

City of Half Moon Bay, Miramontes Point

Sea Level Rise Vulnerability and Fiscal Impact Assessment



Photo: Integral Consulting, 2022

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Acronyms, Abbreviations, and Definitions

APN	Assessor's Parcel Number
basal unit	Lower geologic formation of the cliff
BID	Business Improvement District
bluff	Soft unconsolidated materials found in the marine terrace deposits
bluff contact	Location where the bluff meets the cliff
cliff	Hard consolidated rock under the bluff
CCC	California Coastal Commission
CoSMoS	Coastal Storm Modeling System
DEM	Digital Elevation Model
DSAS	Digital Shoreline Analysis System (USGS)
ENSO	El Niño Southern Oscillation
HMB	Half Moon Bay
MHW	Mean High Water
NOAA	National Oceanic and Atmospheric Administration
OPC	California Ocean Protection Council
PDO	Pacific Decadal Oscillation
SWL	still water level (observed tides including storm surge effects)
toe of the cliff	Location where the base of the cliff meets the beach
TOT	Transient Occupancy Tax
TWL	Total Water Level (tides + wave run-up)
USGS	U.S. Geological Survey
LCP	Local Coastal Program
LHMP	Local Hazard Mitigation Plan

Disclaimer

This study is part of an ongoing process to understand and prepare for coastal erosion associated with sea level rise for the City of Half Moon Bay around Miramontes Point. The maps and associated analyses are intended as planning tools to illustrate projected hazard exposure to existing infrastructure and other resources associated with a variety of future sea level rise scenarios.

There are inherent uncertainties associated with modeling and projecting future hazards and their potential impacts. Maps and tables produced for this report are based on model outputs and cannot account for all complex and dynamic ocean, terrestrial, and anthropogenic processes or future adaptation approaches such as shoreline protection. The contributors and sponsors of this product do not assume liability for any injury, death, or property damage.

Executive Summary

The City of Half Moon Bay (HMB) is a small incorporated city on the Pacific coast of central California 25 miles south of San Francisco. The majority of the city's coastal cliffs are of variable height, except for the area immediately adjacent to Pillar Point Harbor. Narrow beaches are located seaward of the cliffs in most locations. Seasonal winter storms impact the coast, eroding beaches and causing coastal bluff retreat.

The project study area is located near the southern boundary of the city. There are two golf courses, a Ritz-Carlton Hotel, and a popular section of the California Coastal Trail (hereafter referred to as the Coastal Trail). These recreational and tourism facilities are large contributors to the overall economy of Half Moon Bay, with revenue from the Ritz-Carlton Hotel representing nearly one-fifth of the entire city budget (Schnayerson 2021). There is growing concern that with continual seasonal storms and higher sea levels associated with climate change, some of the recreational facilities will be impacted. This leads to the need to understand possible future vulnerabilities and when the various facilities will be affected by retreating bluffs.

Integral Consulting Inc. (Integral) was awarded a contract with the City of HMB in December 2021 to conduct a **Miramontes Point Sea Level Rise Vulnerability and Fiscal Impact Assessment**. The project was undertaken in several phases. Phase 1 is a historical coastal bluff retreat analysis to understand the processes of bluff retreat and to generate rates of historical change which are required for future vulnerability modeling. This was accomplished using both historical aerial photography, more recent lidar digital elevation models (DEMs), and a new photographic survey collected via drone in the winter of 2022. Cliff toe and bluff top edges were automatically extracted from the DEM surfaces using the U.S. Geological Survey (USGS) Cliff Delineation Tool (Seymour et. al. 2016) and visually interpreted from the older aerial photography. The study then used the USGS Digital Shoreline Analysis System (Himmelstoss et. al. 2018) to measure rates and amount of change of the cliff toe and bluff top edge positions.

The study area was divided into six sections, extending from Section 1 in the north to Section 6 in the south. The sections are largely based on the orientation, geology, and morphology of the cliffs. The geology throughout the study area is variable in that there is a lower, basal unit of the Purisima Formation overlain by poorly consolidated marine terrace deposits. The Purisima Formation dips to the northeast, and as a result, its thickness in the cliff face varies from as low as three ft in the north to more than 30 ft to the south. The Purisima Formation is more resistant to erosion than the marine terrace deposits, and where wave runup exceeds, or will exceed in the future, the contact between the two units, and rates of bluff retreat are expected to be higher. As such, rates of erosion vary substantially along the study area, with the highest retreat rates occurring in the three northern sections, including Miramontes Point. The lowest rates were

measured in the southernmost section, where the thickness of the stronger basal unit is the highest.

As part of Phase 2, a coastal bluff retreat vulnerability assessment was undertaken to estimate what infrastructure would be at risk or lost due to bluff retreat in future periods with sea level rise for 2040, 2070, and 2100. Impacted infrastructure includes features associated with two golf courses, the Coastal Trail, the Ritz-Carlton Hotel, and associated hotel property amenities. Forecasting future bluff retreat position is a complex undertaking, and the methods used applied appropriate state of the science models. However, there are a number of associated assumptions and uncertainties, such that the outcomes presented in this report should be considered as estimates to be used for planning and decision-making, but are not absolute. As a result, the outcomes are presented as bands of potential future bluff positions to account for uncertainties.

The model used to forecast future bluff positions for this study is based on methods developed by ESA (2016) and adapted from work by Revell et al. (2011). The model is applicable for cliff compositions that have variable lithologies, like those found in the study area. The model accelerates historical rates of bluff retreat using future total water levels and generates exceedance curves for when the water levels will increasingly exceed both the cliff toe and the contact between the geologic units. The increase in the area beneath the exceedance curve through time is a proxy for accelerated rates of bluff retreat. The estimated future bluff top positions are then translated to maps that show the bands of future bluff position, and evaluate what assets will be impacted in which period (2020–2040, 2040–2070, and 2070–2100).

Overall, the study found a rapid acceleration of bluff retreat, increasing through time, with the highest retreat rates in the northern four sections of the study area. By 2040, features at risk include small portions of the Coastal Trail and two scenic overlook areas. By 2070, features at risk include a tee box, areas of rough in the bluff-adjacent portions of the golf course, as well as portions of the Coastal Trail. Features at risk by 2100 include fairways, greens, and tee boxes associated with the golf courses, nearly 1,500 ft of the Coastal Trail, and the Miramontes Terrace of the Ritz-Carlton Hotel, as well as 1,500 sq ft of the hotel structure. Assets and infrastructure concentrated at Miramontes Point will experience the greatest impacts.

Due to coastal regulations in California, and given the remoteness of this locale, there are limited adaptation strategies available in the traditional, structural sense such as seawalls or riprap. Reducing irrigation and possibly regrading certain areas may help to slow the retreat of the bluff, but will not be sufficient to stop it, as the bluff retreat is driven by a combination of marine and terrestrial processes. The forecasted bluff position bands for 2040, 2070, and 2100 time periods, however, do provide managers and decision makers with the tools needed to understand what will likely need to be relocated, realigned, or removed, and what time

horizons these actions will need to begin planning and implemented by to avoid these future erosion hazards.

1 INTRODUCTION

Purpose of this Study

The purpose of this study is to identify and project existing and future vulnerabilities, economic impacts, and adaptation planning options to coastal erosion hazards and sea level rise at the study site in southern Half Moon Bay (HMB). As sea level rises, the dynamics of beach erosion and bluff retreat will shift, increasing the risk of damage to two golf courses, a popular recreational trail, beach access infrastructure, and the Ritz-Carlton Hotel, which together constitute the study area.

This study will provide technical information based on the best science to understand when the various features on the bluff top will be impacted in the future with continued storms plus sea level rise forecast out to the year 2100. It will also provide an economic assessment of the impacts and losses to the community and the City of HMB. Although there is not a wide array of adaptation strategies available for this stretch of coastline due to the geomorphology, wave exposure, and state policies, the study does provide recommendations for viable adaptation strategies as well as suggested planning horizons for implementing the strategies.

Study Area

The Miramontes Point study area is located at the southern end of the City of HMB adjacent to the Ocean Colony and Cañada Cove neighborhoods and encompasses a one-mile stretch of coast between Redondo Beach and the city limit to the south (Figure 1-1).



Figure 1-1. Study area.

The area is characterized by medium to high coastal bluffs fronted by a relatively narrow beach. A golf course, recreation trail, and the Ritz-Carlton Hotel are on the top of the bluff within the study area. The recreation trail is part of the California Coastal Trail (hereinafter referred to as the Coastal Trail) and is a 10-ft-wide paved path located at the bluff top with a beach access stairway immediately north of Cañada Verde Creek in the middle of the study area. Cañada Verde Creek is the largest drainage in the area, and it creates a roughly 200-ft break in the bluffs (Figure 1-2). A small watercourse also drains at the northern section of the study area through the Old Course 18th fairway and is the outlet for stormwater from the Ocean Colony neighborhood to the east. The Ritz-Carlton Hotel is the only structure in the study area.



Figure 1-2. Drainage at Cañada Verde Creek. Source: *Integral Consulting, 2022*

The study area is crenulated, similar to many locations on the central California coast. There are changes in orientation, and numerous promontories and embayments; both of which impact the wave energy reaching the cliff during any given wave event. In addition, there are alongshore variations in the bluff elevation, the geological makeup of the cliff, and variable exposure of rocks in the surf zone that all influence rates of retreat. To accommodate the variations, for the

vulnerability assessment and the forecasts of future cliff retreat, the study area was divided into six sections (Figure 1-1).

The largest coastal promontory in the study area, Miramontes Point, is located in the southern portion of Section 2. Another small, unnamed point (referred to herein as Manhattan Beach Point) defines the boundary between Sections 5 and 6, south of Cañada Verde Creek. Manhattan Beach stretches along most of Sections 3–6 and can be accessed from the stairs at Cañada Verde Creek, although the southern stretch of the beach south of Manhattan Beach Point is narrow and is rarely accessible. Three Rocks Beach is a narrow stretch of beach within Sections 1–2 and is seasonally accessible from Manhattan Beach when tides are low enough for one to walk around Miramontes Point (Figure 1-1).

The study area is a popular destination for tourists and locals for recreation, including golfing, walking and biking along the Coastal Trail, and visiting the beach. As mentioned in the City's Local Coastal Program, the long-term viability of and access to the Coastal Trail is a community priority, as it widely serves residents and visitors alike as a significant recreational, scenic, and low-cost visitor-serving experience (City of Half Moon Bay 2020).

2 COASTAL PROCESSES AND HAZARDS

Coastal processes along the HMB coast that create coastal hazards include tides, waves, and related storm conditions. An important measure of coastal hazards is the total water level (TWL) elevation—the combined effect of wave run-up height, storm surge, tides, and sea level elevations (Figure 2-1). River discharge is not a contributing factor to TWL in the study area. A combination of large waves occurring at high tides during storm conditions poses the largest potential for coastal erosion; including beach erosion and bluff retreat. As sea levels rise, both the wave run-up dynamics and the tide elevations will change, leading to higher total water levels for longer durations. Each coastal process is summarized below.

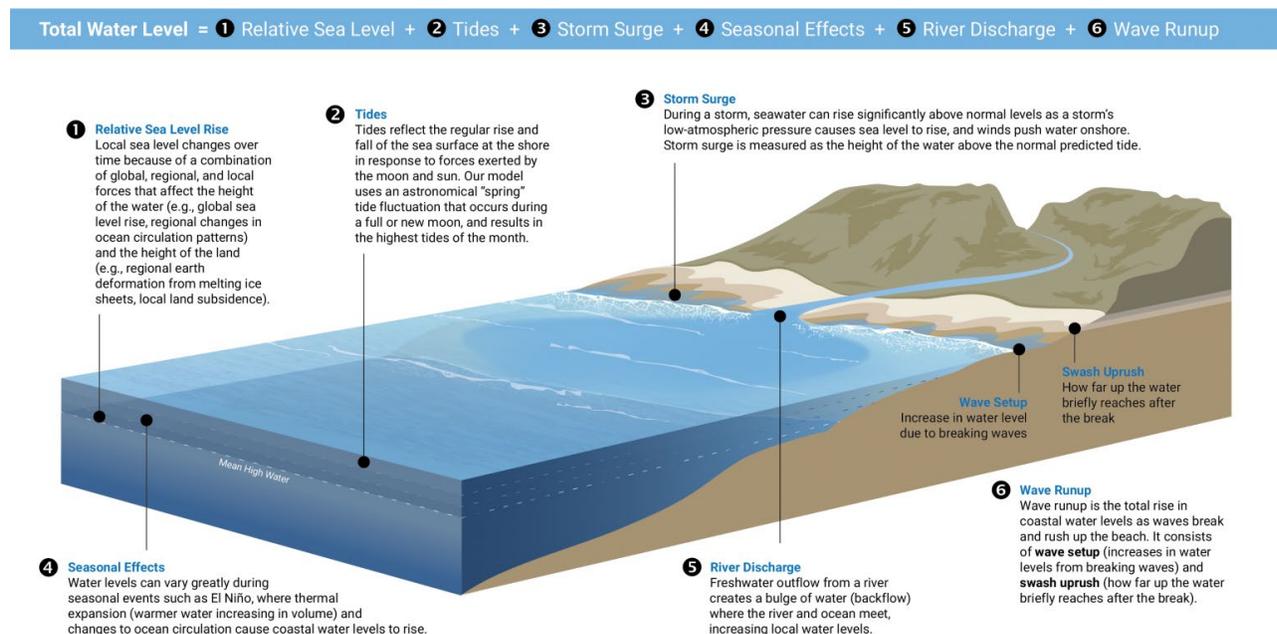


Figure 2-1. Conceptual diagram of the components of total water level. Image courtesy of Our Coast Our Future Web Platform (Point Blue and USGS 2021).

2.1 Waves

Waves created by distant and local winds, are one of the key drivers of wave run-up and resulting coastal change. When distantly generated waves approach the coast as swell, they interact with coastal and bathymetric features. A wave measured at a buoy offshore in deep water is quite different from one that breaks at the coast. Although Pillar Point refracts waves in the vicinity of Pillar Point Harbor and the coastline to the immediate south, the study area for this analysis is too far south to be impacted, and therefore is openly exposed to waves and swell from any westerly direction.

The waves that approach the study site are characterized by three dominant types, depending on their wave source and direction. The northern hemisphere waves typically are generated by cyclones in the North Pacific during the winter and bring the largest waves (up to 25 ft). The southern hemisphere waves are generated in the Southern Ocean during the summer months and produce smaller waves with longer wave periods (greater than 20 seconds). Local wind waves are generated throughout the year; either because of storms coming ashore during the winter, or strong sea breezes in the spring and summer. The shoreline varies in orientation throughout the site, trending either north–northwest or north–northeast, and therefore may be affected differently by the angles of wave approach.

Most wave energy approaches the study site from the northwest and west (Storlazzi and Wingfield 2005). This swell tends to peak in size and period during the winter months. Additional wave energy from the northwest approaches the area in the form of wind waves, which occur frequently between April and October (Storlazzi and Wingfield 2005). During the summer months, strong storms in the southern hemisphere generate swell, although this occurs with less frequency and intensity (Figure 2-2). Wave climate fluctuates over interannual and longer time periods with ocean-atmosphere oscillations like the El Niño southern oscillation (ENSO). These storms tend to follow a more southerly track when El Niño conditions are strongest, resulting in more erosion potential for the study area. El Niño conditions generally occur every three to seven years, with particularly intense events every 10 to 20 years (Storlazzi and Griggs 2000). There are also longer-term climatic oscillations such as the Pacific decadal oscillation (PDO). PDO warm phases have been associated with periods of increased storm frequency and intensity, resulting in accelerated erosion rates (Orme et al. 2011; Russell and Griggs 2012).

North Pacific Swell

GENERATION:
Storms in the North Pacific, mid-latitude lows, and cold fronts
OCCURRENCE:
Throughout the year; largest in October-May; largest waves to impact the region
HEIGHT: 2-10 m
PERIOD: 10-25 s

Northwest Wind Waves

GENERATION:
Northwest winds generated by the California High blowing over the open ocean; sea breezes
OCCURRENCE:
Throughout the year; dominant in April-October; summer: 90-95 percent, winter: 55-65 percent of the time
HEIGHT: 1-4 m
PERIOD: 3-10 s

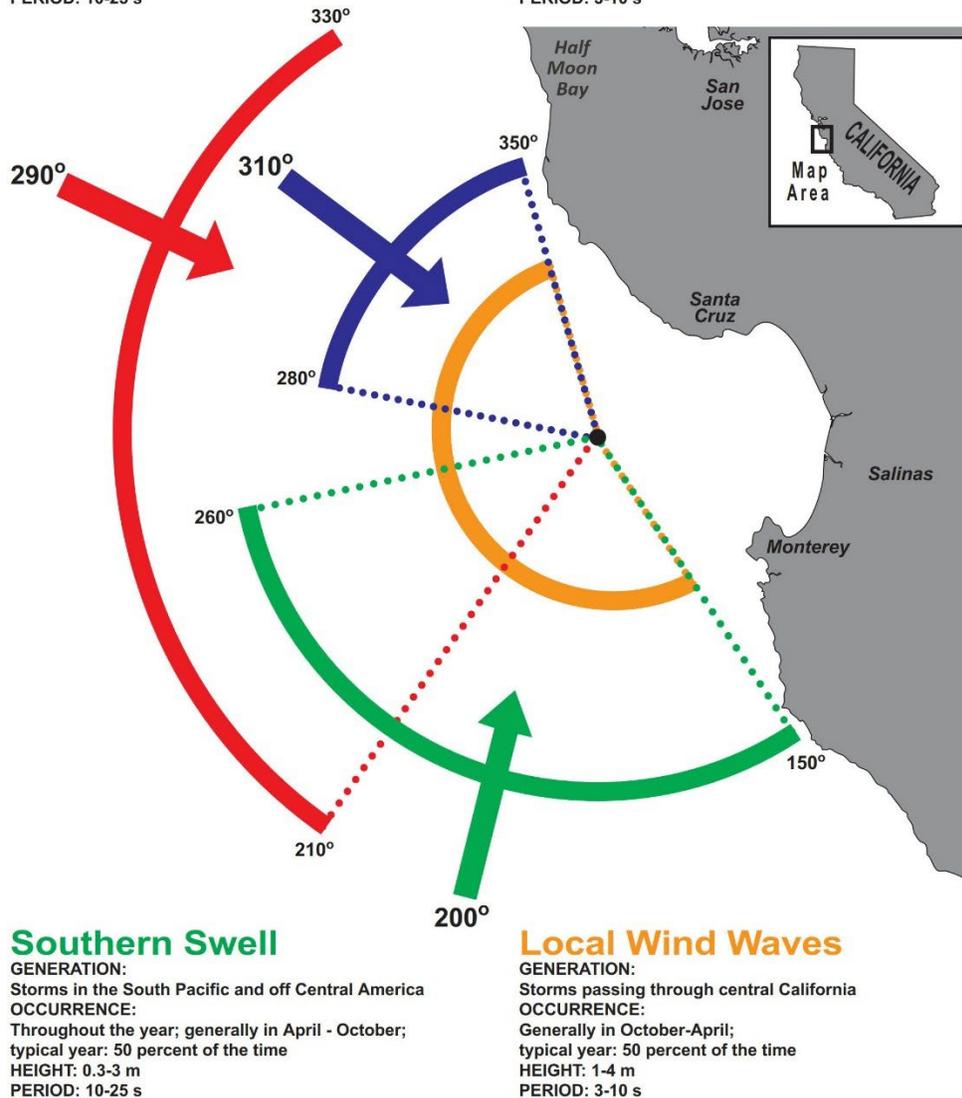


Figure 2-2. General wave patterns (degrees of azimuth) along the Central Coast (1993–2002) (Storlazzi and Wingfield 2005).

Waves change as they approach the shore, and bathymetry and wave conditions drive this change in a process called wave transformation, which is an important component in assessing vulnerabilities for this project. Waves break offshore at depths that are related to the wave height and the wave period. In general, the bigger the wave and the longer the wave period, the

deeper the water the wave will break. Smaller waves can travel much closer to shore before breaking and often pose more risk of causing damage than larger waves. Once the wave breaks, it runs up the shoreline and the slopes and roughness affect its elevation and inland extent across the surf zone and beach. Depending on the frequency of breaking waves, wave setup can occur when a series of breaking waves pile up water allowing subsequent waves to travel closer to shore before breaking with more energy. As sea levels rise, not only will the still water level (SWL) be affected, but the deeper water close to shore will allow waves to break closer to shore with less potential to dissipate the wave energy.

The U.S. Geological Survey (USGS) has created a database of nearshore waves that include hindcast, as well as modeled historical and future projected waves for the coast of California, as part of the Coastal Storm Modeling System (CoSMoS; <https://www.usgs.gov/data/coastal-storm-modeling-system-cosmos-southern-california-v30-phase-2>). The wave data are derived from a series of wave buoys located in deeper water. This study utilized the USGS nearshore wave data to then calculate total water levels at the study site (see the Methodology and Approach section in this report for additional detail).

2.2 Tides and Water Level Data

Tides in the study area are mixed, predominantly semidiurnal, and are composed of two low and two high water levels of unequal heights per 24.8-hour tidal cycle. Typically, the largest tide ranges in a year occur in late December to early January when the moon and sun are in alignment and closest in their orbits to the earth. These astronomical high tides are known as “king tides,” and often result in coastal flooding unrelated to storm events.

Maximum water levels occur due to astronomical tides, wind surges, wave setup, density anomalies, long waves (including tsunamis), and El Niño and PDO events. On longer time scales, the tides will reach higher elevations as sea level rise rates accelerate. The San Francisco Station 9414290, the station nearest to HMB with readings extending to the mid-1800s, is shown below (Figure 2-3). The relative sea level rise trend in this graph shows 1.97 mm/yr. with a 95 percent confidence interval of ± 0.18 mm/yr. based on monthly mean sea level data from 1897 to 2020, which is equivalent to a change of 0.65 ft in 100 years. These measured local relative sea level rise trends when compared to the global average provide estimates of land motion, in this case, the land is rising, but just not as fast as sea levels.

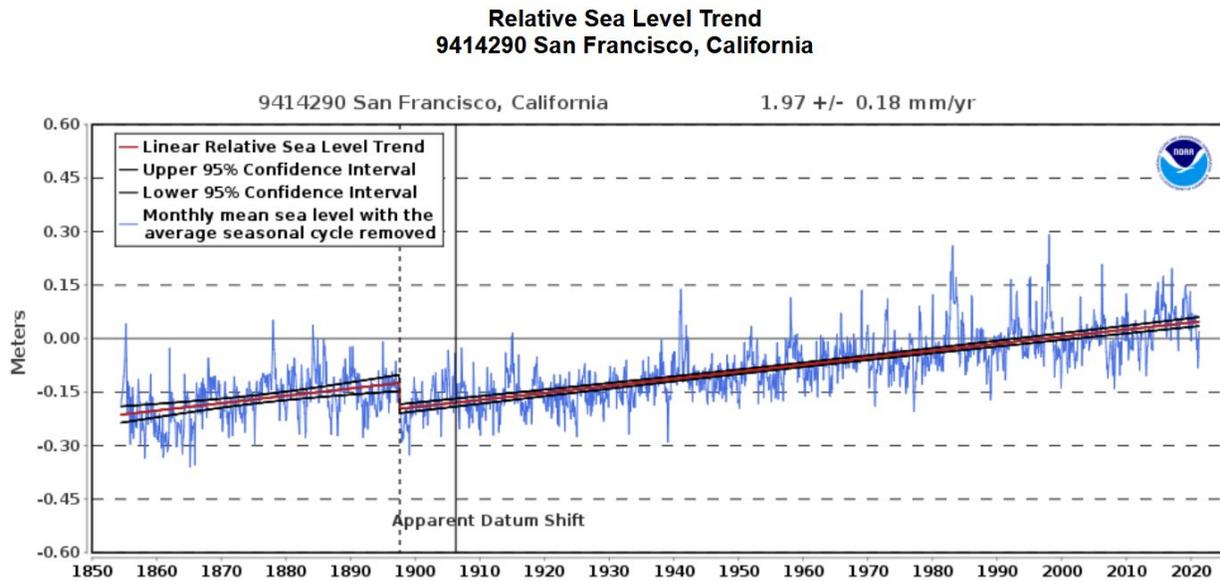


Figure 2-3. Relative sea level trend for the NOAA San Francisco tide gauge (Station 9414290)

2.3 Sea Level Rise

Sea level rise is not the same everywhere around the world. Due to local differences in tectonic uplift; isostatic rebound; subsidence caused by oil, gas, and groundwater extraction; and saltwater intrusion; the land itself is moving vertically. According to OPC (2018), California experienced about seven inches of sea level rise from 1905 to 2005, and the rate of increase is projected to continue to increase over this century. Based on the updated sea level rise science, in 2018, the California Ocean Protection Council (OPC) and California Coastal Commission (CCC) both issued guidance documents that are meant to guide local jurisdictions on sea level rise planning. They are:

- State of California Sea-Level Rise Guidance Year 2018 Update, adopted by OPC in 2018
- CCC Sea Level Rise Policy Guidance, certified by the Coastal Commission in 2018

Based on this guidance, this study used a medium–high-risk aversion scenario which sees 6.5 ft of sea level rise between 2020 and 2100 (Figure 2-4).

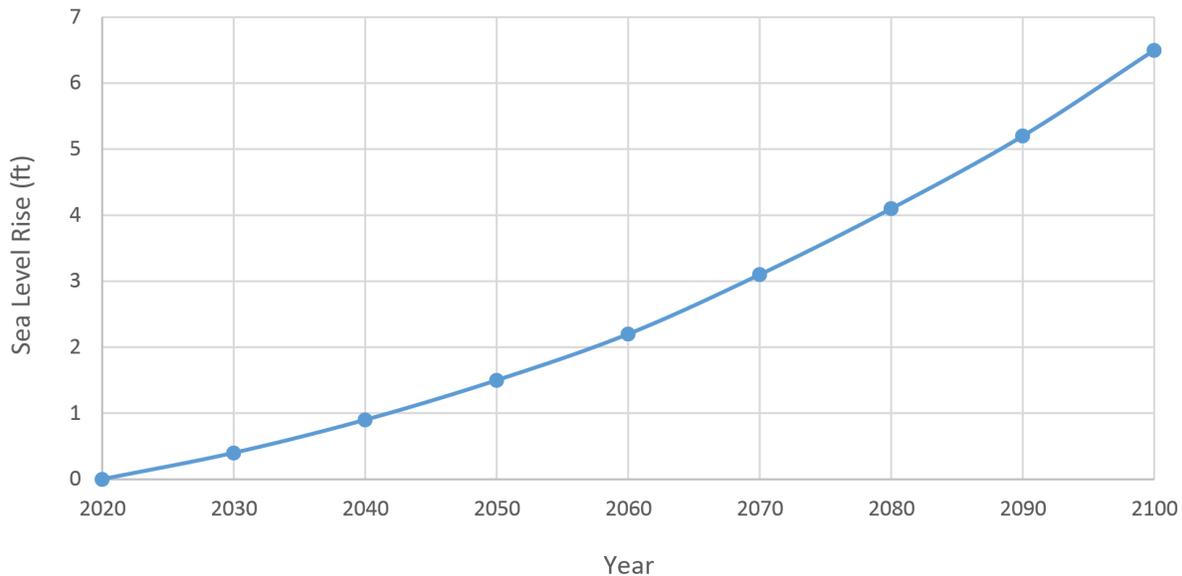


Figure 2-4. Study-specific rate of sea level rise from 2020 to 2100, based on OPC Guidance (2018).

