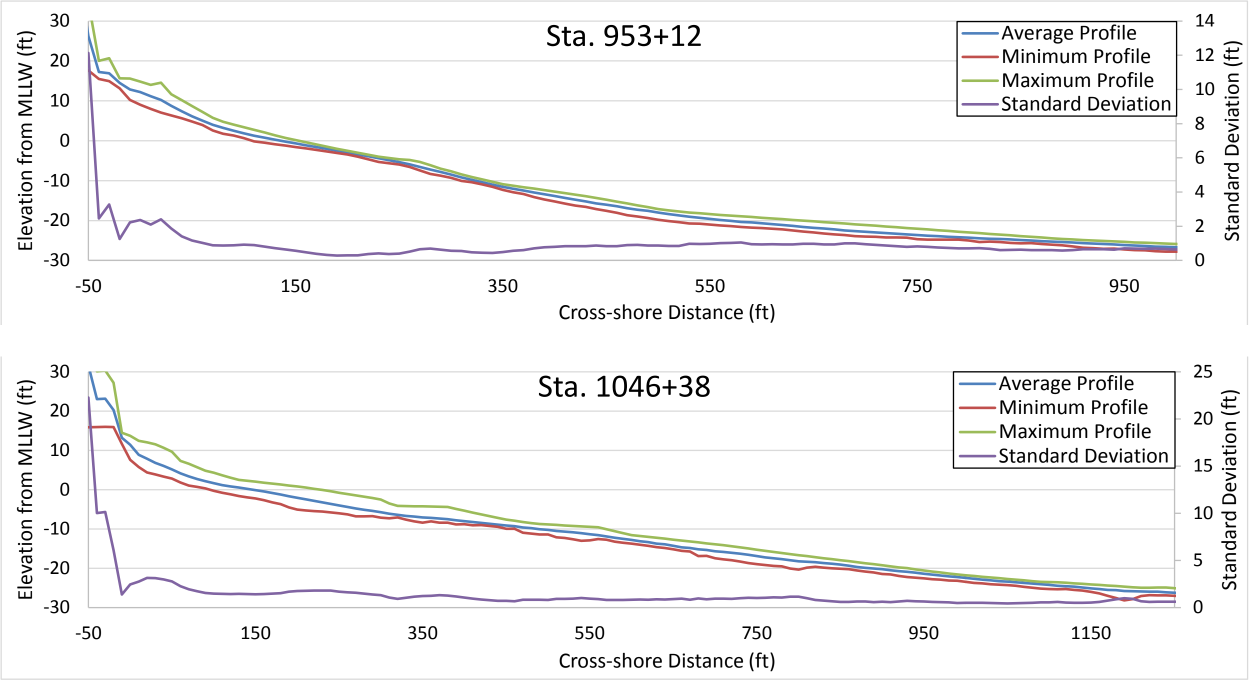

Figure 4.2-2: Analysis of profile survey data in the vicinity of proposed placement areas.

The limited profile data does not accurately show the response of the nearshore to a storm event based on the small deviation of less than 2 ft. This may be because of the relatively low wave climate and the timing of surveys. Summer and winter comparison profiles were taken in the early to middle 2000's which show a very small change in the nearshore profile.

4.3 Beach Fill Modeling with GenCade

GenCade is a relatively newly developed numerical model which combines the engineering power of GENESIS and the regional processes capability of the Cascade model. GenCade calculates shoreline change, wave-induced longshore sand transport, and morphology change at inlets on a local to regional scale and can be applied as a planning or engineering tool. GenCade is operated within the Surface-water Modeling System interface, bringing functionality of a geo-referenced environment together with accessibility to other USACE numerical models, and was developed by the Coastal Inlets Research Program and the Regional Sediment Management Program (Frey, 2012). A simplified implementation using version 1.0, Release 3, dated September 2012 was used to evaluate the probable changes to the shoreline between alternative placement sites and times along adjacent shoreline of Malibu Lagoon.

The shoreline model for Malibu is a one-line model approximately 4.25 mi (6,900 m) in length with a conventional x-y coordinate system with the y axis pointing offshore. The initial conditions for the model is shown on Figure 4.6, with x increasing from east to west and y increasing from north to south with a cell size of approximately 82 ft. (25 m). The main assumption for all one-line models is that the coast and offshore contours are straight and parallel. GenCade attempts to alleviate this limitation by introducing a regional contour line. This line defines the shape of the coast and offshore contours. The regional contours provides a more general application of the GenCade model but still is limited; given a long enough simulation time, the shoreline will always follow the regional contour regardless of the wave conditions.

GenCade model implementation is even more simplified in this case because the sediment contribution from Malibu Creek is simulated as a continuous inflow rate with a alongshore length approximately the width of the lagoon inlet, instead of a more complicated modeling of an inlet with the accompanying sediment storage of ebb and flood tide shoals, and an allowance on inlet bypassing. This simplification is justified because Malibu lagoon has a small tidal prism without complex inlet dynamics, and is closed off to the ocean for a good portion of the year. However, along this sediment starved coastline, the sediment yield from Malibu Creek could be significant and was modeled as equivalent to an annual coarse grained sediment yield of 24,000 yd^3 by a beach fill placed between November 15th and April 15th for every year of the simulation (6.54 yd^3/hr (5 m^3/hr)). The total length of simulation was 10 yrs with 6 yrs being after the last fill event and was determined to be adequate in describing the dispersion of the placed sediment.

The shores of Malibu are developed by private residences that are protected by mostly revetments and some seawalls. This armoring causes the shoreline to be fixed and erosion cannot occur landward of this structures. This armoring line is applied to the GenCade simulations in the form of a seawall. Malibu Pier is assumed to have a negligible effect on the wave climate, so it is ignored in the analysis. Extensive calibrations of GenCade were not performed but the modeled longshore sediment transport magnitude and direction agree with the previously stated literature. A more comparative analysis will be presented to show the influence of the placement location.

Figure 4.3-1: GenCade model domain and initial conditions. Black line indicates the cells and reference line, red circle shows offshore wave input location, blue line is the seawall/revetment and orange line is the shoreline

4.3.1 Without Project Conditions

The without project condition is shown in **Figure 4.3-2** and the magnitude of the longshore transport is shown in **Figure 4.3-4** with the negative sign representing a net easterly transport. Note that the zero point corresponds to the eastern edge of the modeling domain. The magnitude and direction of the net sediment transport agrees with previous studies and falls within the range of 150,000 to 250,000 yd³/yr. At the end of the ten year simulation, the shoreline has eroded to the extent of the seawalls/revetments over the entire shoreline. Although the simulation length is from 2002-2011, the trend has continued and the eroded shoreline can be seen in **Figure 4.3-3**, a recent aerial image (Google, 2016). Note that Malibu Pier is at a distance of 12,600 from the zero point and the Malibu Lagoon is between 14,000 and 14,600 ft in the alongshore position. Although an extensive calibration of the GenCade model was not performed, a comparison of the without and with project shorelines will be made which brings each analysis on equal footing. The main purpose of this study is to show the fate of the placed material and since the modeled longshore transport rate closely agrees with the rate stated in the literature, GenCade is an acceptable tool to analyze the shoreline behavior.

Figure 4.3-2: Without project conditions after 10 years. Colors are the same as in Figure 4.6 and the thin green line indicates the initial shoreline

Sea level rise is a minor factor in the GenCade analysis. After the 10 yr simulation period, the difference between even the low and high sea level rise cases is less than 0.5 ft. According to the Bruun rule, the difference in shoreline position due to this increased water level is only 10 ft and will occur regardless of the project implementation.