2.4 Coastal Erosion

Several important physical processes shape the coastline in the study area—beach erosion and progradation, and coastal bluff retreat. Beaches can gain or lose sand in both the cross-shore and alongshore directions. Beaches are continually shaped by waves, and a common pattern along the central California coast is for beaches to erode in the winter in response to winter storms, then gradually build back in the summer. The beaches in the study area vary in width, and wider beaches provide more protection to the coastal cliffs. As sea levels rise, however, even the relatively wider beaches will experience more inundation and the duration that the cliffs are exposed to wave energy will increase. Beaches also change due to the alongshore transport of sediment, and within the study area, the dominant direction of transport is from the northwest to the southeast (Griggs and Patsch 2007). This means that if a beach to the north erodes, some of the sediment will gradually move to the south and may cause beaches at the site to prograde.

Coastal bluff retreat processes are somewhat more complex due to the episodic nature of bluff failure that can be driven by marine, terrestrial, or human-induced forcing. Over time, the more frequently coastal cliffs are exposed to waves, the more they will retreat. As wave energy and scouring attack the cliff base, this can lead to instability and bluff failure. For a time, the bluff material from the retreat event may stay on the beach, protecting it from further wave attacks. However, this material will gradually erode, leaving the bluff exposed once again.

Coastal bluffs can also retreat after heavy precipitation events or a series of high rainfall days. In general, there is a lag time between rainfall events and bluff failure. As the rain infiltrates and saturates the bluff-forming material and increases the pore pressure, it can drive retreat occurrences. Rainfall can also cause erosion in very soft bluffs via overland flow, as the rain cascades over the bluff top and down the cliff face, the running water can form rivulets and small gullies. It is fairly common for big storm events to have both large waves and high rainfall, which results in coastal bluff retreat from a combination of the two.

One of the predominant ways that human activities can contribute to bluff retreat is by irrigation, especially near the bluff top. These activities are generally associated with landscaping or agriculture. In the study area, both the golf courses and the Ritz-Carlton Hotel irrigate their lawns and greens. Irrigation water, along with contributions from other sources such as non-irrigation stormwater runoff and drainage from areas higher in the local basin, can contribute to saturation through the basal unit. This is evident by the vegetation growing along the basal unit highlighted by the red ovals in Figure 2-5. Note that saturation through the basal unit is highly variable, as is apparent with the relative lack of vegetation growing at the point itself. Saturation of the basal unit and weaken it, thus accelerating erosion.



Figure 2-5. Miramontes Point (just under the hotel property) with patches of vegetation evidence of high groundwater highlighted by the red ovals. Source: *Integral Consulting, 2022*

Overall, coastal erosion is episodic and nonlinear, making it difficult to estimate the position of the bluff top for any given future year. A portion of bluff may retreat one year, and then remain relatively stable for many years after. As a result, bluff retreat rates are highly variable year to year, and across spatial scales.

2.5 Geology and Geomorphology

The cliffs within the study area are composed of Miocene to late-Pliocene siltstones and mudstones of the Purisima Formation, which are overlain by Pleistocene marine terrace deposits. The Purisima Formation is more resistant to erosion than the overlying marine terrace deposits, which are composed of loosely consolidated gravels, sands, and clays. As a result, in

many areas, especially in the northern and central parts of the study area, the slopes of the two units are different, with the Purisima Formation forming a near-vertical face and the marine terrace deposits generally more gently sloping (Figure 2-6). In some areas, the marine terrace deposits have eroded more quickly than the underlying Purisima Formation creating a ledge or platform. The Purisima Formation dips to the northeast and as a result, the thickness of the basal unit exposed varies significantly along the length of the study area, ranging from only a thin layer less than three ft thick in the north to more than 30 ft thick in the southern area (Figure 2-7).

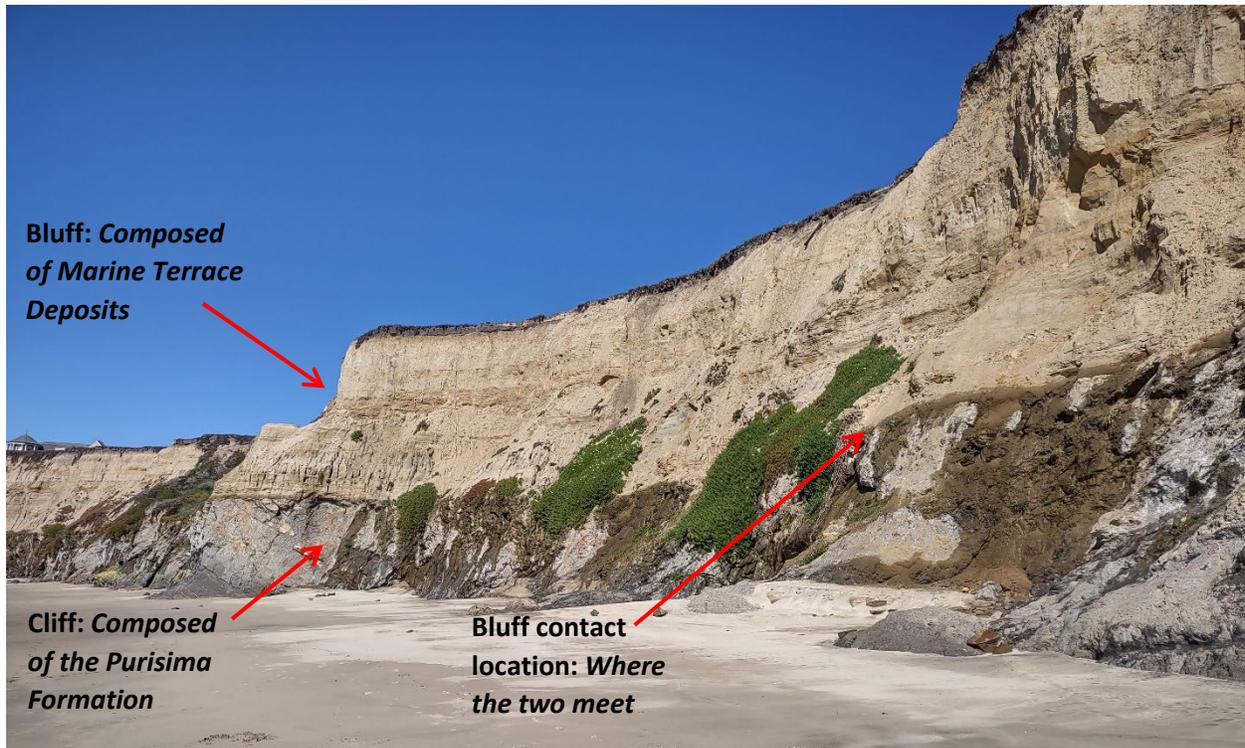


Figure 2-6. Lower portion of cliff is comprised of the Purisima Formation, which forms a steeper slope in most locales as compared to the upper bluff marine terrace deposits. Source: *Integral Consulting, 2022*

2.6 Historical Erosion Section Overview

This section provides a series of study area diagrams, maps, and a description of each section along with an overview of locations of historical erosion as well as sea caves and undercuts of the basal unit. Included in each section is a three-panel map comparing cliff feature locations over time. Note that the historical three-panel maps include bluff-top locations for all three years, 1932, 1965, and 2022, however, the cliff toe is unresolvable in the imagery prior to 1965. As a result, while historical bluff retreat is calculated using all dataset years, toe retreat is only calculated from 1965 to 2022.

Where previous studies have been made available, results have been compared in this study for reference. Site-specific studies were available for areas in Section 2, where findings were compared to previous studies by the Bay Area Geotechnical Group in 2004 and from AECOM in 2017. Direct comparison of historical erosion rates is difficult because they rely on different data sources, cover different time periods, utilize different bluff-top delineation techniques and transect orientations, and report different statistics.

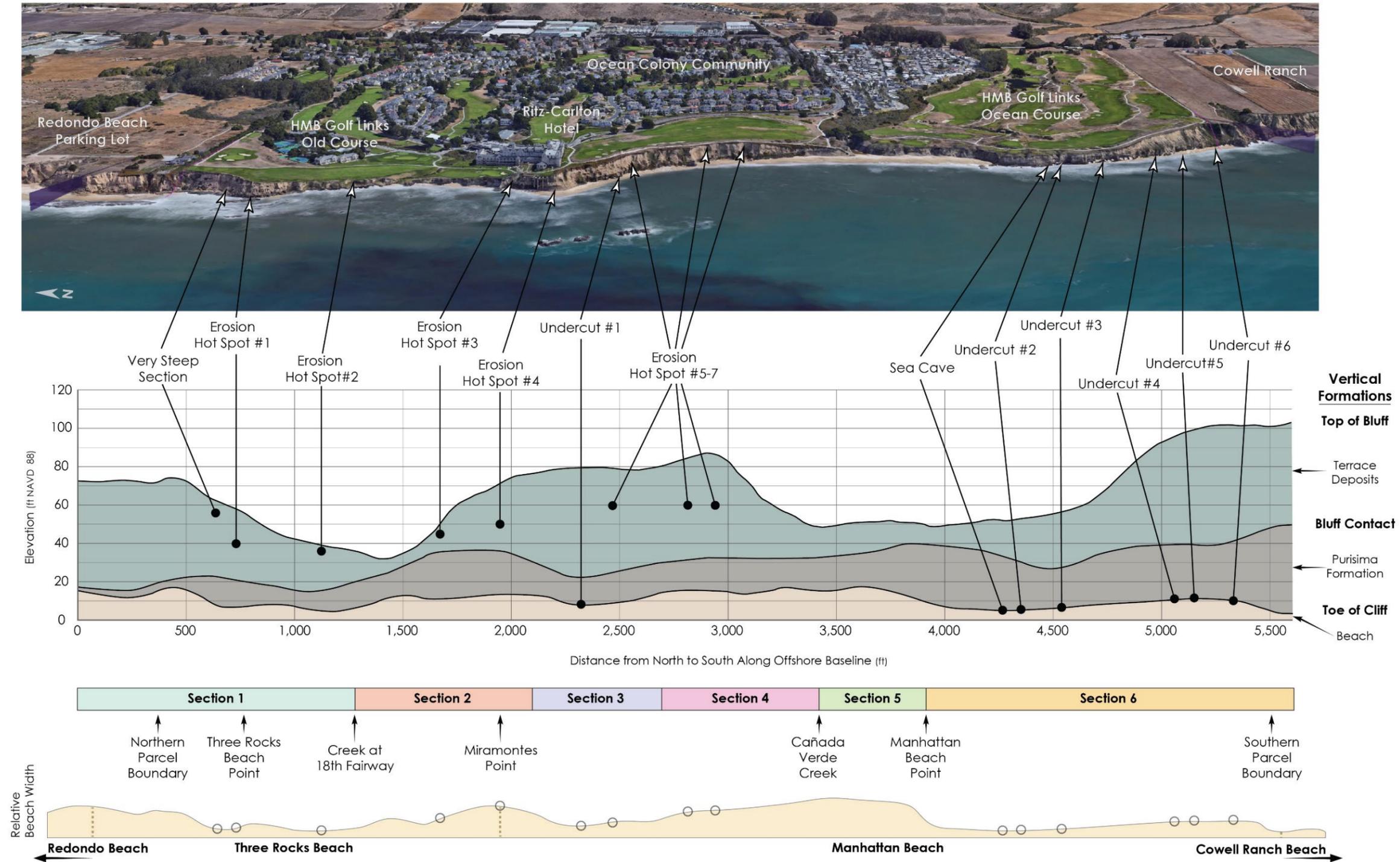


Figure 2-7. Site characteristics showing major points of interest and erosion features.

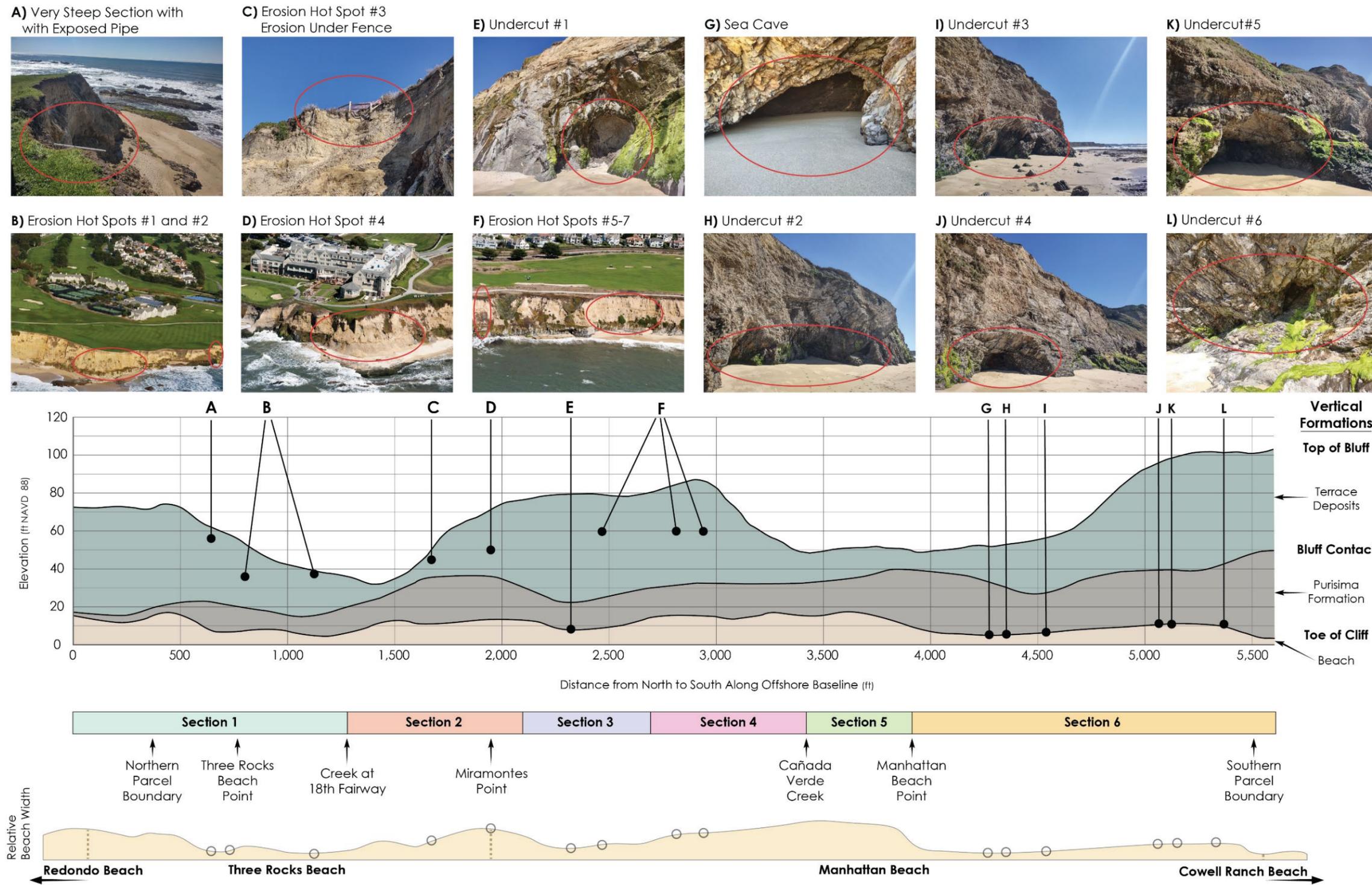


Figure 2-8. Site characteristics showing field photos.

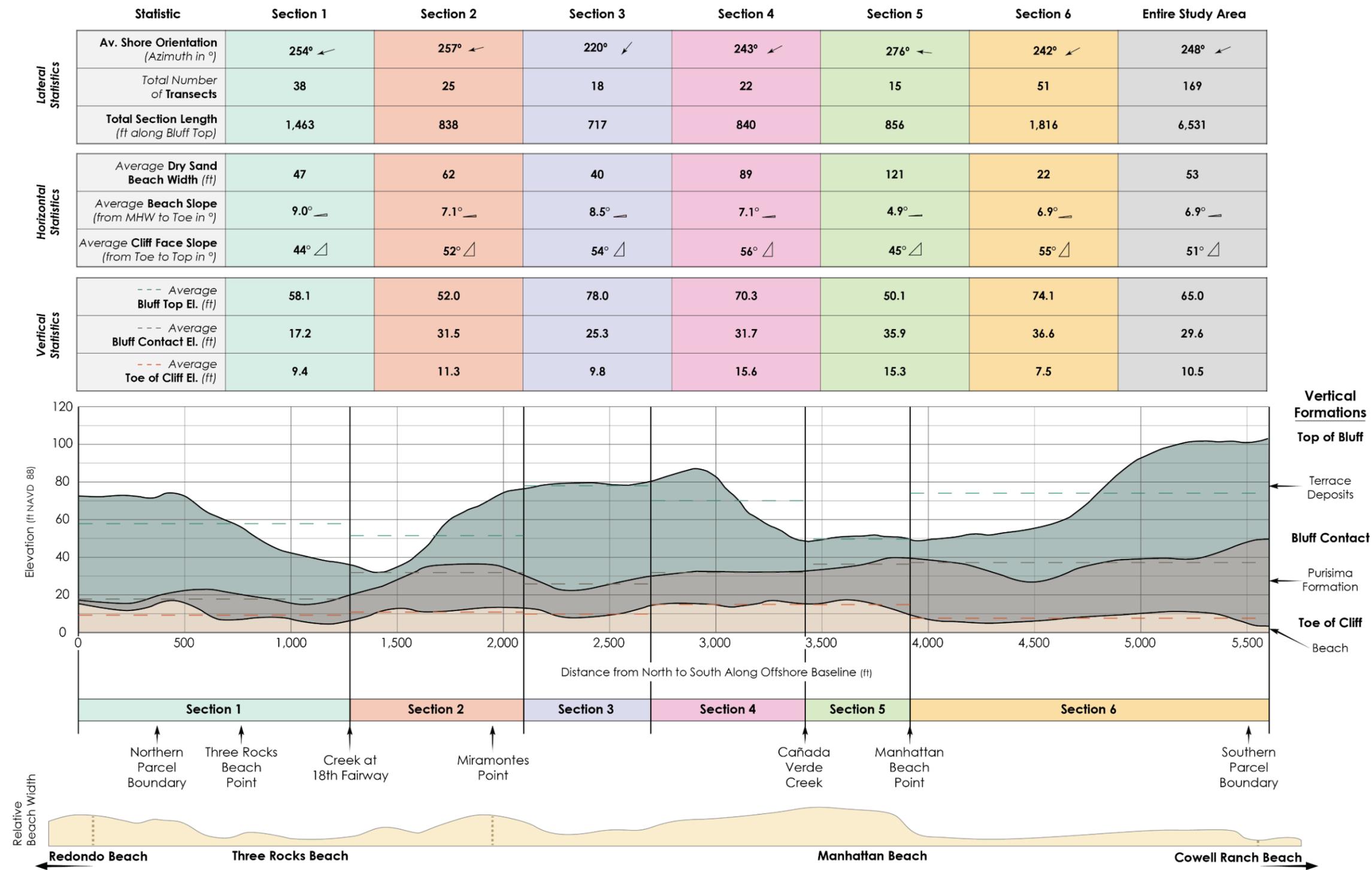


Figure 2-9. Site characteristics showing section-by-section geomorphic parameters.

2.6.1 Section 1. Redondo Beach to Three Rocks Beach

Section 1 extends from Redondo Beach at the northern end of the HMB Golf Links to a small creek that drains at the 18th hole fairway, and is defined by a narrow beach in the southern area and a wider beach in the north. This section is punctuated by a coastal promontory referred to herein as Three Rocks Beach Point and there is rock outcropping in the nearshore waters just off of the point. The 18th hole of the Old Course lies on top of the bluff (Figure 2-10). This part of the course was first built in the early 1970s, then redesigned in 2000, when the 18th hole tee boxes, many of which were once close to the bluff-top edge, were moved inland ~30 ft¹.

This section is oriented north–northeast along its northern half and north–northwest south of Three Rocks Beach Point. The exposure of the Purisima Formation in this section ranges from less than three ft at the northern end and thickens to ~ 10 ft on the southern end, and the bluff is more than 70 ft in elevation to the north and slopes down to a low of ~38 ft in the south towards the small creek (Figure 2-9 and Figure 2-10).



Figure 2-10. Section 1. Source: *Kenneth & Gabrielle Adelman, 2019*

¹ Ocean Colony Partners, owners of the golf course, have monitored erosion at the 18th tee area. Between 2006 and 2022, they have recorded 6-7 inches of erosion (OCP 2022).

Section 1) Three Rocks Beach to Redondo Beach

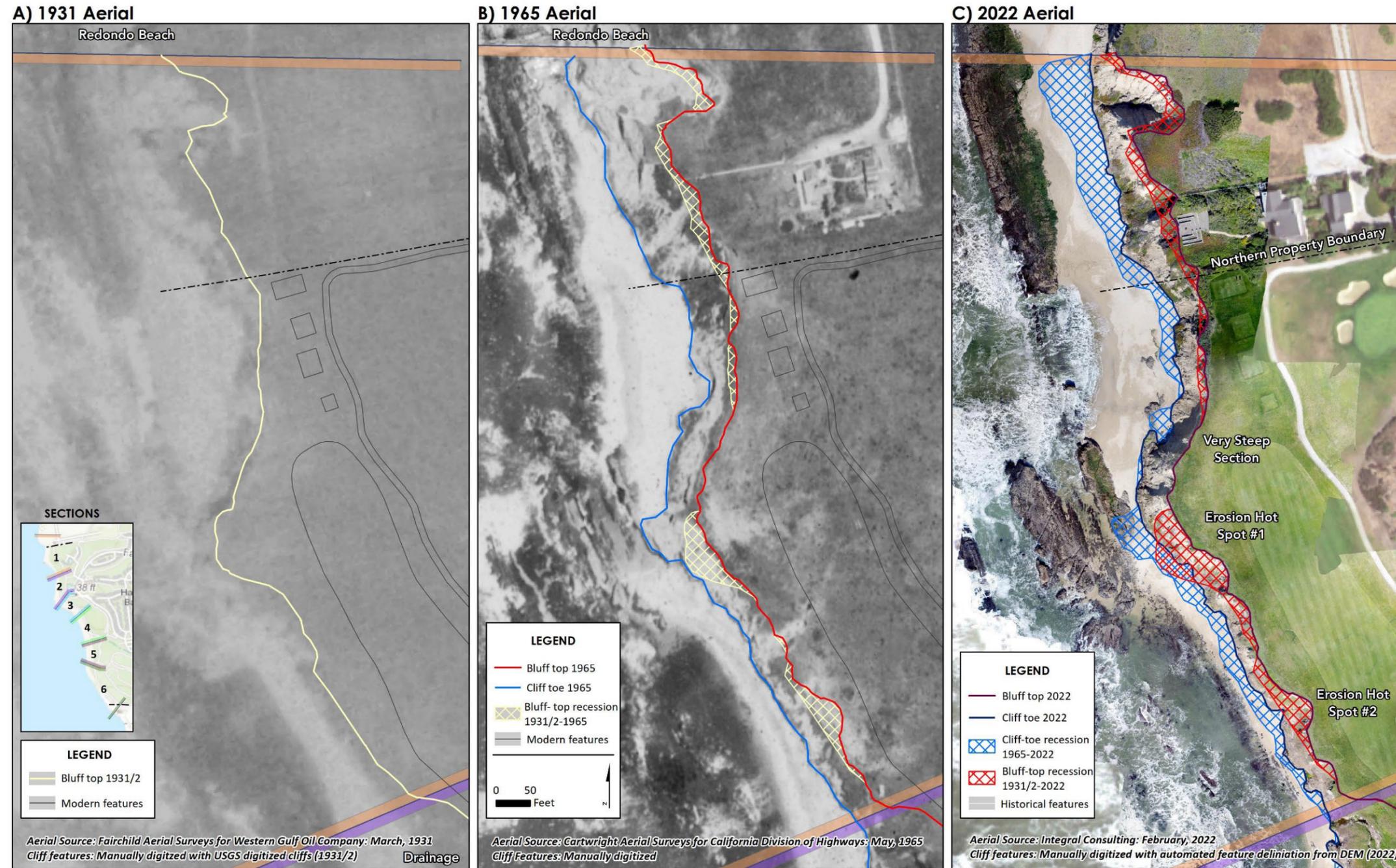


Figure 2-11. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 1, the northernmost section of the study area. The hatched areas in panels B and C represent areas where there has been retreat of the cliff toe or bluff-top edge.

Erosion Hot Spots #1 and #2

Figure 2-11 shows aerial images of Section 1 from 1931 (A), 1965 (B), and 2022 (C). The hatched areas, which are areas of retreat of the cliff toe and bluff-top edge indicate a substantial amount of toe retreat between 1965 and 2022, and gradual retreat of the bluff top edge, except for two erosion hot spots directly at and just south of Three Rocks Beach Point. Significant loss of the toe can be seen after 1972, as at this point the toe can still be seen to extend to the location of the first set of lateral offshore rock (Figure 2-12).



Figure 2-12. The location of the toe at Three Rocks Beach Point can be seen to extend out the location of the offshore rock. Source: *Kenneth & Gabrielle Adelman, 1972*

Area of Erosion Concern: Very Steep Section

The area just shoreward of the 18th hole tee boxes, extending ~60 ft long and ~20–25 ft high above a wave-cut platform, is a very steep section of bluff that is near-vertical towards the top of the bluff face (see 'Very Steep Section' in Figure 2-11 panel C, Figure 2-13). Despite significant erosion at Three Rocks Beach Point, there has been very little change in the bluff-top location in this stretch from 1931/2 to 2022. This location may be protected due to the offshore rock, a more protected shore orientation, and a wider beach than the area to the immediate south. Despite this, the area may be at increased vulnerability to erosion as sea levels rise and wave attack of soft bluff accelerates.