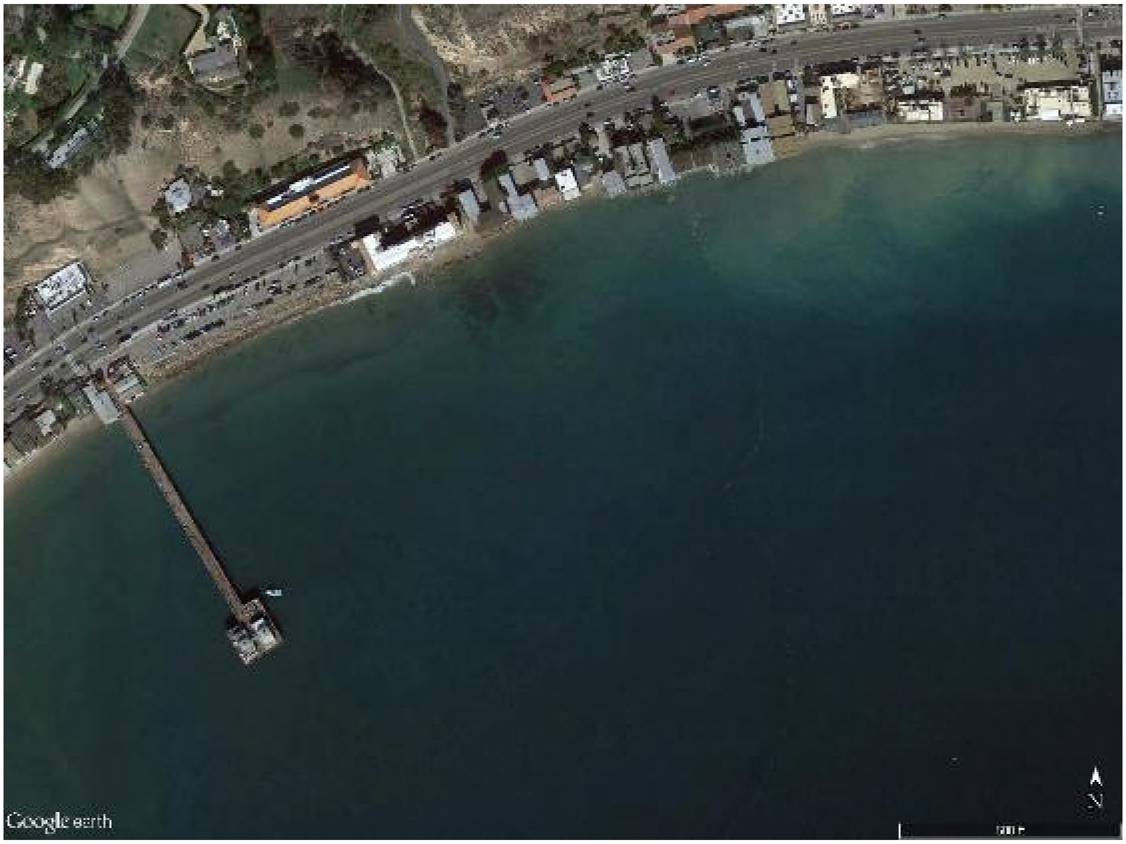

Figure 4.3-3: Present condition of shoreline near Malibu Pier (Google, 2016)

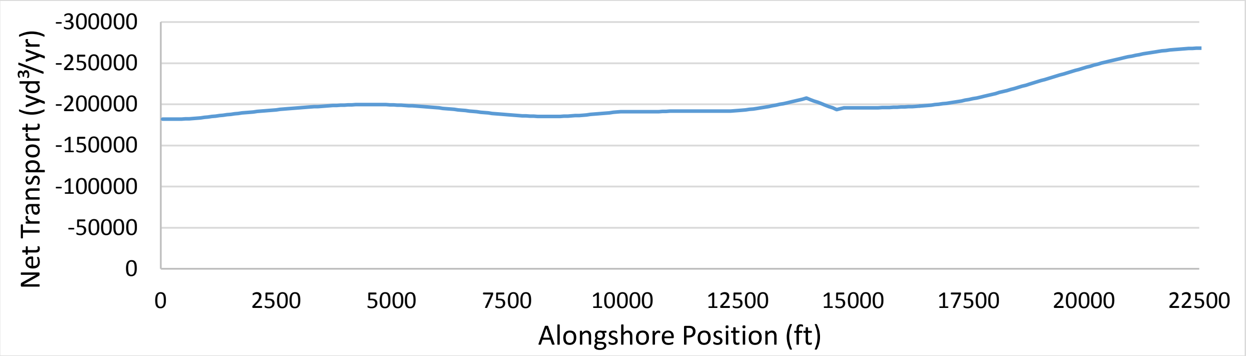

Figure 4.3-4: Without project net sediment transport modeled with GenCade

4.3.2 Malibu Pier Placement Alternative

For modeling purposes, placement of material at Malibu Pier begins in the first year and lasts approximately three months, October thru December. The placement width is approximately 1000 ft (325 m) and sediment inflows at a constant rate of approximately 29, 69 and 52 yd^3/hr (22.35, 52.5 and 39.72 m^3/hr) for years 1, 2 and 3 respectively. The final input volumes correspond to values shown in **Table 3.1-1**. The final shoreline, after 10 years, is shown in **Figure 4.3-5** with the blue line represents the fixed location of the revetments or seawalls, the green line is the existing shoreline and the orange line is the future without project shoreline.

Figure 4.3-5: Malibu Pier placement final shoreline location

Figure 4.3-6 shows the initial stages of the sediment placement at Malibu Pier. Sediment is placed at a constant rate to simulate a steady flow of delivery. In fact, placement will only occur during certain hours. This model also does not account for the initial loss of fine material directly after placement, which will result in a narrower berm than shown, but the transport and dispersion of the placed sediment will be similar to that shown in the following figures. The final stages of placement and the years directly following is presented in **Figure 4.3-7**. During this stage, the placed material begins to spread in an easterly direction following the natural direction of longshore sediment transport. Because of the relatively weak wave climate within the Santa Monica Bay, the placed material remains grouped together. The fate of the placed material is shown in **Figure 4.3-8**. This shows that the placed material will continue to disperse and spread to the east. The berm width will continue to decrease and will eventually recede back to the natural conditions. Sea level rise will have negligible effects based on the above discussion in **4.3.1**. The modeling timeframe is short and only a small difference in shoreline position will be noticed. Wave conditions will not change given the small increase in water level which leads to the same sediment transport patterns.

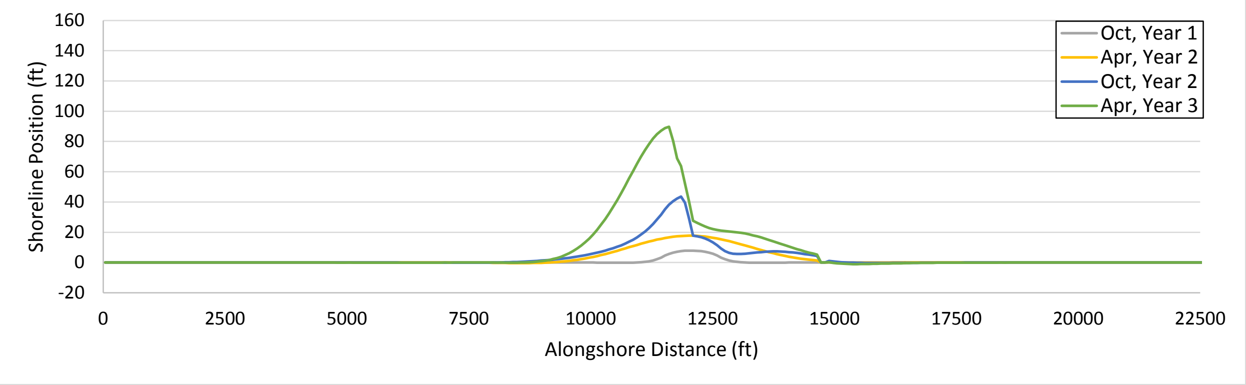

Figure 4.3-6: Shoreline change from without project simulation during Malibu Pier placement events

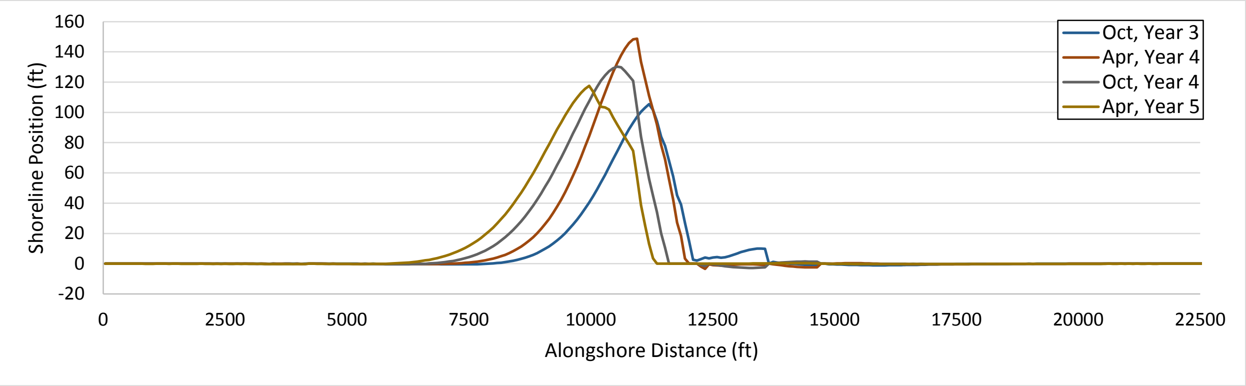

Figure 4.3-7: Shoreline change from without project simulation during the final stages and directly after placement at Malibu Pier