Figure 2-13. Very steep section near the 18th hole tee boxes. Source: *Google Earth, 2022*

2.6.2 Section 2. Three Rocks Beach to Miramontes Point

Section 2 extends from the creek at the 18th fairway to Miramontes Point and the Ritz-Carlton Hotel (Figure 2-14). Historically, a parking lot and vehicle turnaround terminated at Miramontes Point and are visible in historical aerials between the early 1960s to the 1980s. Due to the threat of coastal erosion, the golf course was redesigned and in 2006 changes to the approach to the green, the green itself, and two sand traps that were close to the bluff-top edge were replaced with a single trap further from the bluff-top edge². Due to continued erosion, the Miramontes Point overlook lawn has been moved inland about 15 ft. The previous layout of both the golf course and the overlook lawn can be seen in Figure 2-18.

This section is concave alongshore to Miramontes Point in the southern portion of the section, where the orientation takes a sharp turn to orient north–northwest. The average elevation of the bluffs in Section 2 is 52 ft but there is a significant increase from north to south, with the lowest bluff elevation in the study area of ~30 ft where a small drainage exists in the 18th fairway. In the southern portion of Section 2, the bluffs increase to more than 75 ft in elevation at Miramontes Point. A rock outcrop, known as Three Rocks, is located in the nearshore.

The thickness of the Purisima Formation is also quite variable in Section 2, increasing from ~10 ft in the north to a maximum of 36 ft in thickness at Miramontes Point. The marine terrace deposits also thicken from north to south contributing to the overall increase in bluff height to the south. The average cliff face in Section 2 is also steeper than in Section 1.



Figure 2-14. Section 2: Three Rocks Beach to Miramontes Point. *Source: Kenneth & Gabrielle Adelman, 2019*

² Planning began in 2000 and was implemented by 2006. A detailed list of golf course improvements can be found in the description of Erosion Hot Spot #3 below.



Figure 2-15. Miramontes Point before the development of Ocean Colony. Source: *Kenneth & Gabrielle Adelman, 1972*

Section 2) Miramontes Point to Three Rocks Beach

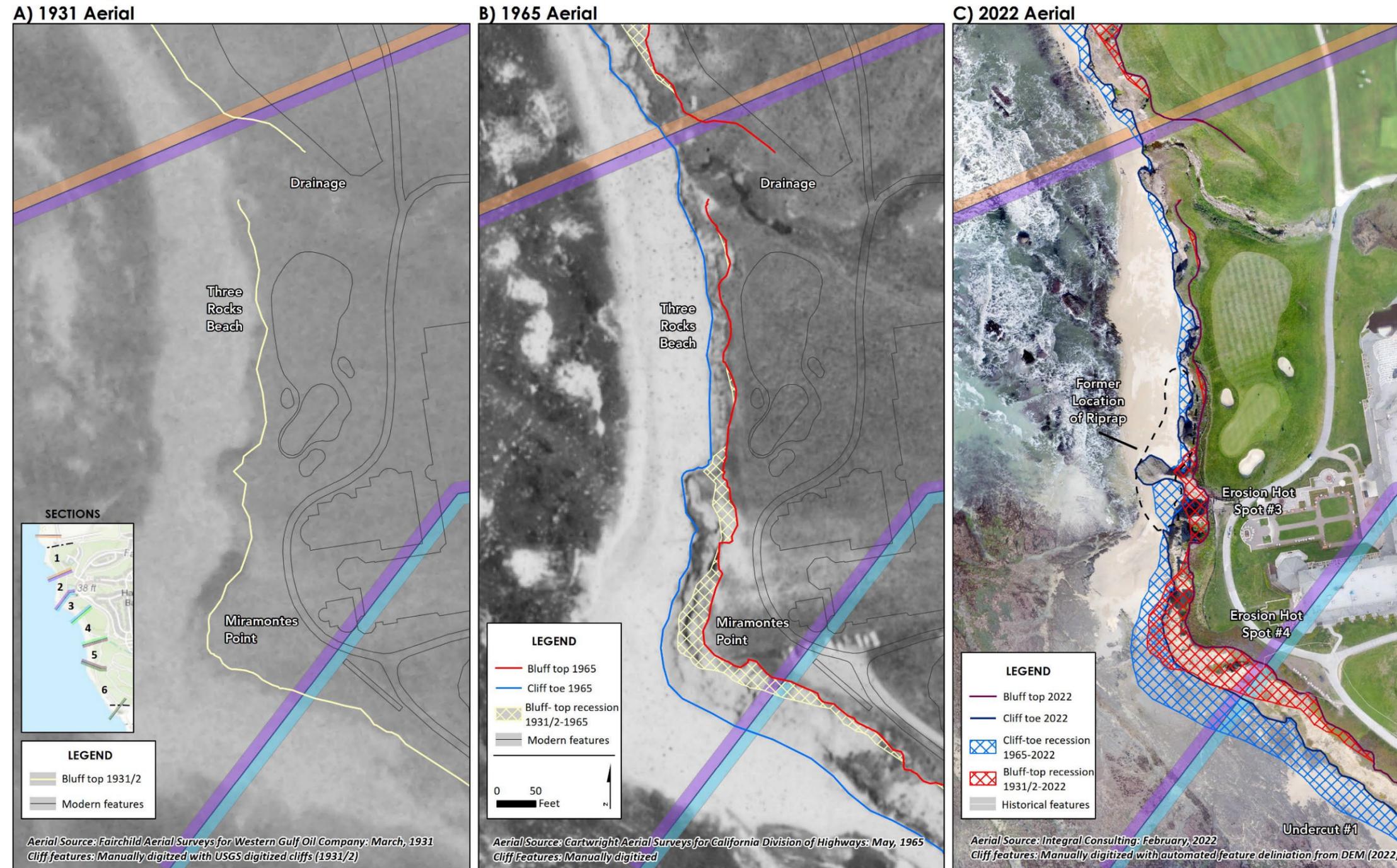


Figure 2-16. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 2, the portion of the study area that includes Miramontes Point and the Ritz-Carlton.

Erosion Hot Spot #3—Near the Old Course 18th Green and Hotel Ocean Lawn

The Bay Area Geotechnical Group led a study in 2002 focused on the area fronting the Old Course 18th Green (Erosion Hot Spot #3 on the maps, and the blue circle in Figure 2-17), and it noted 30 ft of erosion between 1963 and 1973 with a dramatic erosion event in the winter of 1972–1973, where ~15 ft of the bluff was lost. It also noted that between 1973–1998, approximately 10-15 ft of erosion occurred, for total erosion of ~45ft between 1963 and 1998 (CCC 2005). This corresponds to our analysis, albeit at a slightly higher rate, where we found ~10 ft between 1931/2 and 1956, ~15 ft between 1956 and 1965, and ~15 ft between 1965 and 2020, for total erosion of ~40 ft between 1931/2 and 2022.

Ocean Colony Partners, the managers of the Golf Course, have monitored the bluff top erosion adjacent to the 18th hole green (just north of Hot Spot 3) on a regular semi-annual basis. They have observed that between 2006 to 2022, the bluff top at the 18th hole green area has eroded approximately 5-6 inches (OPC 2022). This is a slower rate than the long-term-historical average, and also corresponds with our analysis of this area.

Just south of the 18th hole green there is a fence that is currently overhanging the bluff by up to three feet and is indicative of more recent erosion, likely following the winter of 2017–2018. The Coastal Trail is now located within ~18 ft of the top edge of the bluff near this location (Figure 2-17).



Figure 2-17. Left: Blue circle – Location of Bay Area Geotechnical Study. Red circle – Location of erosion near the Ocean Lawn of the Ritz-Carlton Hotel. Right: A fence was erected, which has been subsequently undermined. Source: *Kenneth & Gabrielle Adelman 2006 & Integral Consulting, 2022.*

Armoring, in the form of riprap, was in place here from 1998 to 2006. Ocean Colony Partners observed that the armoring led to redirected wave energy and significant sand displacement leading the bluff face on each side of the riprap to deteriorate at a more rapid rate and contributed to several episodic incidents of bluff top failure (OPC 2022). At the time of removal in 2006, Ocean Colony Partners implemented the following site improvements:

- 1) Removed the original 1973 concrete and metal slab structures under the 18th hole green and tee areas;
- 2) Relocated the 18th green landward by over 30' and enlarged it so that it could be reduced if additional bluff erosion occurred and further "retreat" was necessary;
- 3) Moved the 18th hole tees landward by approximately 25' to accommodate future bluff erosion;
- 4) Regraded bluff top areas seaward of the 18th green and tees to create a subtle "berm" to help eliminate direct bluff top irrigation and storm water runoff;
- 5) Rerouted all surface and underground drainage systems landward from the 18th green and tees and redirected drainage to the 18th hole natural barranca and outfall;
- 6) Eliminated irrigation lines/sprinkler heads along several portions of the 18th hole bluff top;
- 7) Retained Go Native, a habitat restoration company, to remove areas of ice plant and plant native vegetation on the top and face of the bluff to the extent possible; and
- 8) Erected split-rail wood fencing seaward of the 18th hole green and tees as a safety measure and to deter golfers and coastal visitors from entering those bluff top areas.

Erosion Hot Spot #4—Miramontes Point

Although the point is somewhat protected in the nearshore by the Three Rocks outcrop, the rates of erosion at the point are among the highest in the study area. Examination of a series of historical aerial photographs, and confirmed by a site visit, indicates that the Purisima Formation at the point is continually saturated, likely weakening the bedrock material in this isolated zone. The cause of the saturation needs to be investigated to understand the controlling factors; which could be related to lithology, structures such as joints or faults, or focused infiltration of groundwater.



Figure 2-18 Left - Riprap in place in 2002. Exposed pier foundation structure in the late 2000s. Source: Kenneth & Gabrielle Adelman, 2002, VisualHunt.com CC.

Due to concerns about erosion, the Ritz-Carlton Hotel contracted AECOM to study and monitor erosion at Miramontes Point. In its 2018 report, AECOM reported ~45–55 ft of erosion since 1973, just over a foot per year on average (Simpson 2017) (Figure 2-19). From our analysis, we have found a net bluff-top recession of ~30–40 ft over a similar period (1964 and 2022), and 50–70 ft since 1931/2, which corresponds to a slightly lower rate of 0.5–0.9 ft a year.

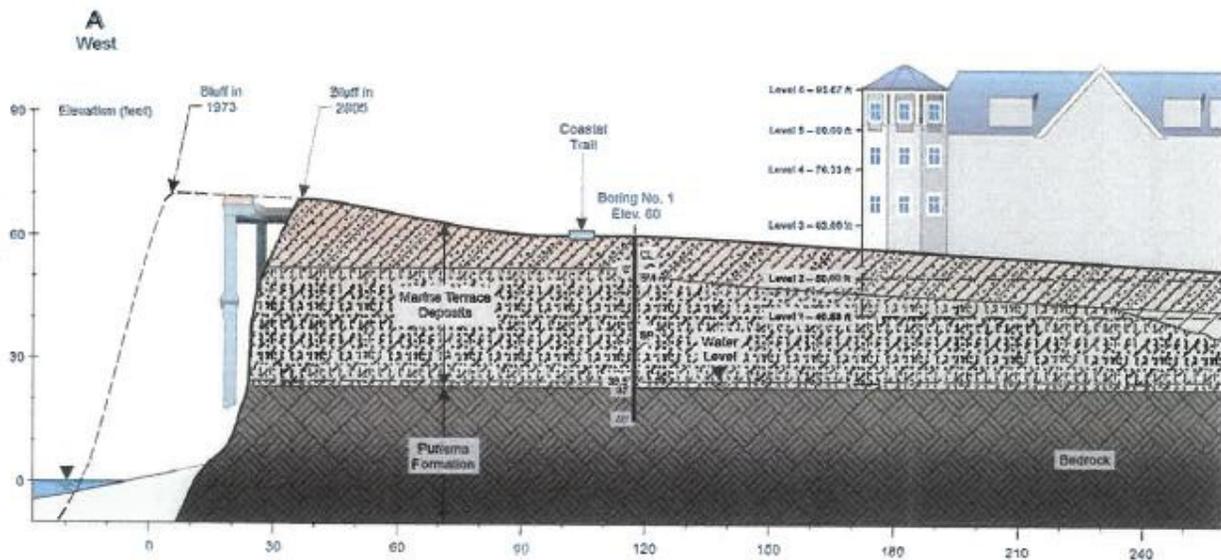


Figure 2-19. Geologic cross section at the Miramontes Point from the AECOM study, 2017.

2.6.3 Section 3. Miramontes Point to Manhattan Beach North

Section 3 extends from Miramontes Point to the fairway of the 18th hole of the Ocean Course. The section is oriented north–northwest and encompasses an area with a relatively narrow

stretch of beach. The elevation where the terrace deposits make contact with the Purisima Formation (bluff contact) is around 25 ft, and the bluff top is ~70 ft in elevation. The Coastal Trail runs throughout this section and is as close as 20 ft from the bluff-top edge in some locations.



Figure 2-20. Section 3: Miramontes Point to Manhattan Beach North. Source: *Kenneth & Gabrielle Adelman, 2019*

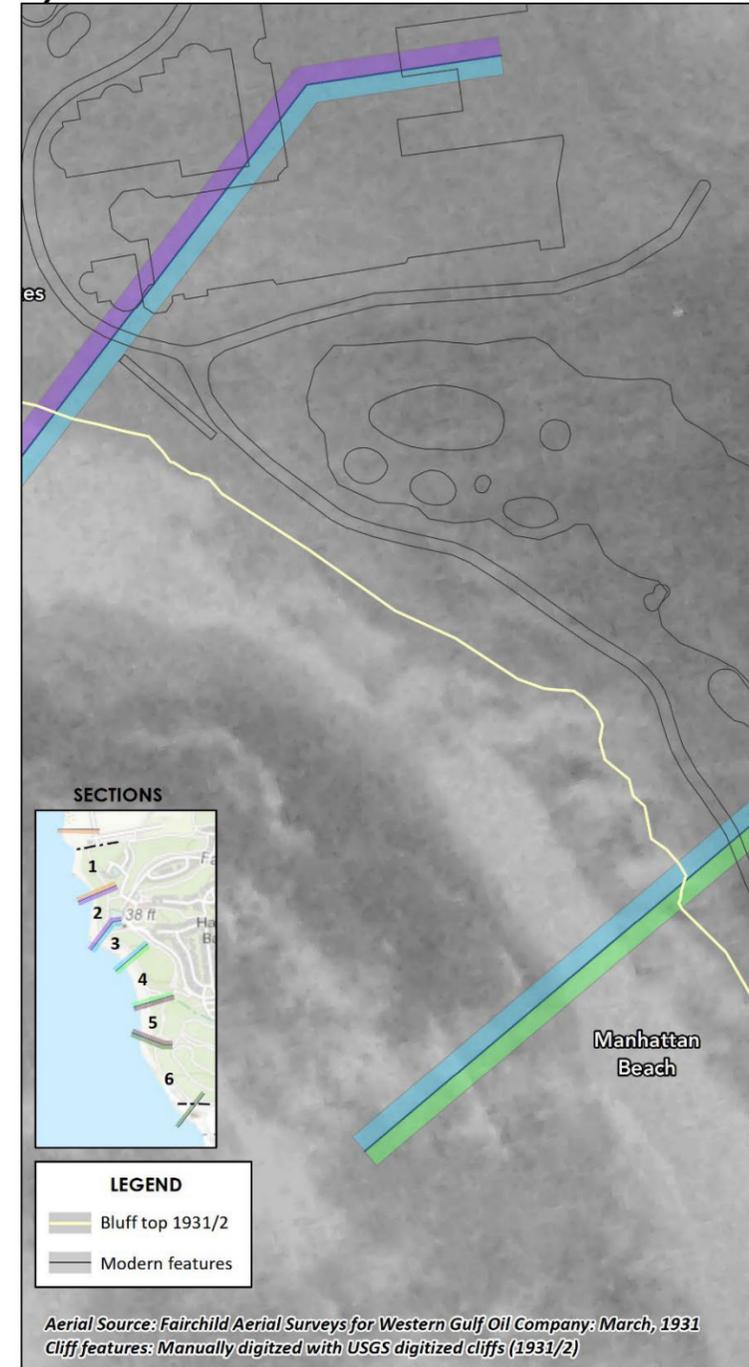
The bluff has small undercuts where the beach is very narrow, and there is less rock in the offshore than in other areas. With little rock to dissipate waves, more wave energy reaches the bluff toe, abrading out small undercuts.

Erosion Hot Spot #5 – Manhattan Beach North

Between 1931/2 and 1956, erosion hot spot #5 shows the loss of approximately 20–25 ft of bluff-top in some areas, with very little change since then. In historical images before 1965, there is a small outcrop in the toe at this location, and from 1982 onward, this feature is no longer apparent. The loss of this outcrop and erosion of the toe has not been related to any significant change in the bluff-top edge over this period.

Section 3) Manhattan Beach North

A) 1931 Aerial



B) 1965 Aerial



C) 2022 Aerial



Figure 2-21. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 3.

2.6.4 Section 4. Manhattan Beach North to Cañada Verde Creek

Section 4 extends from the 18th hole fairway of the HMB Golf Links Old Course to Cañada Verde Creek, is oriented north–northwest, and encompasses an area with a wider stretch of beach than Section 3. The wider beach provides more protection to the base of the cliff from wave attack. The average elevation of the bluffs is ~32 ft, with the bluff-top approximately 85 ft high in the northern area, then gently sloping downward towards Cañada Verde Creek in the south where it is approximately 50 ft in elevation. The Coastal Trail runs throughout this section and is as little as 20 ft from the bluff-top edge in some areas (Figure 2-20). Historically, a parking lot and vehicle turnaround were located in the lower area near the current beach access stairway and are visible in historical aerials between 1960 and 1980 (Figure 2-22). Before the stairway was built, informal beach access trails were visible.



Figure 2-22. Section 4: Manhattan Beach North to Cañada Verde Creek. Source: *Kenneth & Gabrielle Adelman, 2019*

Erosion Hot Spot #6 and #7 – Manhattan Beach

There is little change in the position of the bluff top between 1931/2 and 1956. Between 1956 and 1965, however, ~ 10 ft of bluff-top recession is observed in some places, and between 1965 and 2010, another 10 ft of erosion is observed in the same locations. Currently, the area identified as erosion hot spot #7 is very steep and the concave shape where bluff failures have occurred is indicative of recent, rapid erosion (Figure 2-23). There has been a significant amount of cliff toe erosion in the area stretching between erosion hot spots #6 and #7, as measured between 1965 and 2022 (Figure 2-22).



Figure 2-23. Steep and concave bluff is indicative of recent, rapid erosion at hot spot #7. Source: *Google Earth, 2022*

Section 4) Manhattan Beach



Figure 2-24. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 4

2.6.5 Section 5. Manhattan Beach South

Section 5 is located between Cañada Verde Creek and a small point where there is a change in shore orientation, referred to in this report as Manhattan Beach Point (Figure 2-23). The 17th hole of the Ocean Course is located at the top of the bluff in Section 5. The section is concave and oriented north to north–northeast with the orientation taking a turn in the southern part of the section. The beach is wide to the north and narrows to the south. The basal Purisima Formation is relatively thick in this section accounting for about 70 percent of the total cliff height. The average bluff-top elevation is 50 ft, and the elevation of the marine terrace deposit contact is around 36 ft. The section is characterized by numerous gullies cutting down through the marine terrace deposits and into the Purisima Formation in some locations. Gullying is indicative of overland flow cutting channels into the surficial material, although an investigation of specific processes is beyond the scope of this study.



Figure 2-25. Section 5: Manhattan Beach North to Cañada Verde Creek. Source *Kenneth & Gabrielle Adelman, 2019*

The historical rates of cliff toe erosion are relatively low compared to the more northern sections (Figure 2-23), and most erosion of the bluff top is in the southern portion of Section 5 and appears to have occurred primarily between 1931/2 and 1965, with little additional retreat in the period from 1965 to 2002.

The beach north of Manhattan Beach Point is wide compared to the beach south of the point. A linear outcrop of the Purisima Formation that extends from the base of the cliff, as well as outcrops in the surf zone likely reduce sand from moving south along the coast, acting somewhat like a natural groin that impounds sand and helps maintain a wider beach. In addition, Cañada Verde Creek supplies some sediment to the system in the area north of Manhattan Beach Point. If the linear outcrop erodes in the future, the protective wide beach may experience increased erosion.

Section 5) Manhattan Beach South

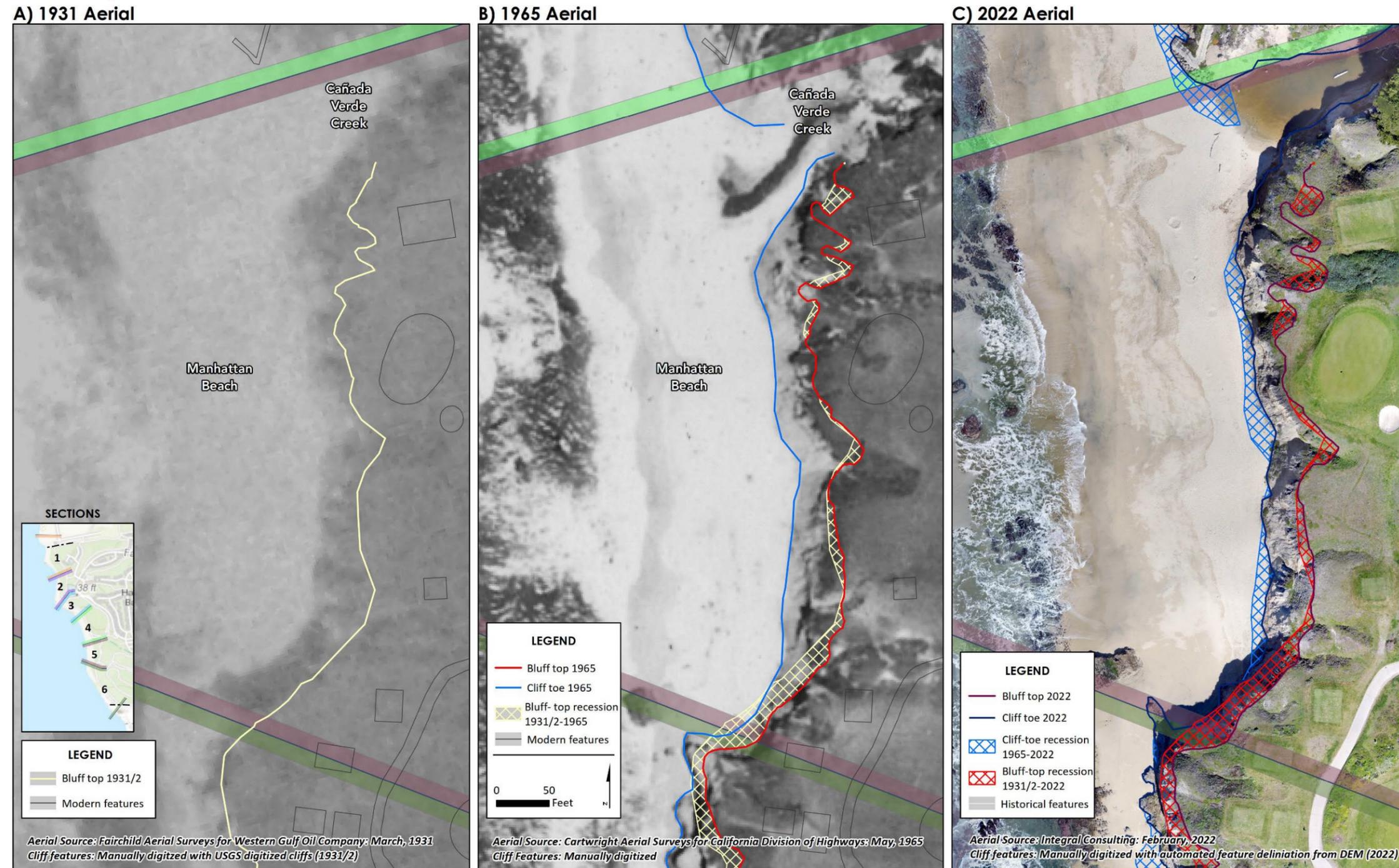


Figure 2-26. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 5.

2.6.6 Section 6. Manhattan Beach South to HMB City Line

Section 6 extends from Manhattan Beach Point to the HMB City line (Figure 2-27). The Coastal Trail is as close as 10 ft from the bluff-top edge in some areas of this section. There is a small drainage at the northern end of the section between the 17th hole tee boxes where there is a small bridge for the Coastal Trail.

The section is oriented north–northwest and gradually increases in elevation from approximately 50 ft in the south to just over 100 ft in the southern portion of the section. As the height of the bluff increases, the slope of the bluff face of the terrace deposits decreases. The beach is very narrow in this section and there are numerous undercuts at the base of the cliff. Waves frequently impact the base of the bluff due to the narrow beach, as is evidenced in Figure 2-28, where waves reach the base of the bluff and the wave splash has created a wetted surface on the lower portion of the cliff. However, the area is protected by offshore rock that dissipates wave energy, so that the waves reaching the base of the cliff are fairly low in energy. The Purisima Formation is fairly thick in this section (~30 ft) and as such, the elevation of the contact between the marine terrace deposits and the Purisima Formation is relatively high, especially on the southern end.



Figure 2-27. Section 6: Manhattan Beach South to HMB City Line. Source: *Kenneth & Gabrielle Adelman, 2019*



Figure 2-28. Waves crashing along the cliff of Section 6 near the 17th tee boxes. Source: *Kenneth & Gabrielle Adelman, 2002*

Erosion rates overall are low throughout this section based on the historical imagery (Figure 2-27). The rates of bluff retreat in Section 6 are so low that they are within the range of positional uncertainty of our ability to delineate bluff features. The greatest toe recession in this section has occurred in the northern area in proximity of a sea cave and undercut #2. The sea cave is visible in Figure 2-28 below the southern tee box for the 17th hole.