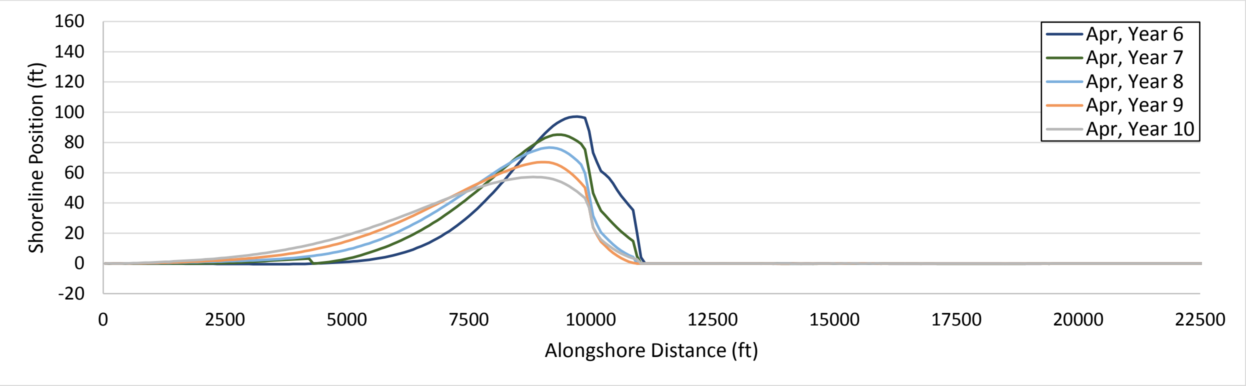

Figure 4.3-8: Final shoreline change from without project simulation after Malibu Pier placement events

4.3.3 Nearshore Placement Analysis

The evolution of material placed in the nearshore will act in the same manner as the previously described shoreline change models with beach placement. As long as the placement depth is less than the depth of closure, the material will eventually move shoreward. The berm width would not be as large as direct beach placement method but the perturbation to the natural shoreline will travel in a net easterly direction and will be beneficial in nourishing the littoral cell and providing more protection from incoming waves. As stated earlier, sea level rise will not impact the wave conditions which is a direct driver of the longshore sediment transport. The direction and magnitude of the transport will not change and the same rate will be observed regardless of the water level.

4.4 Physical Impacts to Near Shore Habitat

Some impacts will be observed to the nearshore environment, but mainly would be negligible. Since the placement of sediments would only occur over a three year period and natural conditions will soon return, sea level rise will have no impact on the alternatives. Complete dispersion would occur before a noticeable rise in sea level would be observed. The placed material would also have a positive aspect in buffering any infrastructure, reducing the effects of damaging waves.

Beach and nearshore placement will only occur in area where the natural habitat is sandy bottom; direct covering of other habitats is not expected. As the placed material is dispersed by natural wave action, some covering of the adjacent rubble field is expected. This temporary coating of sediment should not remain for more than a few years. Naturally occurring sediment discharges from Malibu Creek would have the same effect on the adjacent rubble field. Although some impacts on the adjacent habitat type will be observed, no lasting effects are expected as sediment will naturally travel towards the east.

4.5 Evaluation of Effects to Surfing

The area at Surfrider Beach is a world-renown surfing location. Waves almost constantly break year round at Malibu Point, which attracts surfers of all skill levels and board sizes. There are three main individual spots in this location which are all right hand waves; First, Second and Third Points shown in **Figure 4.5-1**. Starting in the West, Third Point mainly consists of cobbles and boulders which cause the wave to abruptly break similarly to a reef. This wave is not usually surfable unless there is a large southern swell. Next, Second Point breaks more normal to the coastline and is the shortest, in terms of rideable waves, of the three locations. Lastly, First Point is hot spot of the area which is always busy with longboarders and paddleboarders even on small days. This wave break is very smooth, consistent and can be ridable for more than 500 ft. During a Southern swell event, shown in **Figure 4.5-2**, Malibu Point waves can reach up to 20 ft and there is even recorded evidence of triple overhead waves, **Figure 4.5-3**.

Although sand will be added near Malibu Point, it will not interact with the surf spot. The net direction of sediment transport is to the east. Some placed sediment may temporary move to the west, but it will eventually travel east and away from the famous surfing area. The shoreline change model shows some increased beach width near Malibu Lagoon but will return to the normal levels by the end of the placement window. This increased beach width will not alter the waves at Malibu Point but may cause the waves to break slightly further offshore for a short period of time.

Figure 4.5-1: Surf Breaks at Surfrider Beach, Malibu, CA (Write, 2008)

Figure 4.5-2: Malibu Point during a Southern Swell (Write, 2008)

Figure 4.5-3: Evidence of triple overhead waves at Malibu

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