Section 6) Cowell Ranch to Manhattan Beach

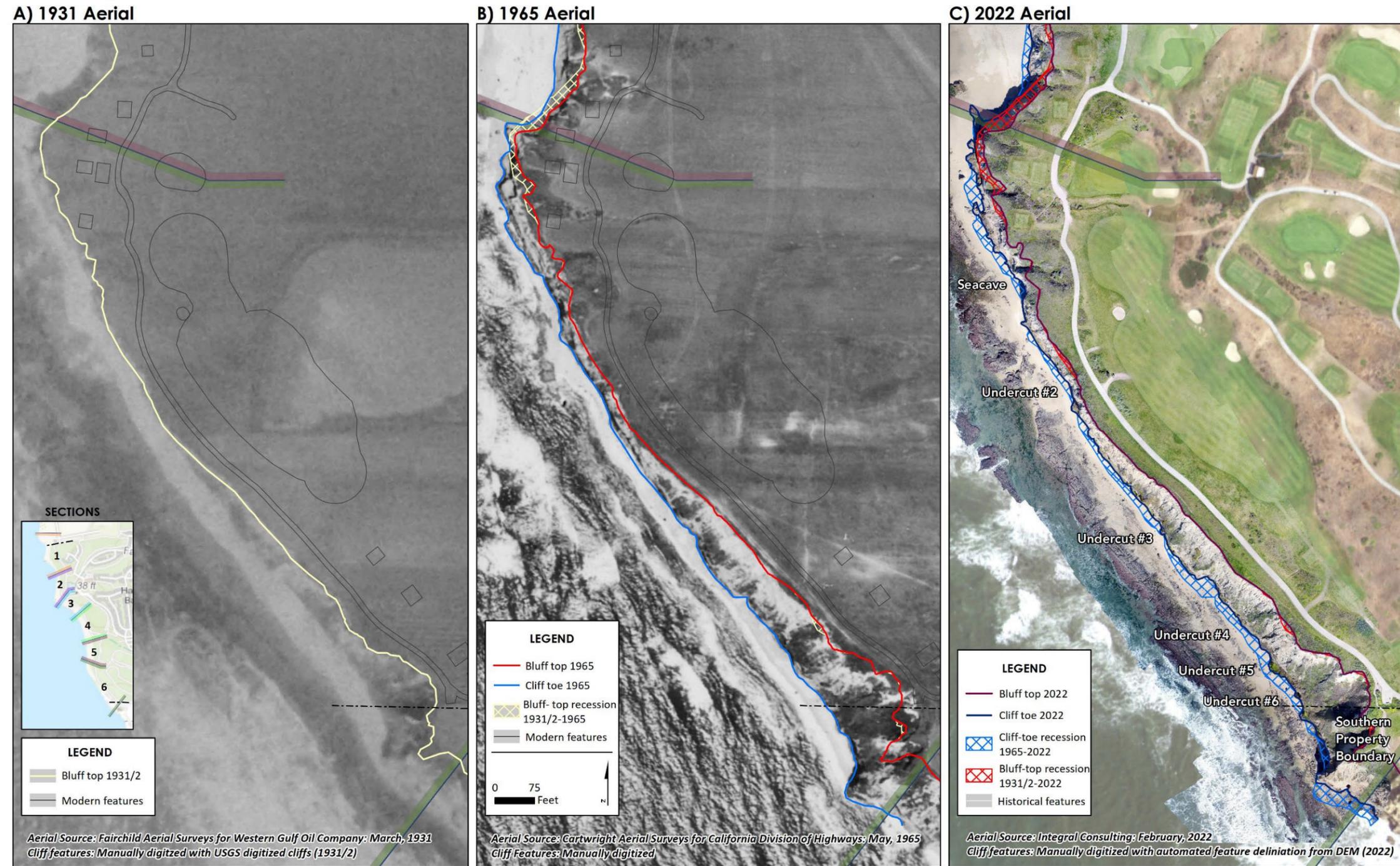


Figure 2-29. Historical and modern aerial photographs from 1931 (A), 1965 (B), and 2022 (C) of Section 6.

2.7 Coastal Armoring and Anthropogenic Terrace Changes

In the early 1970s, a developer erected a 7,300 sq ft concrete and steel foundation structure at Miramontes Point. Over the years the pier and grade structure became exposed due to erosion and collapsed on the beach, and ~160 linear feet of concrete and steel piers fronting the Ritz-Carlton were removed in 2018 (Simpson 2017) (Figure 2-30, Figure 2-31). The original 1973 hotel foundation may have included upwards of 20 piers with connecting grade beams and/or slab, and many piers, grade beams and slab foundation elements are still unexposed and underground beneath the seaward hotel landscaping, coastal trail, and hotel improvements.

In addition to the pier structure, ~200 ft of riprap fronting the Ritz-Carlton Hotel and the 18th hole of the HMB Golf Links Old Course was added without a permit in 1998. This structure was removed in 2006 (CCC 2005, Ocean Colony Partners 2022) (Figure 2-30).



Figure 2-30. Left: Riprap structure and foundation piers in place, 2004. Right: Riprap is no longer present and some of the foundation piers were removed in 2019. Source: *Kenneth & Gabrielle Adelman 2004 & 2019*



Figure 2-31. Remnants of the foundation piers that remain, 2022. These piers were not fully exposed from the bluff in the 2004 image. Source: *Integral Consulting, 2022*



Figure 2-32. Toe protection of beach access stairway. Source: *Integral Consulting, 2022*

Toe protection in the form of engineered riprap is located at the base of the beach access stairway at Cañada Verde Creek (Figure 2-32). This stairway is vulnerable to erosion from both coastal storm wave events and overland flow, and the toe protection riprap may become increasingly vulnerable to scouring and structural failure in the future.

3 METHODOLOGY AND APPROACH

This section describes the methods used to determine historical erosion rates and forecast future bluff positions.

3.1 Shore Sections and Subsection Block Delineation

The one-mile study area is divided into six sections (Figure 1-1). The sections were delineated based on coastal orientation, geology, and beach width. Sections were then split into smaller subsection blocks by grouping transects with similar characteristics. The blocks are typically 50–150 ft alongshore and contain between three and six transects.

3.2 Beach and Cliff Feature Delineation

Topographic features were generated from historical data sets for seven years: 1931/2, 1956, 1965, 2009/10, 2014, 2017, and 2022 (Table 3-1).

Table 3-1. Data Sets Used in Cliff Feature Delineation

Year	Type	Source	Elevation Data Resolution	Flight Resolution	QA Source	Image Resolution (ft)	Positional Certainty for Cliff Feature Delineation
1931	Aerial	Western Gulf Oil Company (now Chevron)	N/A	1:18,000	USGS Digitized Cliffs 1931/2	2.5	Low
1956	Aerial	USDA	N/A	1:20,000	none	3	Medium-Low
1965	Aerial	California Division of Highways (now Caltrans)	N/A	1:12,000	none	1.5	Medium
2009/10	Lidar DEM	NOAA	3.3 ft	N/A	USDA Aerial 2009	2	Medium-High
2014	Lidar DEM	USACE	3.3 ft	N/A	USDA Aerial 2014	2	Medium-High
2017	Lidar DEM	SM County	3.3 ft	N/A	USDA and SM County Aerials 2018	2	High
2022	SFM DEM	Integral	0.2 ft	N/A	Integral Drone Flight 2022	0.05	Very High

Beach and cliff profiles were analyzed to identify topographic features that were pertinent to the coastal erosion analysis, including the bluff-top edge, contact between the Purisima Formation and the marine terrace deposits, cliff toe location, and beach width and slope. Representative transects spaced 10 meters (33 ft) alongshore were generated using the DSAS Tool for ArcGIS (Himmelstoss et. al. 2018).

Bluff-Top Features and Elevations

Bluff-top edge features were delineated using a combination of both historic aerial photos as well as historic elevation data. The historic aerials required manual photo interpretation and the historic elevation data allowed for automated extraction techniques.

For the years when no digital elevation data were available (1931/2, 1956, and 1965), edge features were digitized manually based on aerial photograph interpretation. The quality of the 1931 aerial photographs was quite poor, so USGS-digitized cliff edges from the National Assessment of Shoreline Change for the years 1931/2 (Hapke and Reid 2007) were used as a feature reference.

For years with digital elevation data (1998, 2004, 2017, and 2022), cliff feature delineation was automated using the USGS Cliff Feature Delineation Tool performed at each cross-shore transect (Seymour et. al. 2016). All geomorphic feature locations were then mapped over high-resolution aerial imagery with multi-directional hillshade to manually correct and verify automated feature interpretation.

Terrace Deposit Contact Elevations

The terrace deposit contact location was determined using an interpretation of the 2022 high-resolution drone-based imagery and multi-directional hillshade, and contact elevations were taken as a weighted average of the high-resolution 2016 USGS DEM.

Cliff-Toe Features and Elevations

Only two reference years were developed for this study: 1965 and 2022. Aerial images before 1965 had insufficient image quality for manual determination of toe locations, and DEM resolution needed to be very high resolution for accurate feature toe detection. Cliff-toe features for 2022 were delineated using automated extraction techniques and manually corrected based on aerial photo interpretation.

Backshore Beach Width and Slope

For this study, beach width and slope were derived from the distance between the mean high water (MHW) line to the cliff toe (dry beach). Where offshore rocks interrupted the MHW line, the foreshore line was drawn on the shoreward side of the rock. To better simulate winter conditions (when most erosion occurs), a composite elevation surface was generated taking the

lowest elevation from the three most recent high-resolution DEMs (2014, 2016, and 2017). Backshore beach slope was determined by taking the average slope for each study area section.

Uncertainty

The location of cliff feature positions includes a degree of uncertainty related to manual digitizing error, which is dependent on image quality and tonal contrast, error related to the spatial resolution of the DEMs, and for the aerial photographs, positional error related to georeferencing of the historical aerial as well as distortions and displacement related to camera altitude, orientation, tilt, lens properties, the film printing process, and the terrain relief itself, which can significantly affect interpretations of feature locations (Hapke 2004). These factors combined yield an uncertainty value that is incorporated into the historical erosion analysis and is calculated in a quadrature method (Hapke and Reid 2007).

3.3 Rate of Sea Level Rise

The rate of sea level rise used is based on OPC (2018) guidance and the select scenarios were confirmed with the City of HMB. For more information see Section 2.3.

3.4 Nearshore Wave, Total Water Levels, and Exceedance Curve Calculations

Wave properties, including wave height, period, and direction, were derived from unpublished data as part of the USGS nearshore waves for the central California data set (Hegermiller et al. 2017). This data set was part of a larger model that was incorporated into CoSMoS. The time series of nearshore waves along the central California coast, including hindcasted for 1980–2010 and projected to 2010–2100, was done using global climate model forcing for 1975–2005 and 2012–2100. Each section in the study area was linked to the nearest nearshore station location, with a total of five stations matched. Due to the large variation in beach width, Section 1 was split out into two subsections (a and b) for the analysis, but they are not shown separately in the results. The Stockdon wave runup equation was then used to determine TWLs along each study area section (Stockdon et al. 2006) (Figure 3-1).

These TWL elevations were turned into exceedance curves for each section. These exceedance curves show how frequently wave run up elevations are reached over time (Figure 3-2). For example, a 1% exceedance would be the equivalent of a 100-year storm wave run up elevation.

Once these curves are generated for existing conditions, then the curves are elevated with the projected sea level rise for each decade (Figure 3-3). The difference in the area below the decadal sea level rise adjusted exceedance curves represents an increase in the cumulative hours of wave attack and is used to accelerate erosion rates in the modeling effort (see Section 3-5).

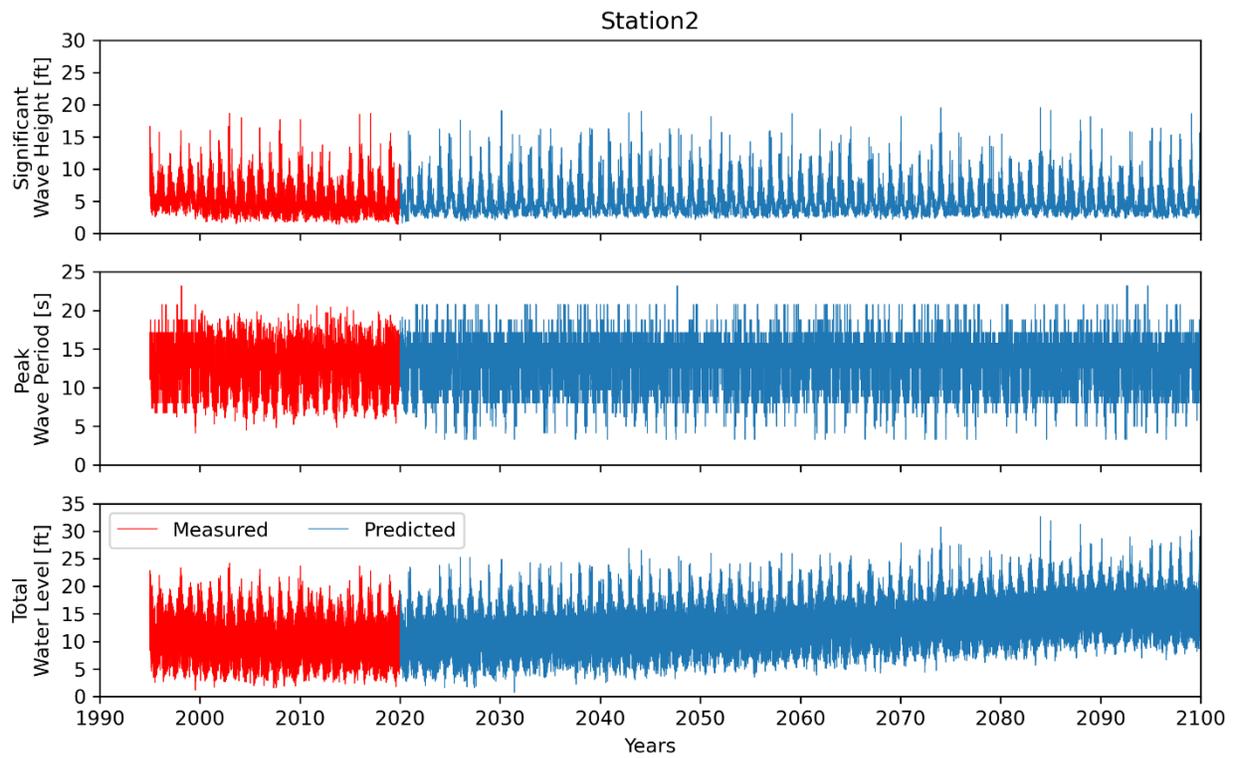


Figure 3-1. Example of wave parameters including significant wave height, peak period, as well as total water level for the nearshore at Station 2 (corresponding to Section 2).

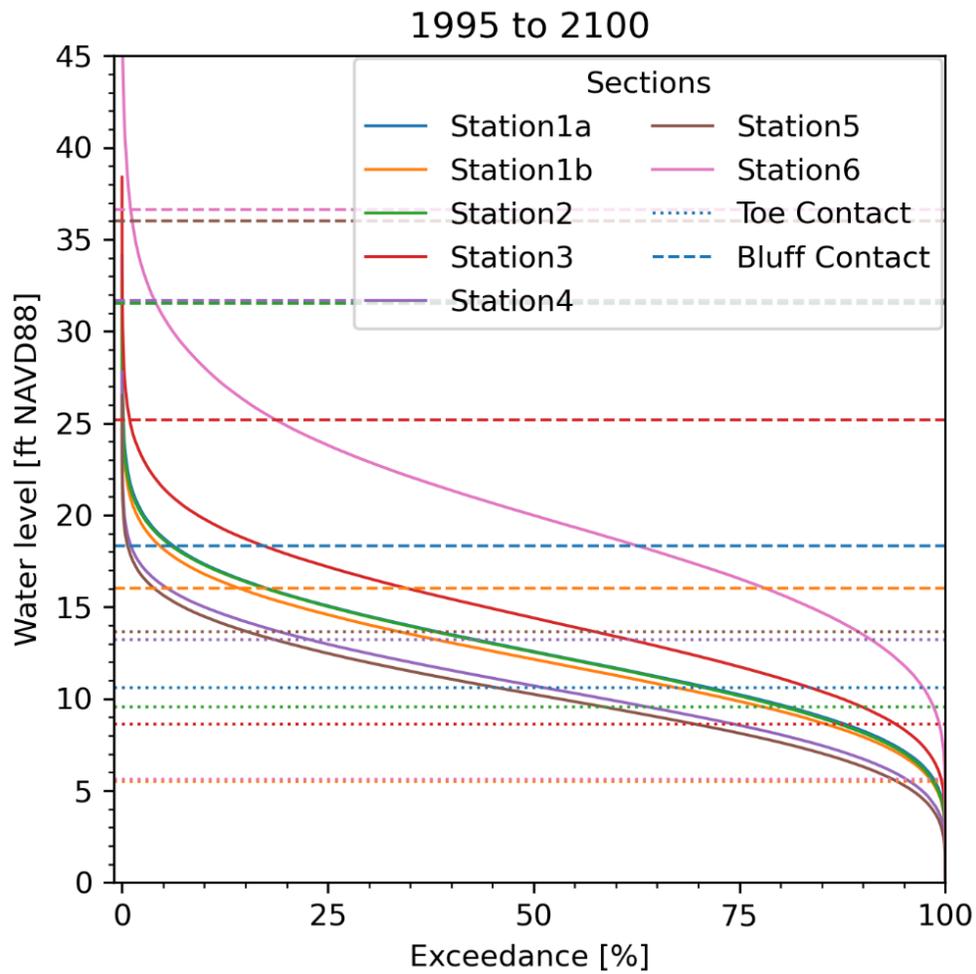


Figure 3-2. Total water level exceedance curve for each section (station) for 1995 to 2100 along with toe and bluff contact elevations for each section.

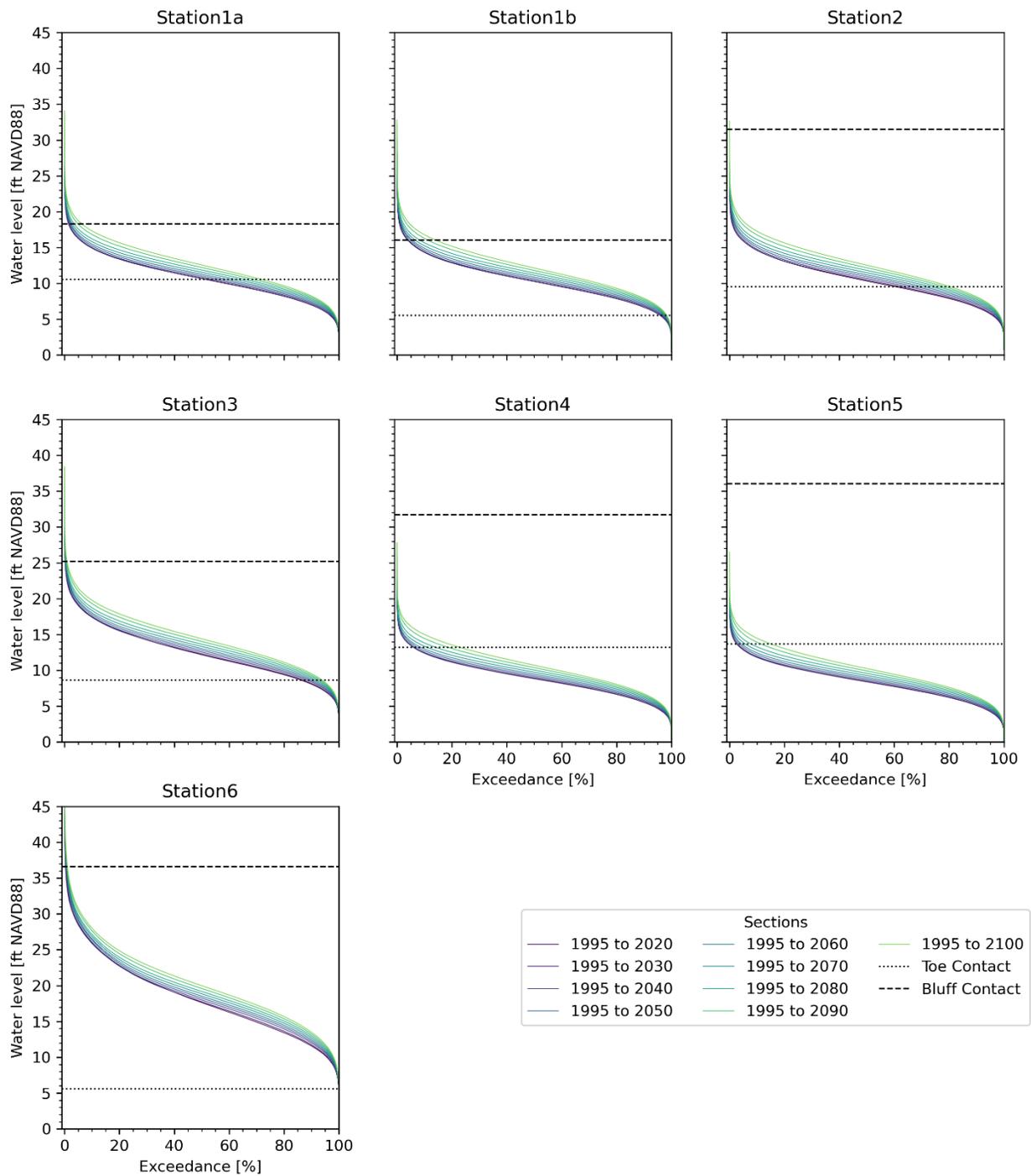


Figure 3-3. Total water level exceedance curves for each section (station) for each period of time.

3.5 Erosion Rate Calculations

The erosion rate calculation used for this study is based on methods published by ESA (2016) and adapted from work by Revell et al. (2011). Rates relied on using the relative exceedance of the TWL above the cliff toe and bluff contact elevation to drive the acceleration of historical erosion. The most important variables for predicting future cliff retreat using this model are historical erosion rates, beach slope, wave data, and the rate of sea level rise. In this model, wave data and sea level rise are incorporated into a single statistic called total water level (TWL).

Erosion rates are calculated at both the toe of the cliff and at the top of the bluff, with the erosion of the toe only driving erosion at the bluff when the slope of the cliff face exceeds 90 degrees.

Long-term Erosion Equation:

$$Erosion\ Rate_{future}(t) = Erosion\ Rate_{historical} * \left(\frac{A(t)}{A(historical)} \right)^m$$

Where A is the area below the total water level exceedance curve and above the existing erosion feature elevation (either the toe or terrace deposit contact), and can be seen as representative of the intensity of wave impact (Figure 3-4 at right). The period of time is represented as t , which is variable every 10 years from 2020 to 2100. Finally, an exponent is included, m , which is set to 0.5. The value of m was derived in a study by Ashton et al. in 2011, who investigated this value using various data sets for calibration and confirmed that $m = 0.5$ applies to cliffs/bluffs dominated by wave-driven erosion. Erosion rates were calculated for each of the 34 subsection blocks in the study area.

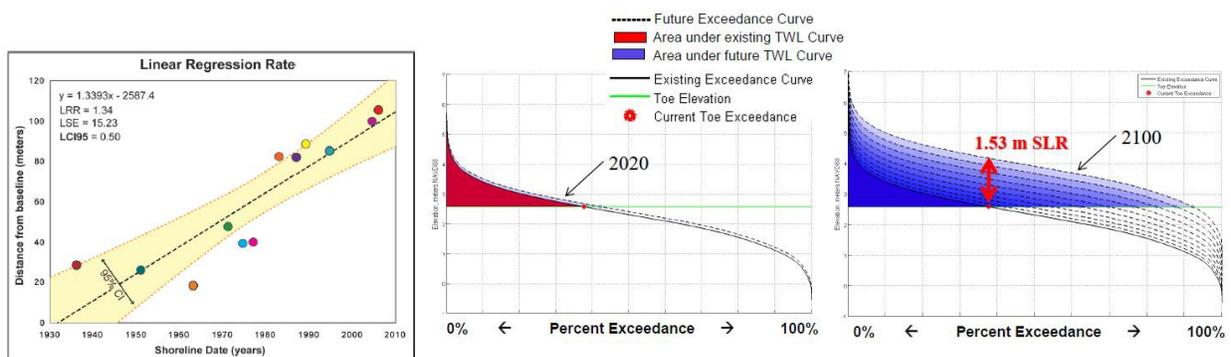


Figure 3-4. Left: Example of a DSAS linear regression rate statistic represented as a best-fit regression line (dotted line) among the bluff-top locations (colored points). The yellow shaded line represents the 95 percent confidence band for the position of the regression line. This band was used to determine the factor of safety. Right: Example of the area represented under both the existing (red) and future (shades of blue) exceedance curve and above the toe elevation (green line).

Erosion Factor of Safety

To account for the risk of localized block failures that could not be captured by the long-term average erosion rate, an additional factor of safety was included in the erosion calculation (see the yellow band in Figure 3-4 at left). Two different factors of safety were used for the study area. For areas with a higher degree of certainty and where more historical erosion has been observed, the study utilized one standard deviation of the historical erosion rate times the planning horizon. For areas with less certainty and where very little historical erosion has been observed, the study used two standard deviations of the historical erosion rate. This was done to minimize bias in areas where erosion is not well documented over the 90-year historical timeframe, as well as to account for the potential for localized near-term failures.

Caveats/Disclaimer

Some subsection blocks had much wider beach widths, and as a result, total water level elevation predations were significantly reduced. As a result, these subsection blocks did not experience a significant exceedance of the bluff contact elevation, thus, the erosion equation did not substantially accelerate bluff erosion from historical rates.

The erosion model does not account for the evolution of nearshore slopes over time, including the beach and shore platform, which is likely to evolve as sea levels rise and erosion forcing conditions change.

Small variations in initial parameter values can lead to significant variations in model predictions as they are multiplied over long time scales. As a result, the uncertainty in erosion rate predictions generally increases over time and may vary between subsection blocks.

Finally, the future holds many uncertainties that may influence erosion, ranging from potential changes in precipitation, temperature, wave climate, frequency and magnitude of precipitating storm events, and anthropogenic responses to erosion. Due to the highly uncertain nature of these processes, caution should be used with all erosion prediction results.

Given these disclaimers, however, all efforts have been made to utilize the best available science and methods and carefully document uncertainties. These results represent the state of the practice in coastal cliff erosion projections.

3.6 Erosion Rate Results

This study found bluff-toe recession to be more significant in the observed historical period than bluff-top edge recession, indicating a steepening of the cliffs. The average net movement of the cliff toe for the entire study is 20.8 ft between 1965 and 2022, and the average net movement in the bluff top is 1.6 ft between 1965 and 2022. Over the longer period from 1931/2 to 2022, bluff top net movement is 8.7 ft, still significantly less than net toe movement. Note that since there

are only two data points for toe erosion, rates may represent an overestimate due to an amplification of positional errors between the 1965 and 2022 aerial imagery.

Average end point erosion rates at the bluff top are around 0.1 to 0.2 ft/yr. The average rate obscures the fact that erosion has been primarily concentrated in approximately half a dozen areas, or erosion hot spots, where historical rates are often higher than 0.5 ft a year along a single transect.

The areas of greatest cliff-toe recession are consistently focused at headlands and along the northwest-oriented cliffs between Cañada Verde Creek and Miramontes Point, which include Sections 3–4. The focusing of wave energy, combined with the relatively narrow beaches in the areas immediately south of Miramontes Point and Three Rocks Beach Point, is likely driving these high rates, and underscores the importance of geology, beach width and slope, wave energy, and water level on processes of coastal cliff retreat. For Section 6, with its narrow beach width and high cliffs, very small amounts of historical erosion have been observed; however, the stretch contains the largest concentration of sea caves and undercuts making it a location of future erosion concern.

Table 3-2. Bluff Top and Cliff Toe Erosion Result

Section	Description	Bluff-top (1931/2–2022)		Cliff-toe (1965–2022)	
		Net Movement (ft)	Linear Recession Rate (ft/yr)	Net Movement (ft)	End Point Rate (ft/yr)
1	Three Rocks Beach	15.6	0.1	26.5	0.5
2	Miramontes Point North	15.5	0.2	15.4	0.3
3	Miramontes Point South	9.9	0.1	34.1	0.6
4	Manhattan Beach North	9.3	0.1	32.4	0.6
5	Manhattan Beach South	7.4	<0.1	5.7	0.1
6	Manhattan Beach to City Line	0.1	<0.1	12.8	0.2
Grand Total	Three Rocks Beach to HMB/SM County City Line	8.5	0.1	20.8	0.4

Comparison to the USGS Statewide Assessment

Hapke and Reid’s National Assessment of Shoreline Change (2007) found that along California’s sea cliffs, for ~75% of the coastline, erosion rates averaged ~10 inches a year over the observed historical period (0.83 ft). For this stretch of coast, they found rates of seven inches (0.58 ft) a year. This rate is higher than the average rate seen throughout much of this study area. These differences are likely because the National Assessment of Shoreline Change study relied on fewer reference years and had lower transect coverage. Note that corresponding bluff-top recession rates of half a foot a year to up to two feet a year were seen in individual transects in the study area, notably the areas around Three Rocks Point, Miramontes Point, and areas of Section 3-4 near erosion hot spots 5-7.

4 VULNERABILITY ASSESSMENT

Erosion rates throughout the study area generally accelerate in the future with a more notable acceleration in erosion rates beyond 2070. This corresponds to both the accelerating nature of long-term sea level rise, as well the cliff erosion model predicting a gradual steepening of the cliff face, with increased wave attack at the toe of the cliff driving long-term erosion rates at numerous locations. Erosion rates are highest at the two coastal promontories, Miramontes Point and Three Rocks Beach Point, as well as in Sections 3 and 4 around erosion hot spots (Figure 4-2).

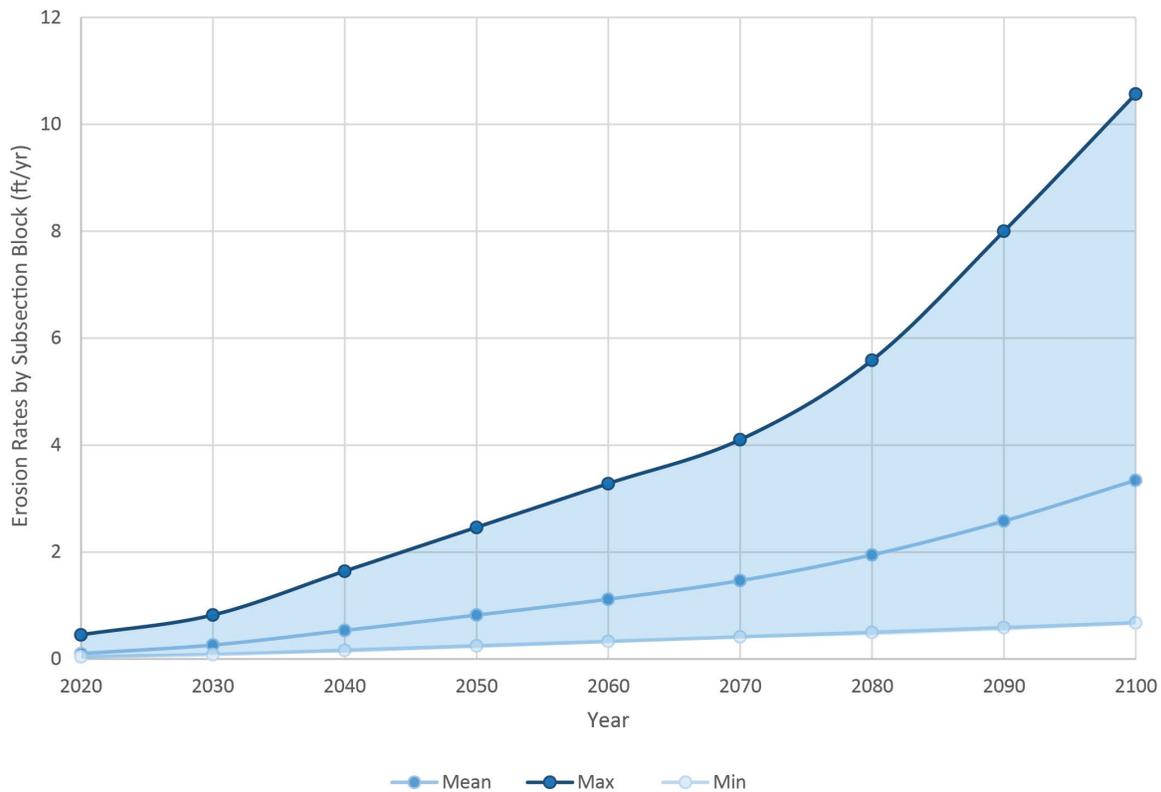


Figure 4-1. Acceleration of erosion rates. The blue shaded area represents the range of erosion rates among all subsection blocks.

Caveats

In some places of the study area, especially in the southern end, there have been no major bluff-top recession events in the 90-year study timeframe, and as a result, future predicted erosion is quite low. These areas are not well captured in the cliff erosion models. From experience, areas that have not eroded much are found adjacent to areas that have eroded and are usually more likely to fail. On the maps, the areas that have been undercut or have sea caves, but have experienced low erosion rates in the past are shown on the maps with a \triangle symbol to indicate areas of erosion concern where past observations may not be signs of future performance.

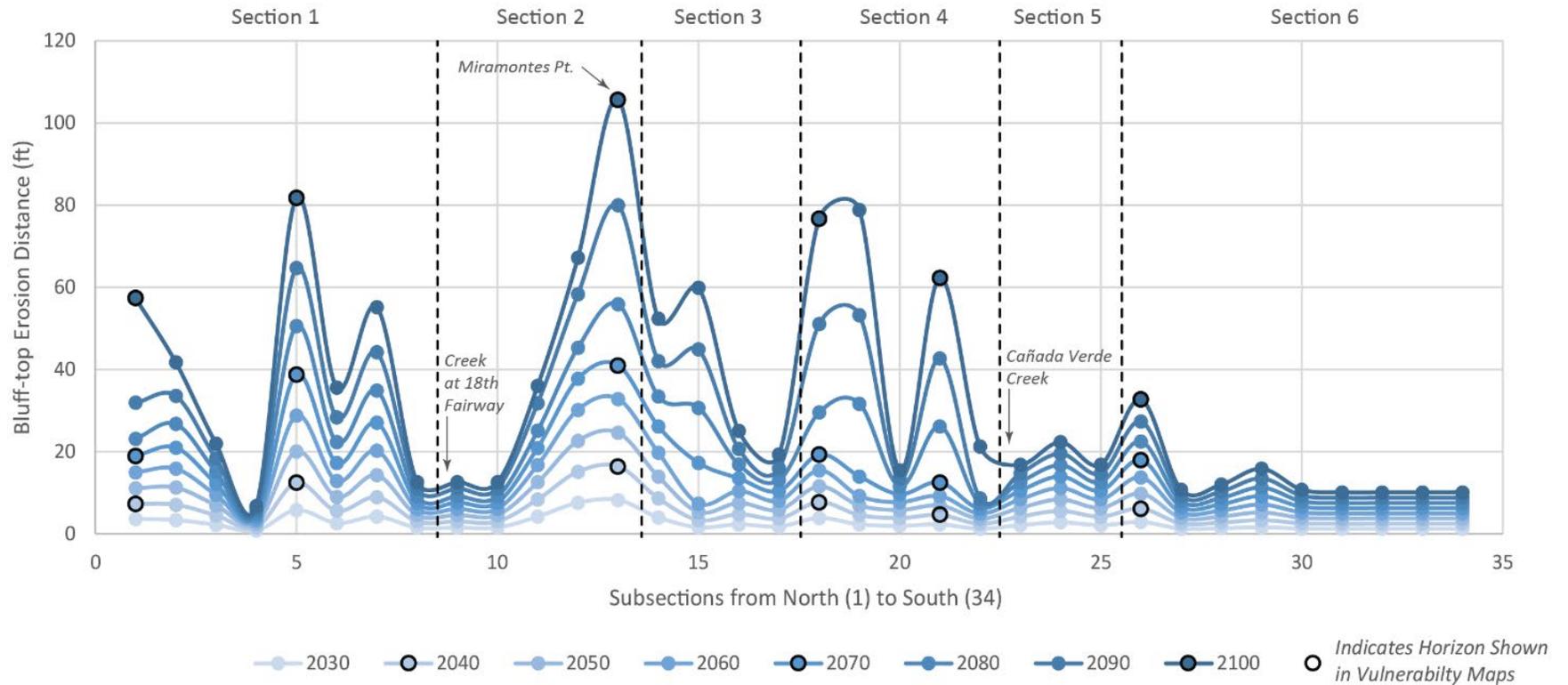


Figure 4-2. Erosion rates by study area subsection blocks. Not particularly in Sections 2 and 4 that sea level rise tends to accelerate the projected erosion distances more rapidly.

4.1 Vulnerabilities

This vulnerability section summarizes the key assets and infrastructure at risk by 2100 followed by study area maps in Section 4.2 that further identify specific areas of concern, and when areas become vulnerable to bluff erosion.

Vulnerability Snapshot by 2100

What Is at Risk?	What Is Vulnerable by the Long-term Sea Level Rise Horizon?	Potential Impacts and Consequences
HMB Golf Links	<ul style="list-style-type: none"> • 14.2 acres of grounds • 3 sets of tee boxes • 2 fairways • 3 greens 	<ul style="list-style-type: none"> • Conflicts between the coastal trail alignment and golf course features • Potential reconfiguration of golf course features
HMB Golf Links Old Course	<ul style="list-style-type: none"> • 2.7 acres of grounds • 490 sq ft of tee boxes at the 18th hole • 6,460 sq ft of the fairway at the 18th hole • 1,000 sq ft of rough near the 18th green 	
HMB Golf Links Ocean Course	<ul style="list-style-type: none"> • 11.5 acres of grounds • 11,000 sq ft of rough near the 18th fairway • 170 sq ft of rough near the 18th green • <20 sq ft of tee boxes at the 17th and 18th hole • <20 sq ft of green at the 17th hole 	
Coastal Trail	<ul style="list-style-type: none"> • 1,444 ft (0.27 mi) of trail between the Ritz-Carlton and the Cañada Verde Creek Stairway • 7 areas of erosion concern • Beach access stairway at Cañada Verde Creek • 2 ocean overlook locations 	<ul style="list-style-type: none"> • Rerouting of trails • Reconstruction or relocation of the beach access stairway
Ritz-Carlton Half Moon Bay	<ul style="list-style-type: none"> • 1,500 sq ft of the Miramontes Terrace • 1,500 sq ft of the Hotel Structure 	<ul style="list-style-type: none"> • Relocation of the vulnerable terrace lawn • Reconstruction or relocation of the western wing of the hotel

Key Areas of Concern and Trigger Points

The list below outlines some of the key areas that are vulnerable to coastal erosion, and the time period they are likely to become exposed.

Near Term (2020 – 2040)

- The Coastal Trail near the Ocean Course 18th green and 18th fairway. Near erosion hot spot #6, adjacent to the Ocean Course 18th hole fairway, the trail is only eight ft from the bluff-top edge. There are six areas of erosion concern in the southern section of the study area near the Ocean Course 16th hole fairway that have sea caves or are undercut at the base that may signify higher future erosion probabilities.
- The stairway at Cañada Verde Creek is currently vulnerable and, with additional cliff recession or toe erosion, may require relocation.
- Scenic overlook locations at Miramontes Point and the at Cañada Verde Creek are vulnerable.

Near-Term Consequences

- Safety considerations for pedestrians where trail sections are close to the bluff top edge. If the trail is rerouted inland, consideration must be given to protect pedestrians from golf balls.

Mid Term (2040 – 2070)

- The Coastal Trail in front of the Ritz-Carlton Hotel is vulnerable. An increasing area of the trail near the Ocean Course 18th hole is vulnerable.
- The golf course features become vulnerable, with the furthest tee box at Old Course's 18th hole and areas of rough on this hole potentially vulnerable.

Mid-Term Consequences

- Potential conflict between the current location of the Coastal Trail and the Ritz-Carlton Hotel and Terrace. The distance between the current bluff-top edge and hotel's Ocean and Miramontes terraces can be as narrow as 40 ft, leaving limited space for inland realignment.
- Tee boxes at the Old Course 18th hole may need to be moved inland for safety purposes.
- Fairway and approach at the 18th hole may need to be reconfigured.

Long Term (2070 – 2100)

- The Ritz-Carlton Hotel structure and the Hotel's Miramontes Terrace are potentially vulnerable.
- Increasing areas of both golf courses are potentially vulnerable, including the Old Course 18th Green, Ocean Course 18th Tee Box, and Ocean Course 17th Green.
- The entire section of the Coastal Trail in front of the Ritz-Carlton Hotel is potentially vulnerable.

Long-term consequences

- With increasing sea levels and accelerating rates of erosion, the hotel building may become vulnerable.
- The realignment of the Coastal Trail is increasingly in conflict with the Ritz-Carlton Hotel and the golf course.

4.2 Vulnerability Maps

How to interpret the vulnerability maps

Each vulnerability map illustrates at what sea level rise elevation/year various study area assets are likely to become exposed to coastal cliff erosion. The cliff erosion hazard areas are color-coded at three sea level rise scenarios (and are represented on a scale from yellow to blue). Exposure of various assets is also color-coded based on the elevation of sea level rise that first leads to potential impacts. The timing of vulnerability to these assets is indicated with a marker nearest to the locations of impact (and sometimes offset to not conflict with the erosion hazard area) and is color-coded based on timing from red to yellow. All of these projected hazard extents assume that no adaptation has been implemented—in other words, a worst-case scenario if nothing is done to plan or adapt to sea level rise in the future.

Section 1a) Three Rocks Beach to Redondo Beach



Figure 4-3. Future bluff position envelope for near-, mid-, and long-term within the northern portion of Section 1 (Section 1a).

Section 1b) Three Rocks Beach

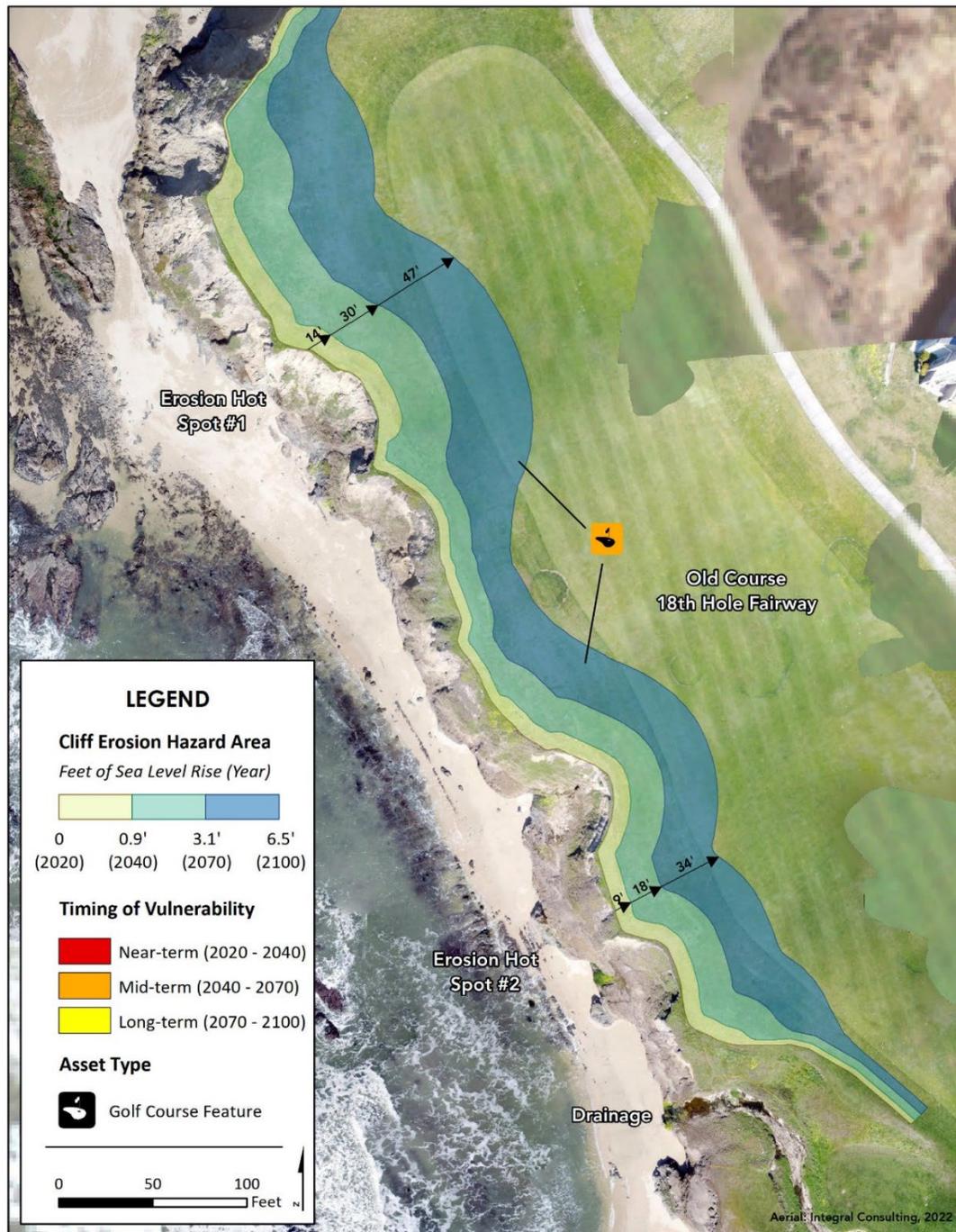


Figure 4-4. Future bluff position envelope for near-, mid-, and long-term within the southern portion of Section 1 (Section 1b).

Section 2a) Three Rocks Beach to Miramontes Point



Figure 4-5. Future bluff position envelope for near-, mid-, and long-term within the northern portion of Section 2 (Section 2a).

Section 2b) Miramontes Point

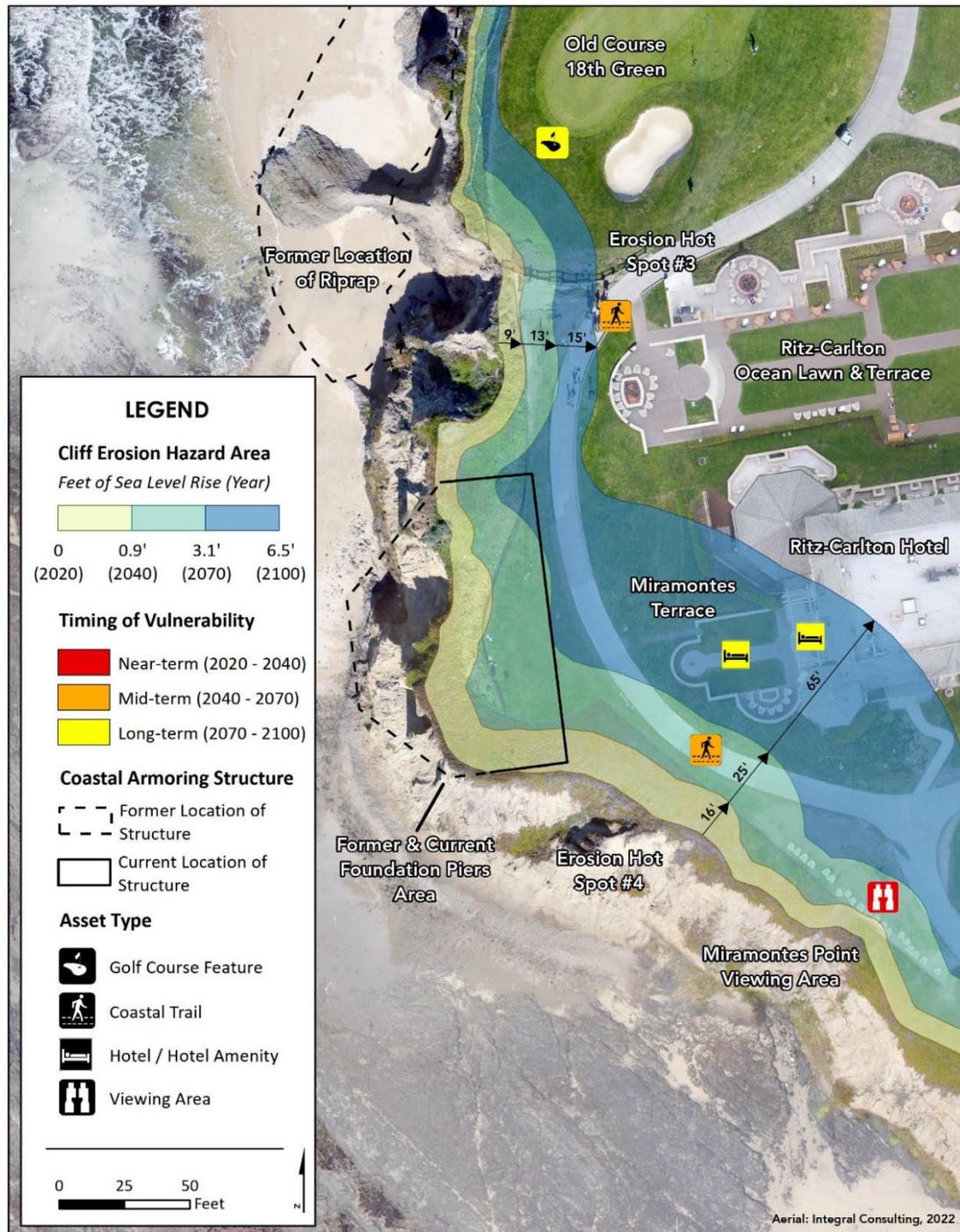


Figure 4-6. Future bluff position envelope for near-, mid-, and long-term within the southern portion of Section 2 (Section 2b).

Section 3a) Manhattan Beach North

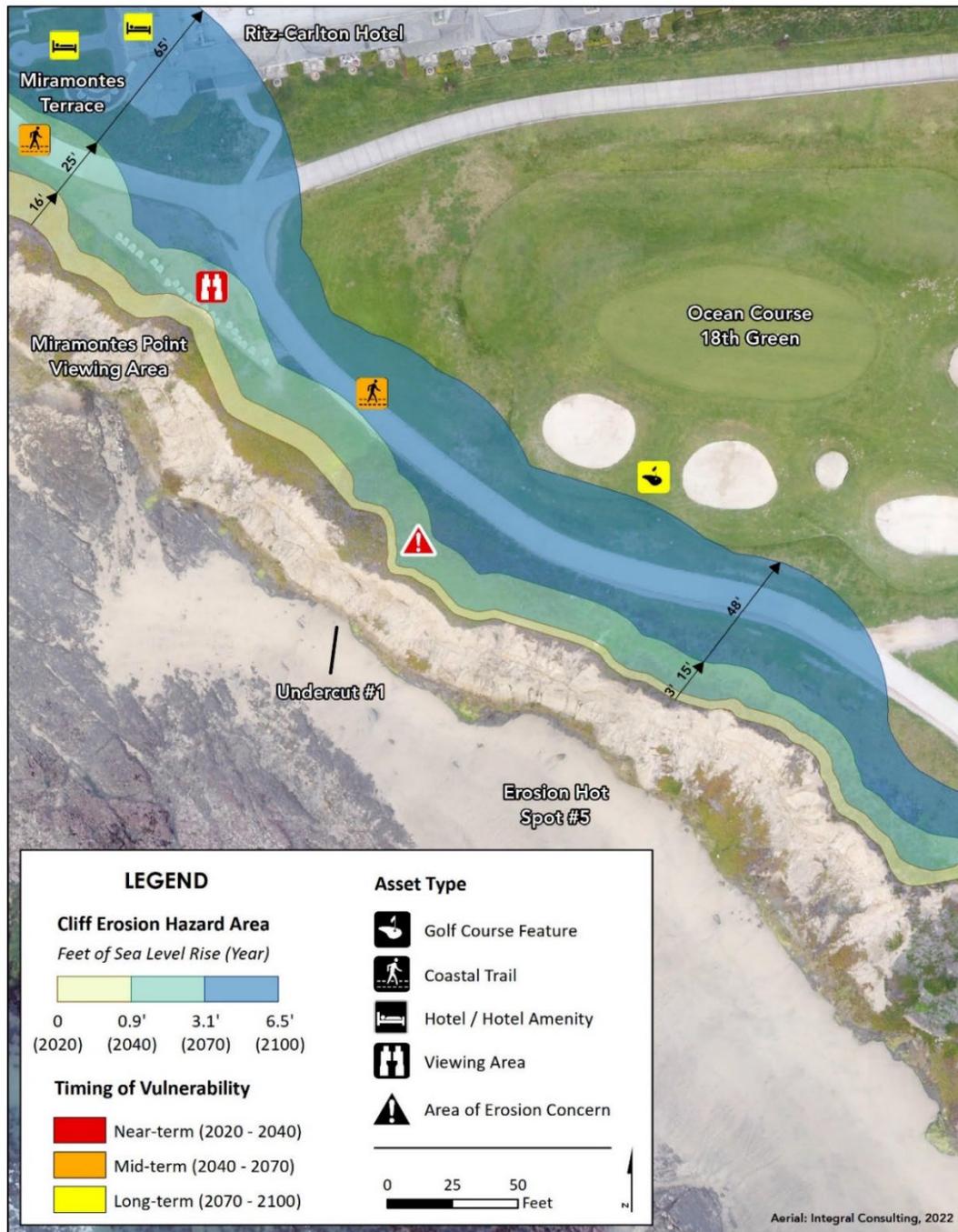


Figure 4-7. Future bluff position envelope for near-, mid-, and long-term within the northern portion of Section 3 (Section 3a).

Section 3b & 4a) Manhattan Beach North

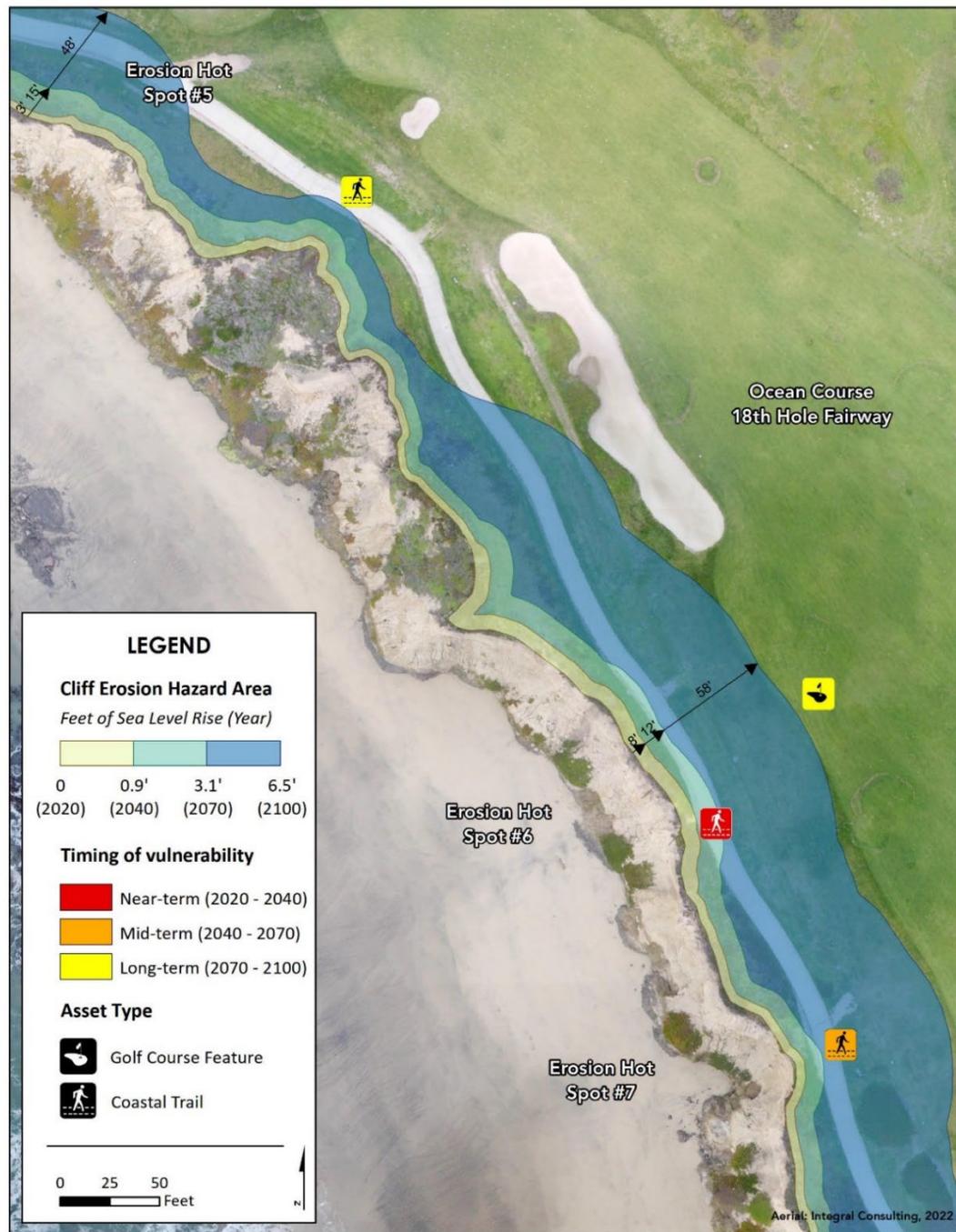


Figure 4-8. Future bluff position envelope for near-, mid-, and long-term bluff position envelope within the southern portion of Section 3 (Section 3b) and the northern portion of Section 4 (Section 4a).

Section 4b) Manhattan Beach

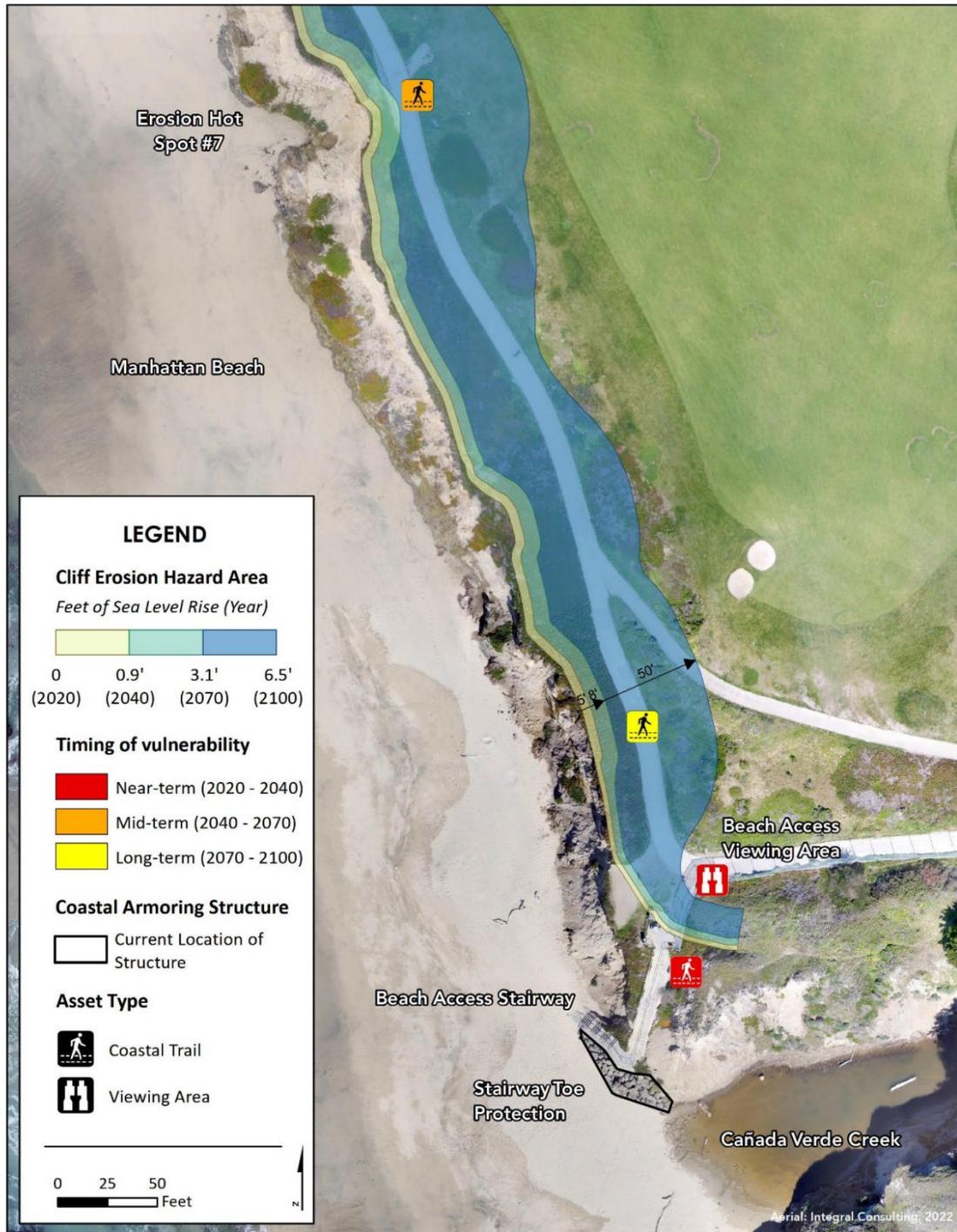


Figure 4-9. Future bluff position envelope for near-, mid-, and long-term within the southern portion of Section 4 (Section 4b).

Section 5) Manhattan Beach South

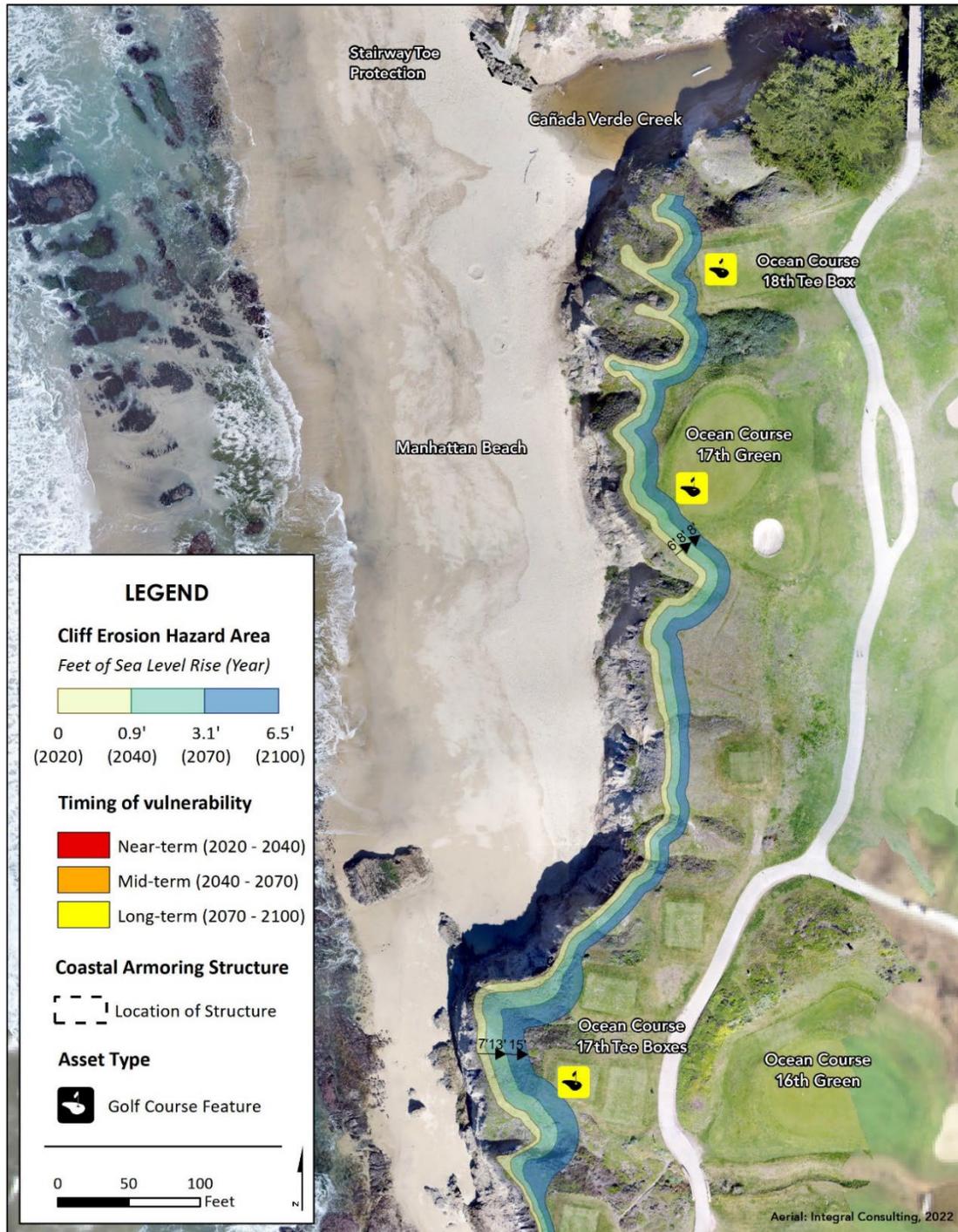


Figure 4-10. Future bluff position envelope for near-, mid-, and long-term within Section 5.

Section 6) Cowell Ranch to Manhattan Beach Point



Figure 4-11. Future bluff position envelope for near-, mid-, and long-term within Section 6.

5 ECONOMIC ASSESSMENT

This section reports on four components of the economic and fiscal values of the study area:

1. Asset values (hotel structure, golf course parcels)
2. Economic values generated within the study area (hotel revenue, golf course green fees, non-market recreational values of beach access and trail use)
3. Fiscal benefits to the City and other entities, including transient occupancy tax (TOT), property taxes, Business Improvement District (BID) fees, golf course fees, and broader economic benefits
4. Impacts on each of components 1–3 due to coastal erosion over time.

Figures are estimated from publicly available data and published studies, with the inclusion of operational information provided by the City of Half Moon Bay, Ritz-Carlton Hotel, and golf course operators, where available.

Impacts in this section are presented in terms of their present value, and no attempt has been made to adjust for the expected increases in the value of built structures or land parcels over time, changes in expenditure or fiscal revenues due to inflation, or for increases in construction or replacement costs. There has also been no attempt to consider the impact of discounting future costs associated with erosion impacts on present-day values, as without a realistic estimate of future asset values this would be a fruitless exercise.

5.1 Asset Values

Table 5-1 presents the assessed values of the four parcels in the study area that are affected by coastal cliff erosion. One of these parcels is the Three Rocks City Beach parcel, which is almost entirely seaward of the cliffs. The other parcels have a component that is located seaward of the cliff boundary. It is assumed that the assessed value of the parcels is applied only to the component that is landward of the cliff (i.e., that the tax assessor has already adjusted for the area that is seaward of the cliff).

Table 5-1 shows the asset values by parcel for the period 2018–2021, for those parcels affected by cliff erosion by 2100. The Three Rocks City Beach parcel is included for completeness but does not have a tax-assessed value.

Table 5-1. Parcel Value Averages for 2018–2022 by APN

Year	APN 66092530: City Beach Three Rocks Assessed value (\$)	APN 66092720: HMB Golf Links Old Course Assessed value(\$)	APN 66092770: Ritz-Carlton Hotel Assessed value (\$)	APN 66580010: HMB Golf Links Ocean Course Assessed value (\$)	Total Assessed Value (\$)
2018–19	0	4,912,263	188,533,406	14,780,859	208,226,528
2019–20	0	5,010,508	191,699,996	15,076,475	211,786,979
2020–21	0	4,055,349	195,607,200	12,234,827	211,897,376
2021–22	0	2,740,889	197,138,538	12,149,349	212,028,776
Four-yr average		4,179,752	193,244,785	13,560,378	210,984,915

A four-year average of asset values is provided, to account for volatility in values caused by the COVID-19 pandemic, which greatly reduced occupancy within the hotel, and the use of the golf course facilities.³ Hotel occupancy in 2020 was approximately half of the long-term average, at 35 percent of available rooms. As commercial property values are a function of their annual income, this slowed the growth rate of the hotel property value and reduced the assessed value of the golf course parcels.

It was not possible to calculate a reliable annual growth rate, due to this volatility in assessed values.

The figures presented in Table 5-1 for the Ritz-Carlton are combined values for the land and all improvements and built assets on the property. Table 5-2 separates these elements into three categories; land, improvements (the hotel structures), and “other” values. Other values are fixtures and personal property.

³ Although a 5-year average is typically preferred, there was a very large increase in assessed values for the Ritz-Carlton property between 2017 and 2018, so inclusion of the earlier values would result in an unrealistically low average for the current assets.

Table 5-2. Average Values by Category for 2018–2022

Year	Hotel Land (\$)	Hotel Improvements (\$)	Hotel Other Values (\$)	Hotel Total Value (\$)
2018–19	44,880,000	138,720,000	4,933,406	188,533,406
2019–20	45,777,600	141,494,400	4,427,996	191,699,996
2020–21	46,693,152	144,324,288	4,589,760	195,607,200
2021–22	47,176,893	145,819,487	4,142,158	197,138,538
Four-yr average	46,131,911	142,589,544	4,523,330	193,244,785

Table 5-2 shows that approximately three-quarters of the value of the Ritz-Carlton Hotel parcel is due to the hotel structure. This is important when it comes to consideration of the value of erosion, as different property values must be applied to the parcel as a whole and to the building footprint.

5.2 Economic Values

This analysis considers both fixed asset values (using tax-assessed values as a proxy for true market values), and the income streams, and uses values of the various facilities and natural amenities.

5.2.1 Ritz-Carlton Hotel

The Ritz-Carlton at Half Moon Bay is a significant contributor to the local economy. As of the 2021 fiscal year, the hotel employed approximately 550 full-time staff, which was 15.6 percent of employment within the City.⁴

Room Revenue

There are 261 rooms available, including 22 suites and 239 standard rooms. As a luxury hotel, room rates for the Ritz-Carlton are higher than other accommodation providers in the region. Average room rates for private bookings range from \$779 to \$1,225 per night, based on a two-night booking for a hotel room. Depending on the package purchased, this may not include additional fees for breakfast, resort fees, or golf course green fees.

The long-term occupancy rate can be estimated from the payments made by the Ritz-Carlton into the BID fund. Participating hotels pay a rate of \$1 per room night into this fund, so annual payments equal the number of room night bookings. Before the COVID-19 pandemic, the long-term average occupancy rate was slightly more than 70 percent, based on BID receipts. The

⁴ City of Half Moon Bay, Comprehensive Annual Financial Report, [Fiscal Year 2020-2021](#), p 121.

COVID-19 pandemic reduced occupancy to approximately 35 percent in 2020, based on BID receipts and the number of available room nights.⁵ Using a conservative figure of \$800 per night (to account for suite bookings at higher rates, and group bookings at lower rates), and an occupancy rate of 70 percent, annual room revenue for the Ritz-Carlton is estimated at around \$53.3 million per year.⁶

This should be considered an upper-bound estimate, as staff from Ritz-Carlton have reported in local news articles that up to 65 percent of hotel bookings are based on group business which are price sensitive.⁷ These group bookings likely pay a reduced rate. Using a room rate of \$500 per night, the average revenue would be approximately \$33.3 million. Likely, true revenue lies somewhere within this range (\$33.3 million–53.3 million per year), and secondary evidence suggests that it must be towards the lower bound. The City of Half Moon Bay Annual Comprehensive Financial Report for the Fiscal Year Ended June 30 2021 provides a breakdown of TOT payments by lodging type. Using occupancy rate information, if the average room was \$500 per night, then TOT receipts from the Ritz-Carlton would represent between 50 and 65 percent of receipts from the hotel/motel sector. Using a room rate of \$800 results in estimated Ritz-Carlton TOT payments that are higher than the total receipts from this sector.⁸ For this analysis, the lower bound is used for further calculations.

Events

The hotel hosts many functions, corporate events, and weddings. No information was available on the aggregate value or specific attendance of these functions. A summary of estimates provided by the Ritz-Carlton is provided in Table 5-3.

Table 5-3. Events by Type at the Ritz-Carlton Hotel

Event Type	Timing/Frequency	Attendees	Average Cost per Event
Wedding	Weekends, 35–45 weddings per year	25–300 per event	\$30,000–\$50,000
Corporate Events	Weekdays, 40–75 per month	Variable	\$1,000–\$50,000

Based on a minimum estimate for the number of events and cost per event, hotel events would contribute an additional \$1.05 million per year for weddings and \$480,000 for corporate events.

⁵ Visit Half Moon Bay Coastsides California, [Business Improvement District 2020 Annual Report](#), p 2; Visit Half Moon Bay Coastsides California, [Business Improvement District 2019 Annual Report](#), p 2

⁶ This represents the product of \$800 per room night x 70% occupancy x 261 rooms x 365 days per year.

⁷ Half Moon Bay Review, HMB voters to decide on ‘tiered’ hotel tax increase, 23 July 2020.

https://www.hmbreview.com/news/hmb-voters-to-decide-on-tiered-hotel-tax-increase/article_162af0f2-ccfa-11ea-89e1-a766da45a8f6.html

⁸ Integral calculations from TOT and BID data.

Using midpoints for frequency, a central estimate of \$40,000 per wedding, and \$10,000 per corporate event results in an estimated value of \$1.6 million for weddings, and \$6.9 million for corporate events.

5.2.2 Golf Courses

Half Moon Bay Golf Links employs 49 people, which is 1.4 percent of the local workforce and makes them the 7th largest employer in the City.⁹ On average, there are a total of between 68,000 and 75,000 rounds of golf played on the Ocean Course and Old Course each year, not including events and tournaments. Pricing per round is dynamic, with course fees determined by demand in a range between \$145 and \$275 per round.¹⁰ A search of online golf forums, and use of the [online tee time booking system](#), suggests that rates of \$140–\$180 per round are more typical of those paid by casual golfers (i.e., those not participating in tournaments or events), with twilight fees of between \$60 and \$100. Using a conservative estimate of \$150 per round, and 70,000 rounds played per year, this represents revenues of \$10.5 million per year.

Golf course staff advised that there are approximately 75–100 golf tournaments per year, with participation ranging from 30 to 288 golfers per event. These visitor numbers are assumed to be part of the estimate of the number of golf rounds played per year. In addition to tournaments, the golf courses host approximately 25–40 banquets or events each year, with an attendance of 40–400 persons. The golf courses also host 10–20 weddings per year, with an attendance of 30–200 persons.¹¹

No information is available about the expenditure associated with these events.

5.3 Recreational Non-market Value

In addition to the monetary values identified above, the Coastal Trail and beach access points provide recreational values and other environmental services that are not captured in existing market transactions. This section does not attempt to estimate the total economic value of services provided by the natural and built features but does provide an estimate of the recreational use values associated with the trail and beach amenities.

There are no existing records of the number of recreational uses in the study area, so usage has been based on accessibility, with basic assumptions about recreational participation. The value of beach and trail use has been estimated using previously published studies.

There are three key sources of recreation participants:

- Hotel guests

⁹ City of Half Moon Bay, Comprehensive Annual Financial Report, [Fiscal Year 2020-2021](#), p 121.

¹⁰ Personal communication, Ritz-Carlton.

¹¹ Personal communication, Kenmark, 2 May 2022.

- Local residents
- Visitors, including golfers, using parking spaces.

5.3.1 Hotel Guest Visits

The Ritz-Carlton advised that the average room occupancy was 1.5 persons per room. Multiplying this figure by average room bookings results in an estimated 100,028 hotel guests per year. There is likely a substantial overlap with the number of golfers (68,000–75,000 per year). It is assumed that 10 percent of hotel guests visit the beach during their stay, and 50 percent take a walk along at least part of the coastal trail during their visit or use part of the trail while playing a round of golf. This results in approximately 10,000 beach visits and approximately 50,000 trail uses per year.

5.3.2 Local Residents

The number of local residents was estimated through counts of local houses, trailers, and RV park spaces. The estimated number of housing units is:

- 302 houses in Ocean Colony
- 160 housing units in MidPen at Moonridge
- 234 trailers at Cañada Cove
- 75 RV parking spaces at Pelican Point.

Beach attendance rates by local residents are a subject of some debate, with estimates ranging from 10 to more than 100 per person per year (King and McGregor 2012). For this assessment, it is assumed that residents take around 20 beach visits per year. It is assumed that houses, housing units, and residential units have 2.67 residents, based on [Census data](#). For RV parking spaces, a figure of two residents was applied. This results in a total estimate of 2,008 residents within walking or cycling distance. Multiplying by 20 visits per year gives an estimate of 40,166 beach trips, which is approximated as 40,000 beach trips by local residents.

Estimating trail usage by local residents is more challenging, as there is little public information about the frequency of use of scenic trails in residential locations. The [Outdoor Recreation Foundation](#) estimated in 2018 that hikers took an average of 14 trips per year, while runners and joggers took an average of 76 outings per year. According to research by Veterinarians.org, dogs in California are walked approximately seven times per week or 365 times per year.¹² For this assessment, a conservative figure of 40 trips per year is assumed, resulting in 80,000 trail uses by local residents.

¹² [Dog Walking Survey: Which States Walk Their Dog the Most?](#), April 20, 2022.

5.3.3 Visitors Using Parking Lots

Visitors were estimated based on parking records provided by the Ritz-Carlton for the 25 parking spaces provided within the parking garage structure, as a condition of the coastal development permit for the property and reinforced by enforcement action undertaken by the CCC in 2019. Ritz-Carlton staff estimate that the parking spaces were used approximately 2,500–3,000 times in a six-month period, which translates to approximately 240 visits per parking space per year. Based on 6,000 visits per year, and a vehicle occupancy of two people, this represents 12,000 visitors per year.

City of Half Moon Bay staff provided information that Poplar Beach Parking Lot fees for 2020–21 totaled \$351,000.¹³ Daily parking fees are \$10 per day. There are also annual permits available for \$165 per year, and alternative passes that can further reduce the fees payable. In the absence of detailed payment information, it is estimated that there were at least 35,100 vehicle visits to Poplar Beach in 2020–21. There are 93 parking spaces in this lot, which results in an annual use rate of approximately 377 visits per parking space per year. This estimate is used to calculate the minimum number of visits from the parking lot on Miramontes Point Road (15 spaces) and Redondo Beach (approximately 30 parking spaces). Based on the free parking available in these locations, parking utilization is likely to be higher. For this assessment, a figure of 400 annual visits per parking space. This results in an estimated 6,000 and 12,000 vehicle visits per year, respectively. Using an occupancy of two persons per vehicle, these parking lots contribute 12,000 and 24,000 visitors, respectively. The majority of visitors to Redondo Beach are likely to be from those accessing the shoreline, rather than the Coastal Trail. It is assumed that 25 percent of the visitors from the Redondo Beach lot access the study area, either via the Coastal Trail or along the beach. Thus, the total figure from these lots is 18,000 visitors to the study area.

Total visitation to the study area from non-residents is estimated at 30,000 per year. It is assumed that approximately 20 percent of visitors descend the stairs to the beach, with the remainder using the Coastal Trail. This gives an estimate of 6,000 beach visits, and 24,000 trail uses.

5.3.4 Total Beach and Trail Uses

Based on the figures presented above for each user category, this study estimates a total of:

- 56,000 beach visits with sand contact (i.e. descending the stairs to Manhattan Beach or along the shoreline at the north of the study area)
- 154,000 coastal trail uses, including all recreational users and golf cart usage.

¹³ City of Half Moon Bay staff, via email, April 19, 2022.

5.3.5 Value of Recreational Activity

For beach recreation, a figure of \$40 per beach visit is applied. This figure represents an average value for California and is derived from work by Pendleton and Kildow (2006).

For trail use, a generic hiking figure is applied. This is likely slightly high for daily use by walkers and cyclists, but may be low for golf cart usage in shared path areas. Walking use is valued at \$20 per trip. This is close to the lower bound of the value of trips to the Virginia Creeper Trail, which provides a reasonable analog for the Coastal Trail (Bowker et al. 2007).

Applying these figures results in estimated non-market values within the study area of:

- \$2.24 million for beach users
- \$3.08 million per year for users of the Coastal Trail.

5.4 Fiscal Benefits

Fiscal impacts estimate the streams of revenue that flow directly to the City of Half Moon Bay, meaning that they appear as revenue items in the budget. The largest sources of general revenue for the city are the TOT, sales tax, and property tax. The Ritz-Carlton and golf course properties are substantial direct contributors to TOT and property tax receipts and a driver of sales tax receipts at the city and county levels.

5.4.1 Property Tax

Analysis of property tax revenue indicates that the hotel and golf courses are likely responsible for approximately 70 percent of annual property tax receipts for the city.

Table 5-4. Property Tax Revenue by Property and Year

Year	Old Course Property Tax (\$)	Ritz Hotel Property Tax (\$)	Ocean Course Property Tax (\$)	Total
2018–19	56,652	2,261,448	161,619	2,479,719
2019–20	60,415	2,415,390	173,084	2,648,888
2020–21	48,275	2,355,871	136,802	2,540,949
2021–22	35,037	2,312,656	134,467	2,482,160
Four-yr average	50,095	2,336,341	151,493	2,537,929

These figures do not include property taxes paid by the Ocean Colony residents, which derive part of their economic value from the presence and popularity of the golf courses, particularly the Old Course.

5.4.2 Business Improvement District

Analysis of revenue from the BID annual reports shows that in pre-COVID years the Ritz-Carlton Hotel accounted for approximately 37 percent of visitor room nights.¹⁴

Table 5-5. Business Improvement District Revenue (2018–2020)

Year	Ritz Carlton BID Payments (\$)	Total HMB BID Receipts (\$)	Ritz-Carlton as Proportion of HMB BID Receipts
2018	69,287	182,870	37.9%
2019	69,923	189,361	36.9%
2020	33,504	107,806	31.1%

Given the impact of the COVID-19 pandemic on tourism during 2020, it is assumed that average BID payments by the Ritz-Carlton are approximately \$70,000 per year.

5.4.3 Transient Occupancy Tax

The amount of TOT paid by the Ritz-Carlton is confidential. Some estimates can be drawn from the estimated revenue from room charges, although it is difficult to estimate the average prices paid per room night, due to the prevalence of group rates.

Using the estimated room revenue of \$33.3 million from Section 5.2.1, and the new higher TOT rate of 15 percent as of July 2022, estimated TOT receipts from the Ritz-Carlton would be approximately \$5.0 million per year. This represents approximately 57.1 percent of forecast TOT revenue of \$8.752 million for 2022–23. This value is likely a lower bound.

Golf course fees are paid to the City and represent a substantial additional revenue stream (Table 5-6).

Table 5-6. Golf Course Fees

Budget Year	Golf Fees (\$) per Fiscal Year, Actual
2017–18	440,459
2018–19	441,494
2019–20	328,864

¹⁴ Visit Half Moon Bay Coastside California, [Business Improvement District 2020 Annual Report](#), p 2; Visit Half Moon Bay Coastside California, [Business Improvement District 2019 Annual Report](#), p 2.

2020–21	546,415
Four-year average	439,308

5.4.4 Total Tax and Fee Revenue

The total estimated value of fees and taxes paid by the combined hotel and golf course properties is estimated to be in the order of \$8 million per year.

5.4.5 Economic Multiplier Effect

The 2019 BID Annual Report provides an estimate of the number of additional rooms booked, room revenue, and economic impact associated with the activities of Visit Half Moon Bay Coastside California.¹⁵ From these figures, it is possible to estimate a multiplier for the room revenues generated by the Ritz-Carlton. From that report, booked revenue was \$1,382,300, and the estimated economic impact was \$3,338,550. This suggests a multiplier of 2.42 for expenditures on accommodation. It is not possible to estimate the broader economic impact of expenditures from golf course fees from day visitors, although the multiplier is likely to be similar in magnitude.¹⁶

Using the room revenue figure of \$33.3 million, the estimated broader economic impact of this expenditure is \$80.6 million. Adding estimated event spending at the Ritz-Carlton, and golf course fees, the included expenditure estimate is \$52.3 million, with an estimated broader economic impact of \$126.6 million. This estimate is relatively limited in scope and excludes event expenditure associated with events held at the golf courses, purchases in the golf pro shop, and sundry items.

5.5 Impacts of Cliff Erosion

The estimates in this section are based on the assumption that it is possible to mitigate or adapt to cliff erosion through the realignment of the Coastal Trail and golf course parcels. It does not attempt to estimate the costs of realignment of the Ritz-Carlton Hotel structure, so the estimates included for building damage should not be interpreted as a full range of potential economic impacts.

5.5.1 Impact of Cliff Erosion on Parcel Values

For this analysis, it is assumed that the unit value of the parcels is distributed evenly. This may not accurately reflect the use of the parcels, for example, the tee box and greens have higher

¹⁵ Visit Half Moon Bay Coastside California, [Business Improvement District 2019 Annual Report](#), p 2.

¹⁶ It is not appropriate to apply the multiplier to the tax and fee income streams identified in this section.

importance than sections of rough. It is assumed that the course could be reconfigured to accommodate the lost area, which would thereby relocate the most valuable areas.

If 10 percent of a parcel is eroded, it is assumed that 10 percent of the assessed value is lost. With course reconfiguration, it may be possible to retain all of the existing value of the affected parcels, so the figures presented in this section should be considered upper-bound estimates of the potential economic damage.

Table 5-7 summarizes the estimated economic impact of erosion on the value of land parcels in the study area by time horizon. Note that for the Ritz-Carlton parcel, the area eroded is multiplied by the value of the land only, as erosion damage to the built structure is treated separately in the next section. Recall that the damage estimated in each time horizon is calculated as a proportion of the landward section of each parcel, and does not include any area seaward of the bluff. The City Beach parcel has been excluded from these calculations as there is no tax assessed value for the parcel, and more than 96% of this parcel is located seaward of the cliff.

Table 5-7. Estimated Economic Impact of Erosion

Year	Old Course (\$)	Ritz-Carlton Hotel (Land Value only) (\$)	Ocean Course Value Loss (\$)	Total Parcel Value Loss (\$)
2030	7,330	100,696	32,415	140,441
2040	8,669	120,346	33,428	162,443
2050	10,790	130,805	34,186	175,781
2060	12,709	140,755	34,735	188,199
2070	14,583	148,483	43,093	206,159
2080	16,909	211,415	73,700	302,024
2090	21,403	359,167	101,141	481,712
2100	24,742	391,290	128,195	544,226

5.5.2 Impact of Cliff Erosion on Hotel Structure

For the Ritz-Carlton Hotel, it is difficult to determine the extent to which erosion will impact the operations of the building, or the economic and fiscal value streams they generate. Based on the layout of the hotel, the majority of the lobby floor space in the west/east wing, which is the wing that will be affected by erosion in 2090–2100, is used for meeting rooms (Figure 5-1). The [Miramontes Room](#) is also used for smaller wedding receptions.

WEST / EAST WING

THE RITZ-CARLTON, HALF MOON BAY

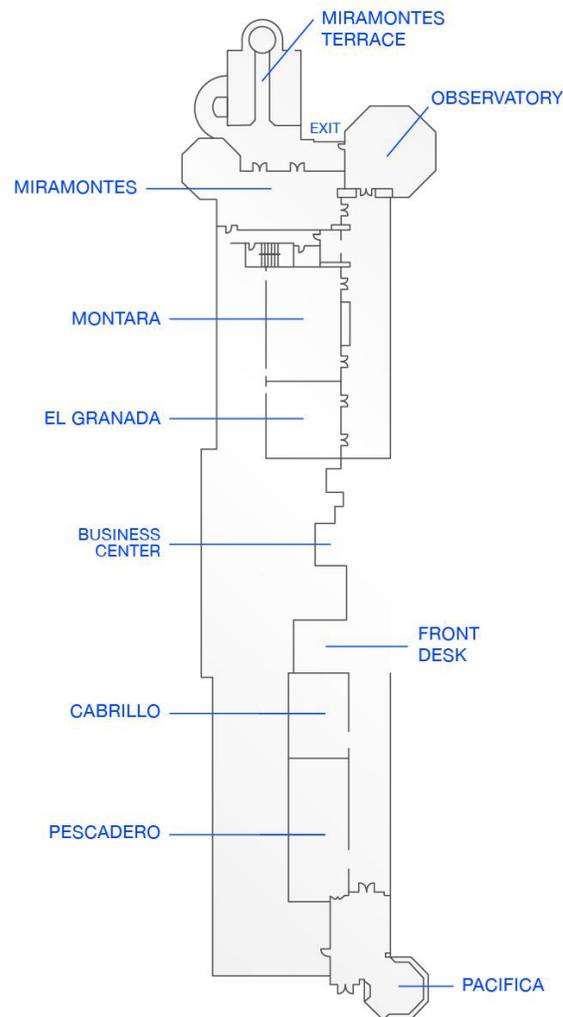


Figure 5-1. The layout of the Ritz-Carlton Hotel West / East Wing

Source: <https://www.ritzcarlton.com/en/hotels/california/half-moon-bay/meetings/meeting-room-details> ;
https://s7d2.scene7.com/is/content/ritzcarlton/HMB%20Lobby%20Level%20Floor%20Plan_v3-2pdf

For this assessment, the damage to hotel values is estimated as a proportion of the building footprint. Meeting and function rooms have a lower value per square foot than guest rooms, but are also responsible for the generation of substantial income for the property. There are also

guest rooms located in this wing, so it is assumed that the per-area value of the property is relatively consistent. Damage to the building itself is not projected to occur until 2090. Table 5-8 shows the estimated value of direct damage to the Ritz-Carlton hotel structure.

Table 5-8. Estimated Value of Potential Direct Damage to Ritz-Carlton Hotel

Year	Percentage of Building Footprint Directly Impacted	Estimated Value (\$)
2090	0.05%	69,284
2100	0.15%	213,236

The values in Table 5-8 should be considered the absolute lower bound of potential damage. It would not be prudent, or legal, to continue to use part of the hotel that was located at the edge of the blufftop.

Use of this wing of the hotel would likely need to be curtailed prior to 2090. The entire western portion of the west/east wing will likely need to be relocated at some point within the study period to avoid serious risk or actual physical impacts. For insurance and safety reasons, and to avoid damage to the public coastal amenities, it is also likely that structural modifications would be required earlier than the occurrence of direct impacts identified in this assessment. It is not possible to estimate the costs associated with this reconfiguration, but these costs would likely be in the tens of millions of dollars.

5.5.3 Impact of Cliff Erosion on Recreational Use

The Coastal Trail is used by golfers on the final holes of both golf courses, which are considered to be the showpiece holes of each course. Thus, there is an economic incentive to ensure that access is maintained and the analysis takes the assumption that the recreational values supported by the trail and beach access will be retained through the relocation of the combined Coastal Trail/cart path to a more landward location. This could include reconfiguration of the 1st and 18th holes of this course. Due to the extensive design and engineering work involved in the siting and construction of a relocated Coastal Trail, it is not possible to estimate the costs associated with this adaptation action without a specifically chosen alignment.

On the northern side of the hotel, on the 18th hole of the Old Course, there is a pinch point between the bluff and the hotel, specifically in the area of Miramontes Point where the Ocean Lawn and Miramontes Terrace extend shoreward from the hotel structure. At some point, path access from the northern side of the hotel property will be restricted on the seaward side, either due to safety considerations or because the trail is no longer present. Currently, this path is part of the Coastal Trail. This section of trail will likely need to be relocated to the landward side of

the hotel structure and parking garage, and rejoin a relocated section of trail on the southern side of the hotel.

No attempt has been made to estimate the costs of the relocated trail on the north side of the hotel, as this would likely be able to follow the existing roads from Ocean Colony (Fairway Drive, Ashdown Place, and Miramontes Point Road), rejoining the existing coastal trail access path on the southern side of the hotel.

5.5.4 Impact of Erosion on Trail Infrastructure

Having assumed that the trail can be reconfigured to preserve recreational use, the primary cost associated with erosion damage to the trail is the replacement of the trail sections affected by erosion in each time horizon. Due to safety requirements, the trail will likely need to be relocated before physical damage is experienced.

Table 5-9 shows the number of linear feet of trail affected by cliff erosion by time period. The cart path is approximately 10 ft wide, and it is assumed that the entire width would be replaced, even if only a smaller section is damaged. ProMatcher¹⁷ provides an estimate for concrete paths in California of \$8.29 per square foot. Given the site location, golf course operations and recreational use, and the need to remove the existing materials, a figure of \$15 per square foot is considered conservative.

Table 5-9. Length of Trail Affected by Cliff Erosion by Time Period and Estimated Cost

Year	Erosion Damage (linear feet)	Cumulative Damage (linear feet)	Estimated Cost of Replacement, Cumulative (\$)
2060	46.0	46.0	6,907
2070	68.2	114.3	17,144
2080	409.5	523.8	78,568
2090	615.7	1139.5	170,920
2100	304.5	1444.0	216,598
Grand Total	1444.0	1444.0	216,598

The relocation of the trail would also require the resumption of part of the golf course. It is assumed that this does not reduce the value of the remaining golf course parcel, so there is no

¹⁷ California Concrete Costs & Prices - ProMatcher Cost Report, accessed 19 July 2022.
<https://concrete.promatcher.com/cost/california.aspx>

economic loss. This section also does not include an estimate of the costs to relocate or replace the Manhattan Beach access stairs at Cañada Verde Creek.

6 ADAPTATION PLANNING

Adaptation planning occurs over multiple time scales and requires a comprehensive approach to implement. Adaptation can be implemented through projects, changes to policy, and in most cases, simply moving back away from the ocean. Various adaptation approaches include protecting, accommodating, and relocating; each with its own set of secondary consequences that need to be considered. From the City and public perspective, the Coastal Trail, beach access, and golf courses are of primary focus. The Ritz-Carlton Hotel, golf facilities, and tax revenues are of secondary focus and will need additional consultation between the City and private entities, including the golf courses and the hotel. This section describes some of the most common adaptation strategies considered for bluff-backed shorelines, summarizing the tradeoffs and identifying the most feasible (economic and regulatory) strategies through time to maintain the upland development, infrastructure and coastal resources.

Adaptation strategies fall into three main categories—protection approaches that attempt to stop erosion, accommodation approaches that allow for erosion and flooding while minimizing damages, and managed retreat or hazard avoidance, which would relocate golf or resort features and/or realign the Coastal Trail.

No one category or specific adaptation strategy is considered the “best” option forever. The effectiveness of different adaptation strategies varies across space and time, with different strategies able to accommodate various coastal hazards and elevations of sea level rise. Some adaptation measures may present secondary consequences, such as negative impacts on beaches, wetlands, habitats, and access which are protected by law for future generations under the California Coastal Act. The City’s Local Coastal Program implements the Coastal Act at the local level and grants the City much of the permitting authority to protect the coastal resources.

Over time, the City and private interests are likely to use several of the approaches discussed in this section as long-term hybrid strategies evolve based on observed environmental or economic changes. Changes, or “triggers,” such as cliff erosion within a certain distance of the Coastal Trail, tee boxes, greens, or the Ritz-Carlton Hotel should catalyze a change from one type of approach to another to maintain function, connectivity, and revenues. These triggers can be easily monitored to identify when it makes sense to shift from one adaptation approach to another.

One key trigger to monitor will be the distance from the Coastal Trail to the cliff edge. When the distance between the cliff edge and the Coastal Trail is near say 10 ft, then preparation for a realignment of the Coastal Trail, including discussions and planning with the golf course and the Ritz-Carlton Hotel should occur.

6.1 Protect

Protection strategies attempt to “hold the shoreline in place” by employing some sort of engineered structure or another measure to defend development or infrastructure in its current location without changes to the development itself. Protection strategies can be divided into “gray” and “green” defensive measures. A “gray,” or “hard,” approach is usually an engineered structure that can be positioned either alongshore (such as a seawall, revetment, or offshore breakwater) or cross-shore (such as a groin or harbor jetty). Green defensive strategies include beach nourishment or cobble berms that widen beaches or absorb wave energy to buffer storm erosion. Some protection structures are cross-shore structures intended to trap sand and widen the beach upcoast of the structure, starving downcoast beaches of sand and accelerating erosion.

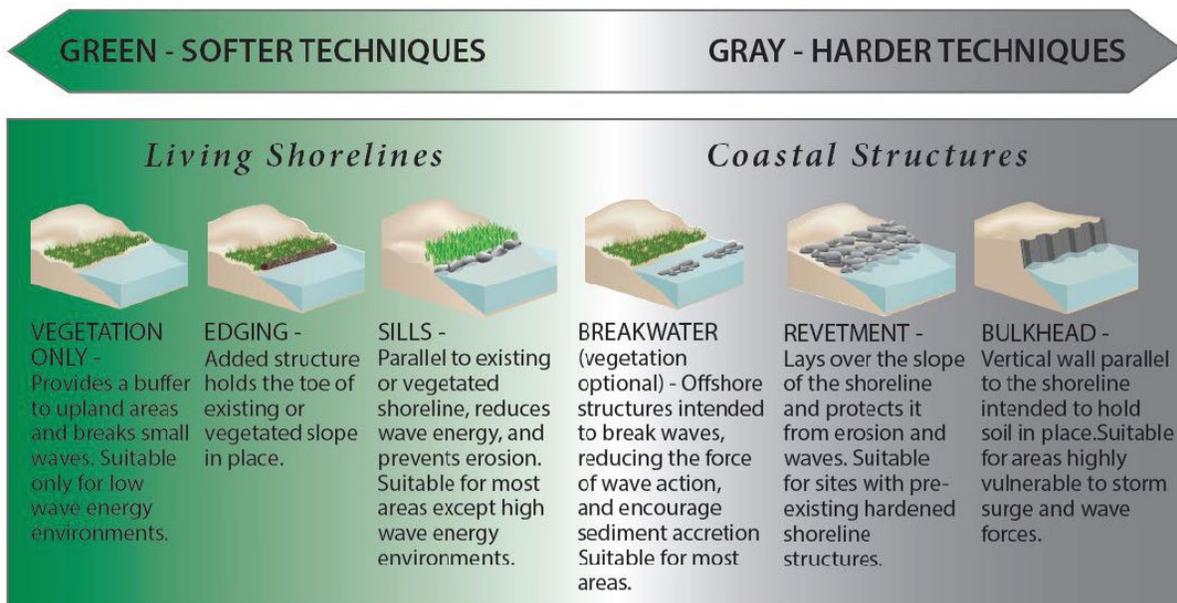


Figure 6-1. A range of green to gray adaptation strategies intended to mitigate erosion, flooding, or both
 Source: www.habitatblueprint.noaa.gov/living-shorelines.

Protection strategies usually attempt to stop erosion by holding the shoreline in place using revetments, seawalls, or soil nail walls. The presence of coastal armoring structures can have negative environmental and social consequences when a structural footprint buries beaches or impedes beach access and recreation. As sea levels rise, passive erosion or coastal squeeze occurs as this “holding the shoreline in place” strategy results in a slow drowning of beaches and nearshore habitats. These impacts raise serious concerns about consistency with the public access, habitat, and recreation preservation policies of the California Coastal Act.

Offshore breakwaters and artificial reefs are constructed to reduce erosion by reflecting, breaking, and dissipating wave energy before waves impact the shoreline. These are similar to some of the offshore rocks and rock reefs that currently exist offshore of the project site. The difference between these two types of structures is the elevation relative to the water level; breakwaters are visible through all tides and stop wave energy whereas artificial reefs tend to be submerged during most of the tidal cycle and cause waves to break offshore and dissipate the wave energy before it reaches shore. These types of structures are unlikely to be viable in the current regulatory environment given that the nearshore and offshore environment is part of the Monterey Bay National Marine Sanctuary.

Nature-based protection approaches attempt to decrease erosion using natural physical processes and native materials rather than trying to stop them. The types of projects that fall into this category include sand and cobble nourishment programs, where sand is added to the beach system, widening the beach and providing additional natural protection. In cliff-backed systems like this area, larger sediments such as cobbles could be placed at the toe of the cliffs to improve resistance to erosion. However, cobbles placed along the back of the narrow beaches in the study area are more likely to cause abrasion at the toe of the cliffs and accelerate erosion. Again, the Monterey Bay National Marine Sanctuary's current regulations forbid beach nourishment from occurring. In addition to regulatory concerns, both of these nourishment approaches to enhance natural beach protection in front of the study area would likely need to be done every few years at great cost.

Sand retention structures such as groins are oriented perpendicular to the coast in a cross-shore direction and are designed to trap and retain sediment to widen the beach and allow the beach to naturally reduce wave energy and reduce erosion. However, obstructing the naturally occurring transport of sediment along the shore can deplete downcoast beaches of their sediment supply and shift erosion to those areas. In some reaches of Sections 1, 2, and 6, offshore rocks currently serve as natural sediment retention; however, as erosion of the offshore rocks continues and sea levels rise, this area may reduce its retention capacity, narrowing the beach with erosion escalating in the future.

Previous gray protection strategies included revetments built by The Ritz-Carlton Hotel that were required to be removed by the CCC. Most of the protection options described above are unlikely to be approved by the CCC or the Monterey Bay National Marine Sanctuary in the future.

6.2 Accommodate

Accommodation strategies refer to the range of adaptation strategies that employ methods to modify existing development or infrastructure or place development in areas that decrease hazard risks and increase resiliency. Some of these strategies include policy approaches such as setbacks or project approaches such as elevating structures. The Ritz-Carlton Hotel opened in 2001 and incorporated development setbacks, but as erosion continues, the setback distance

narrows. The other accommodation strategy is to elevate structures using piles. This elevation approach also has been applied previously at the hotel with the remnant piles now eroded onto the bluff face illustrating that this is not a feasible long-term adaptation strategy (Figure 2-18).

6.3 Managed Retreat/Realignment/Relocation

Managed relocation and realignments are adaptation approaches that acknowledge natural cliff erosion hazards and avoid the projected long-term changes and future impacts by incrementally relocating, realigning, or removing at-risk infrastructure and development. Managed relocation is not done quickly; rather, it is a comprehensively planned approach, phased over time and implemented by the gradual realignment, relocation, and eventual removal of structures and infrastructure from risk-prone areas. Two important steps in implementing a policy approach to managed retreat include requiring real estate disclosures for coastal hazards and sea level rise during property transactions and indemnifying the City by limiting the liability over time for land-use decisions.

Over longer periods and higher sea levels, this “stepping back” strategy becomes the most cost-effective measure in comparison to adaptation approaches that require construction, maintenance, and potential removal of erosion control structures, and are also associated with lost revenues associated with secondary impacts to coastal resources such as the loss of beach recreation revenue. Taking a long-term view, all assets subject to erosion will be subject to some form of retreat in the future. The primary issue is whether it is a controlled process that is optimized to maximize public and private benefits in the interim or whether it is a rapid response to extreme weather events. This is particularly true for properties in this area exposed to cliff erosion hazards, as cliff collapses occur in an episodic and often unpredictable fashion.

The goal of managed relocation approaches is to preserve the public interest and access to the coast while providing an equitable solution for private property owners. When and where to move tends to be highly dependent on local economics and legal and property rights, and must balance public and private interests.

The realignment of the Coastal Trail will require early planning, as well as continuous engagement with the community and private sector to maintain beach access as well as coastal views. If planned in advance and identified in various planning documents such as the City’s Local Hazard Mitigation Plan (LHMP) as the long-term plan for the Coastal Trail, it is possible that the cost of realigning and reconstructing the Coastal Trail could be funded by public entities such as the California Coastal Conservancy (SCC).

The relocation of the golf courses and Ritz-Carlton Hotel will require reimagining and reconfiguring existing holes and structures; but because both properties have plenty of space, these should be possible without losing complete use of the facilities and properties. This would likely fall on the private property owners. Most resort facilities complete remodels on an

approximate 10-year cycle. This timing should be considered in the phasing of any relocation strategy.

6.4 Most Feasible Adaptation Approaches

The City’s primary adaptation goals are to:

- Minimize impacts on the public
- Maintain public access to the beach and along the Coastal Trail
- Minimize changes to the visual character of the site

Based on the team’s knowledge of the current regulatory environment, as well as the history of site development, Table 6-1 summarizes the feasibility of some of the most common adaptation strategies.

Table 6-1. Feasibility of Adaptation Solutions

Strategy	Feasibility	Rationale
Riprap Revetments	Unlikely	Previously removed
Seawalls	No	Regulatory constraints
Soil Nail Tie-back Walls	Unlikely	High cost and regulatory constraints
Artificial Reefs	No	High cost and regulatory constraints
Groins	No	High cost and regulatory constraints
Offshore Breakwaters	No	High cost and regulatory constraints
Sand Nourishment	Unlikely	Effectiveness and regulatory constraints
Cobble Berms	Perhaps	Effectiveness and high cost
Relocation of Vulnerable Section of the Hotel	Yes	Plenty of space
Realignment of Coastal Trail	Yes	Plenty of space
Realignment of Golf Course	Yes	Plenty of space

Ocean Colony Partners Future Golf Course Design Considerations

Ocean Colony Partners has investigated golf course design and reconfiguration changes that may become necessary in response to sea level rise and potential future bluff erosion (Ocean Colony Partners 2022). The potentially impacted areas primarily involve the Old Course 18th hole, and Ocean Course 16th, 17th, and 18th holes.

Old Course 18th hole

- 1) The green is large enough to be reduced on its seaward side by upwards of 25’ and the right greenside bunker eliminated;

- 2) The tees can easily be moved landward by up to 40' and the adjacent cart path relocated; and
- 3) Future fairway erosion at Hot Spot #1 would not significantly affect golf play off the tee, but Hot Spot #2 could, with substantial future erosion, require narrowing of the fairway or a redesign landward.

Ocean Course 16th and 18th holes

- 1) The green, tees and fairways could be redesigned and relocated (or the 18th hole shortened or the tee moved to the north of Canada Verde Creek) if necessary, but only minor coastal trail relocations would be possible in several areas (Hot Spots # 5-7; and Undercut #2 and 3) without significant impacts to the golf course.

Ocean Course 17th

- 2) Ocean Course's 17th hole presents the most difficulty at the green and some of the tee areas if there was future major bluff erosion in those areas. While some landward relocation is possible, any significant bluff erosion would likely require eliminating the hole and rebuilding another hole in an alternative location on the golf course. The existing coastal trail would also be threatened.

6.5 Adaptation Pathway

An adaptation pathway helps visualize some of the sequences of possible adaptation responses through time in a stepwise manner. Every alternative is designed to meet a certain performance level over a period of time, and once it reaches a tipping point where potential damages are no longer acceptable, a transition to another strategy is required. Each strategy requires lead times associated with the planning, outreach, permitting, design, and construction before it can be effective. Thus, before a tipping point of damages is realized, planners should identify possible triggers and anticipate the lead times necessary to implement a new strategy before potential damages occur. Due to the uncertainty over future physical conditions, natural variability, regulatory changes, and changing societal values, these pathways should remain flexible.

Through this adaptation pathway approach, the team identified several short-term (0–10 year) approaches to reduce erosion and buy some time; mid-term (10–30 year) planning such as redevelopment standards and improvements, realignment of pedestrian path, viewing platforms; and long-term (30+ year) relocation and realignment, particularly along the southwestern, ocean-facing wing of hotel and reconfiguration of the golf courses. Long-term adaptation approaches will require careful thought and planning to maximize effectiveness and minimize cost. This longer-term approach may also include envisioning alternative uses and locations in the adaptive reconfigurations of assets in vulnerable areas (Figure 6-2).

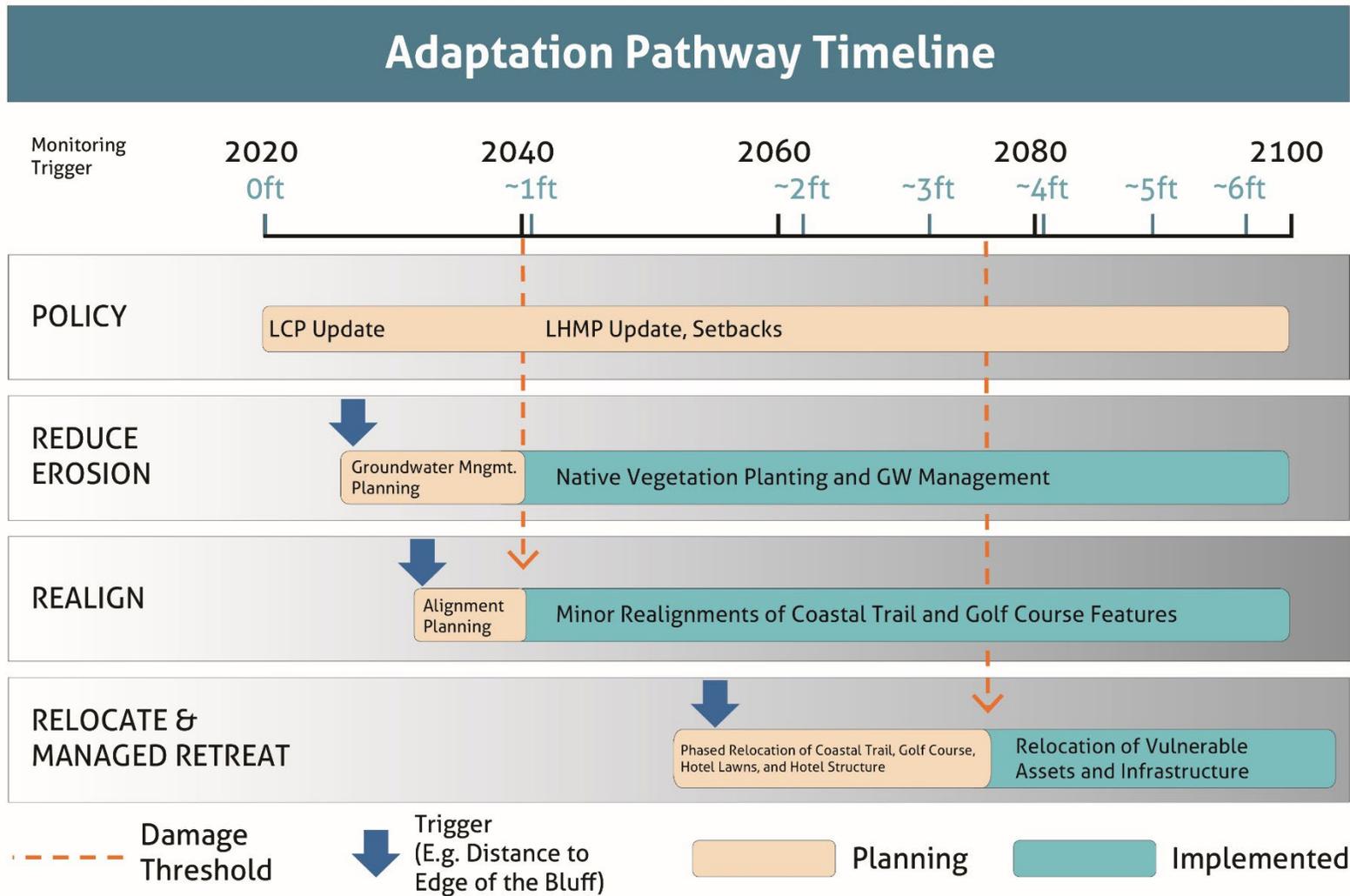


Figure 6-2. Potential adaptation pathway timeline.

Part of this adaptation pathway will require routine monitoring. It is suggested that a simple survey of the distance between the Coastal Trail and the bluff edge be completed at least once a year, and following major storm events. Another aspect of this monitoring would be site investigations of the sea caves that may pose a risk from below.

6.5.1 Short Term (0 to 10 years)

Over the short term, the priority should be reducing the factors that can accelerate erosion rates of the cliffs. As noted in Section 2.5, the high groundwater seepage can weaken the bedrock geology and increase pore pressure, which can result in accelerated erosion rates. This can be alleviated by carefully managing the groundwater and vegetation on site. Ocean Colony Partners have already reduced golf course irrigation scope, timing, and locations for a 40% reduction in irrigation water use between 2008 and 2022 (Ocean Colony Partners 2022). Some recommendations include continuing these efforts to minimize irrigation at the golf course, assess how the hotel can reduce landscape irrigation, and planting native vegetation along the bluffs, hotel landscaped areas, and golf course to the maximum extent feasible. Signage and fencing to reduce pedestrian-caused erosion and vegetation trampling near the bluff edge is also encouraged.

6.5.2 Medium Term (10 to 30 years)

Over the medium term out to about 2050, most of the erosion can be addressed through small to moderate realignment of the Coastal Trail and golf course features. This will be a crucial time to continue monitoring and begin planning for more major relocations and realignments.

6.5.3 Long Term (30 + years)

Long-term adaptation will require major realignment of the Coastal Trail, the coastal wing of the Ritz-Carlton Hotel, and the lawns and patios around the hotel. Priorities should be stated in updated planning documents such as the Local Coastal Program about the preferred location and alignment of the Coastal Trail considering setback distances and alignment on the ocean side of the resort if desired and feasible.

The golf courses will require some redesign and reconfiguration to move both the Old Course's 18th hole tee boxes and greens and Ocean Course's 17th hole further inland, while maintaining public access and safety along the Coastal Trail. This may require additional fencing for pedestrian safety.

7 KEY FINDINGS AND RECOMMENDATIONS

- The City should engage with the Ritz-Carlton Hotel and Half Moon Bay Golf Links to annually monitor the distance between the Coastal Trail and the bluff edge as well as the condition of the sea caves.
- The City should identify triggers and further refine the City's vision for the Coastal Trail.

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Appendix A.

Modern Timeline of Coastal Development and Major Erosion Events

Year

1971	Development of the Ocean Colony Neighborhood and Golf Course, known as the Half Moon Bay Country Club at the time, begins.
1972	A drilled pier-and-grade-beam foundation structure is constructed in anticipation of future hotel development at Miramontes Point.
1972–73	A major El Niño winter causes significant erosion, with evidence of bluff loss around Miramontes Point and Manhattan Beach.
1973	The Half Moon Bay Golf Links (formerly known as the Half Moon Bay Country Club / Ocean Colony Golf Course), opens the Old Course (formerly known as the Links Course).
1973	A retaining wall and 12 by a 24 ft slab of concrete are constructed to support the inland edge of the 18 th green at the Old Course.
Late 1970s	The original developer abandons hotel construction plans at Miramontes Point.
1982–83	A major El Niño winter causes significant erosion around Miramontes Point.
1991	Half Moon Bay City Council and the California Coastal Commission (CCC) approve the development of a new hotel.
1995–96	The retaining wall and concrete slab at the 18 th green of the Old Course is undermined by erosion and breaks apart.
1996	A CDP (08-96) is issued for repairs along the 18 th green of the Old Course. Authorizing repair of the concrete slab as originally constructed.
1997–98	A major El Niño winter causes significant erosion around Miramontes Point.
1997	Half Moon Bay Golf Links' Ocean Course opens.
1998	CDP granted and construction of the Ritz-Carlton Hotel begins.
1998	Riprap is added to the 18 th green of the Old Course without a permit.
2000	Half Moon Bay Golf Links is redesigned with some changes to the layout of the 18 th green including the removal of a sand trap.
2001	Ritz-Carlton Hotel opens.
2002	CCC issues cease and desist order for the riprap revetment at the 18 th green.

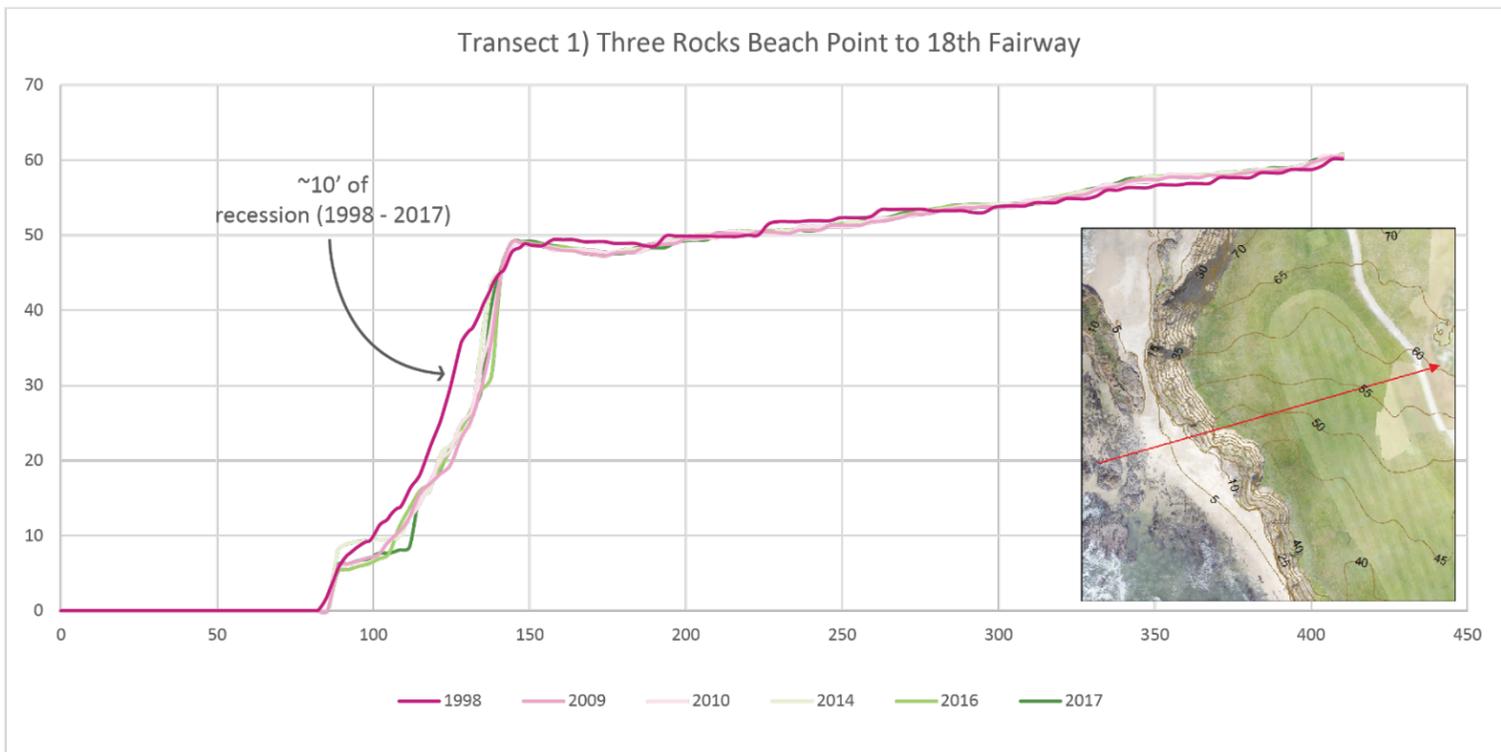
- 2006** Riprap revetment is removed.
- 2016–17** An historically wet winter causes erosion that severely undermines the pier-and-grade-beam foundation structure at Miramontes Point and leads to partial collapse.
- 2018** Partially collapsed foundation piers are removed from Miramontes Point.

Note: Bluff-top or cliff-toe recession is not an inevitable consequence of every El Niño year or high precipitation anomaly winter. Cliff failure dynamics are far more complex and a section of cliff needs to be in a state where it is susceptible to erosion.

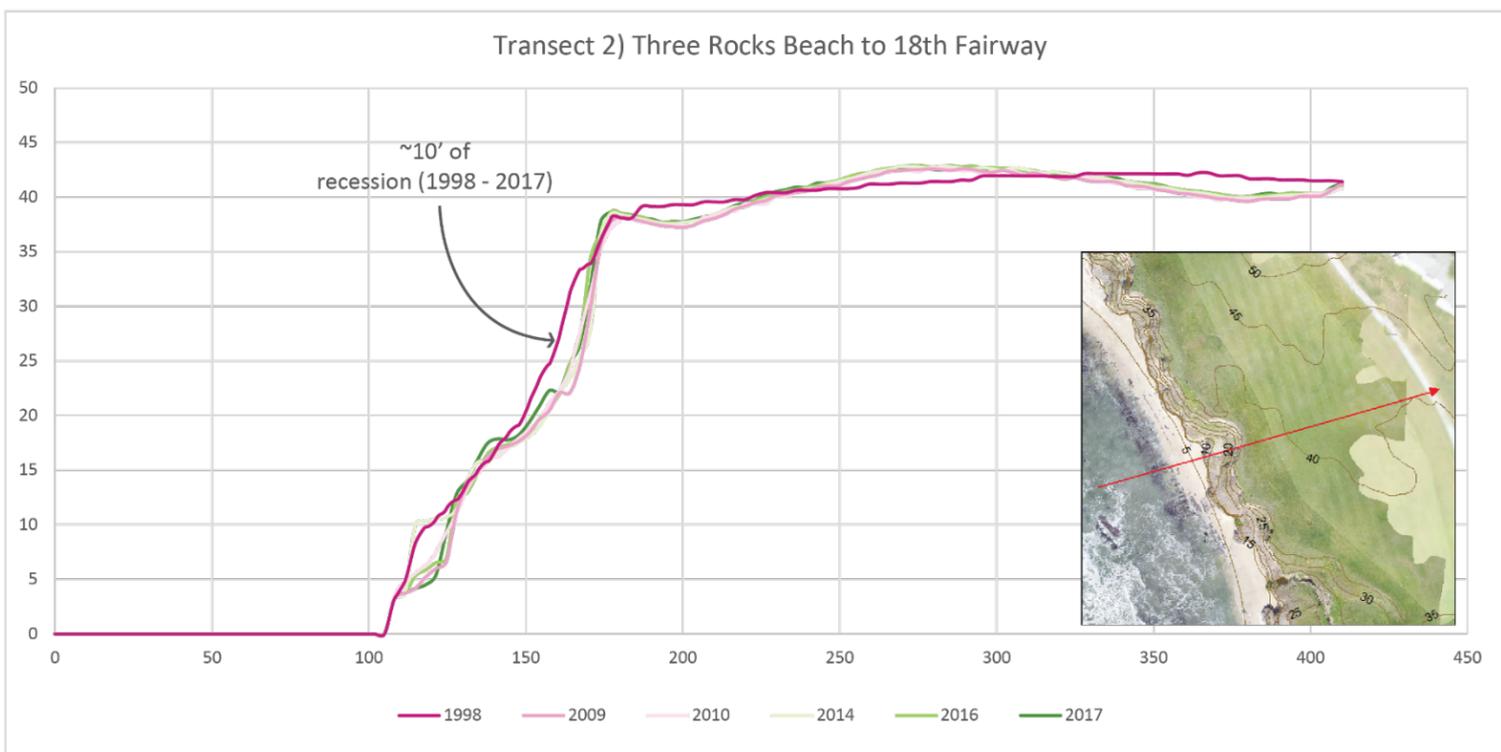
Appendix B.

Digital Elevation Transect Model Comparison

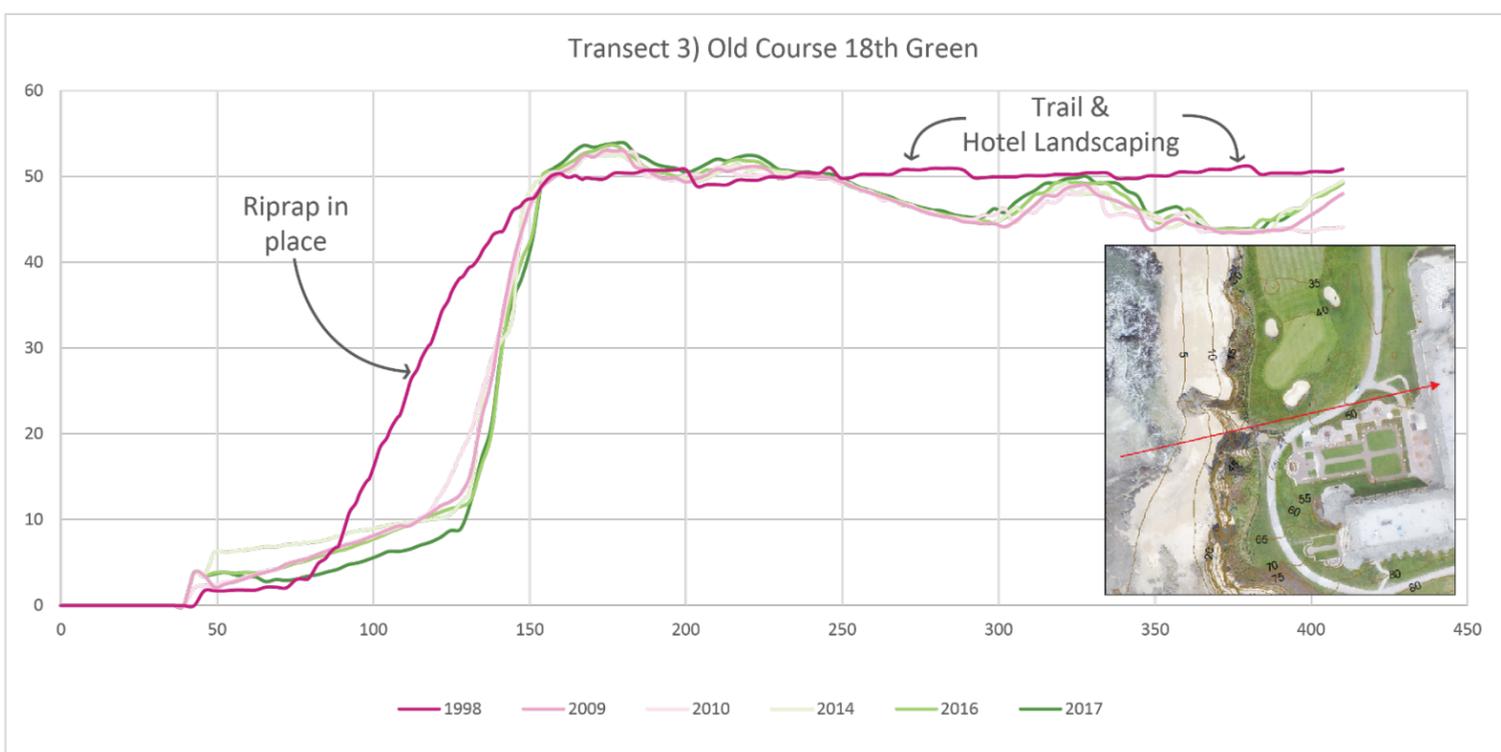


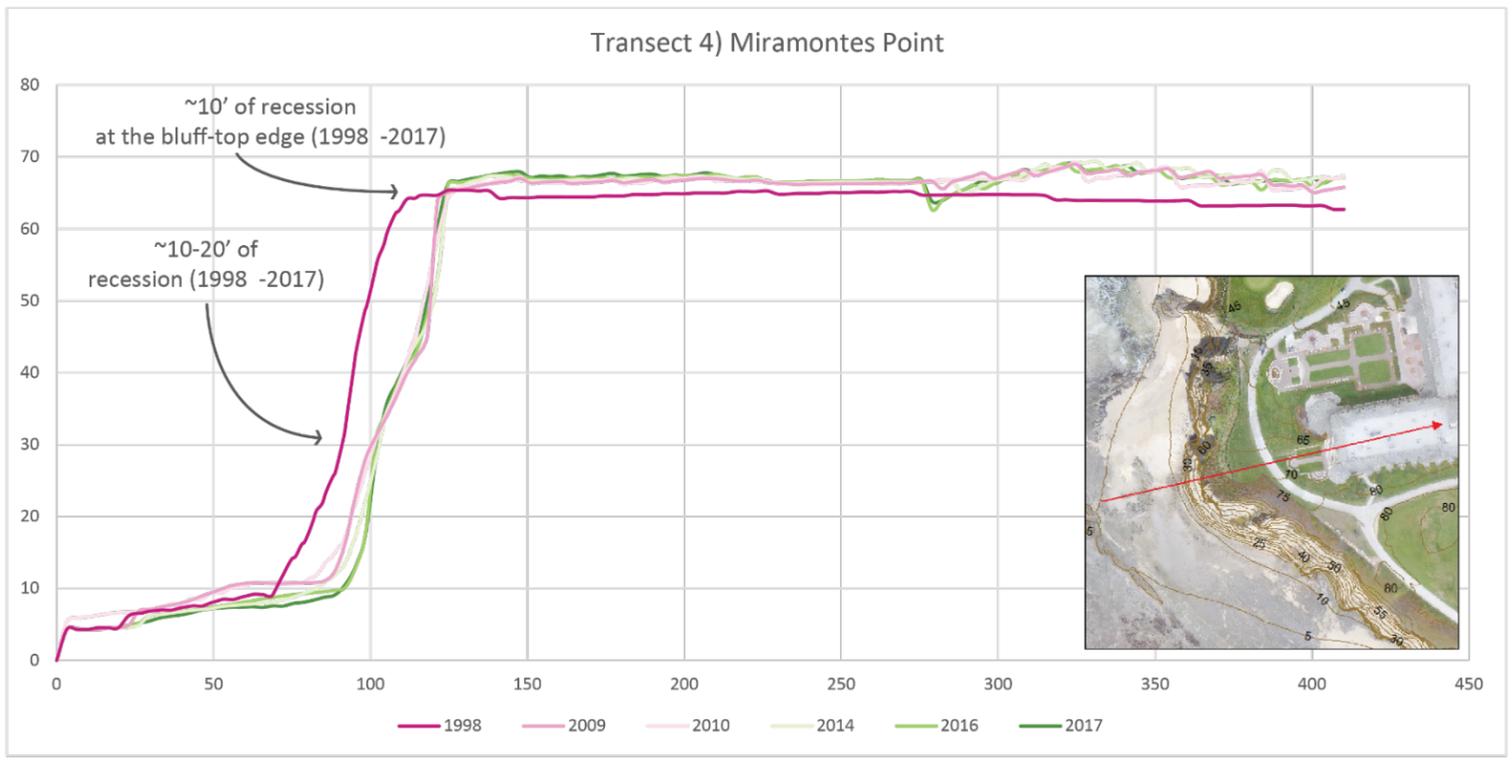


Units in ft (NAVD 88). Horizontal and vertical distances vary.

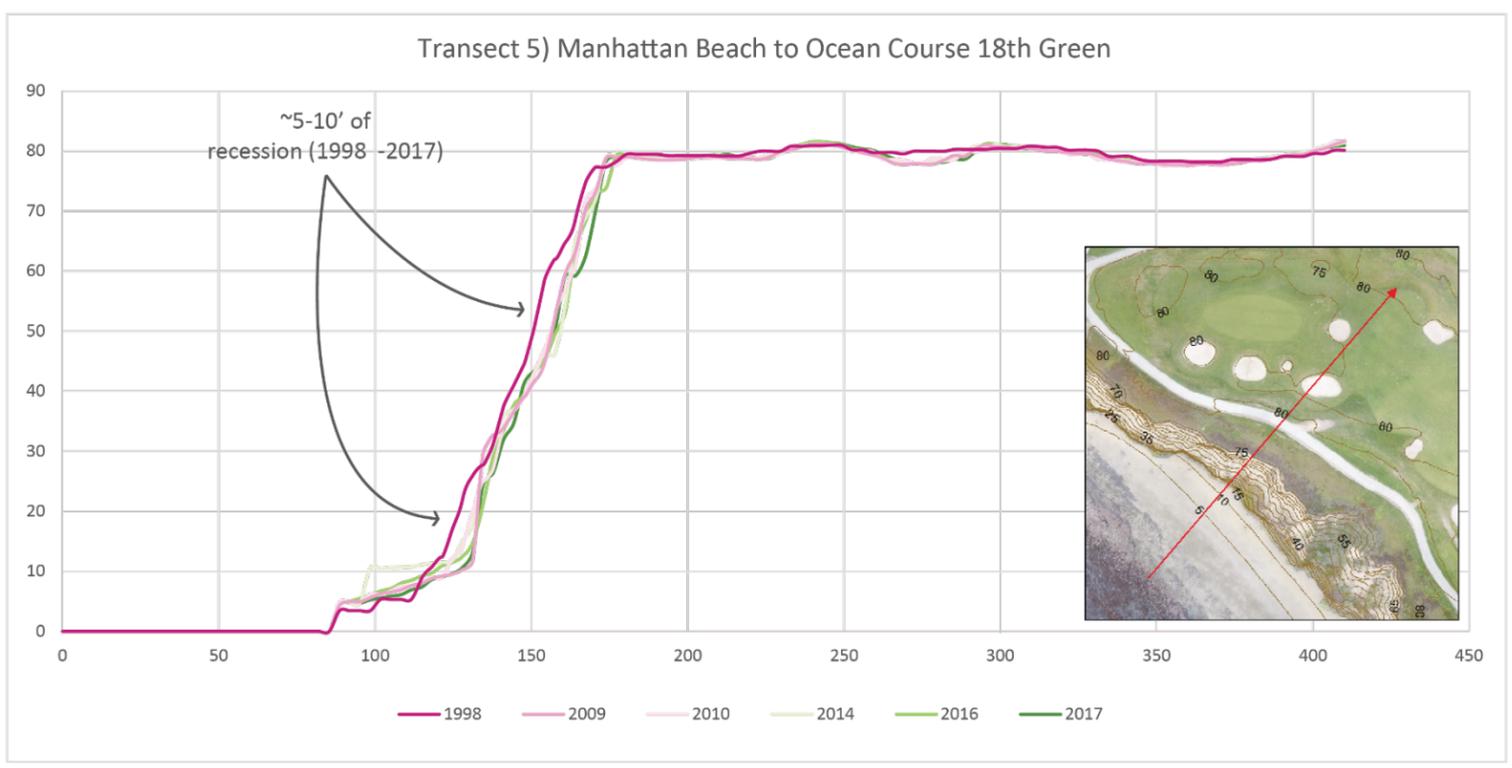


1998 dataset predates construction of the Ritz-Carlton Hotel and a redesign of portions of the HMB Golf Links

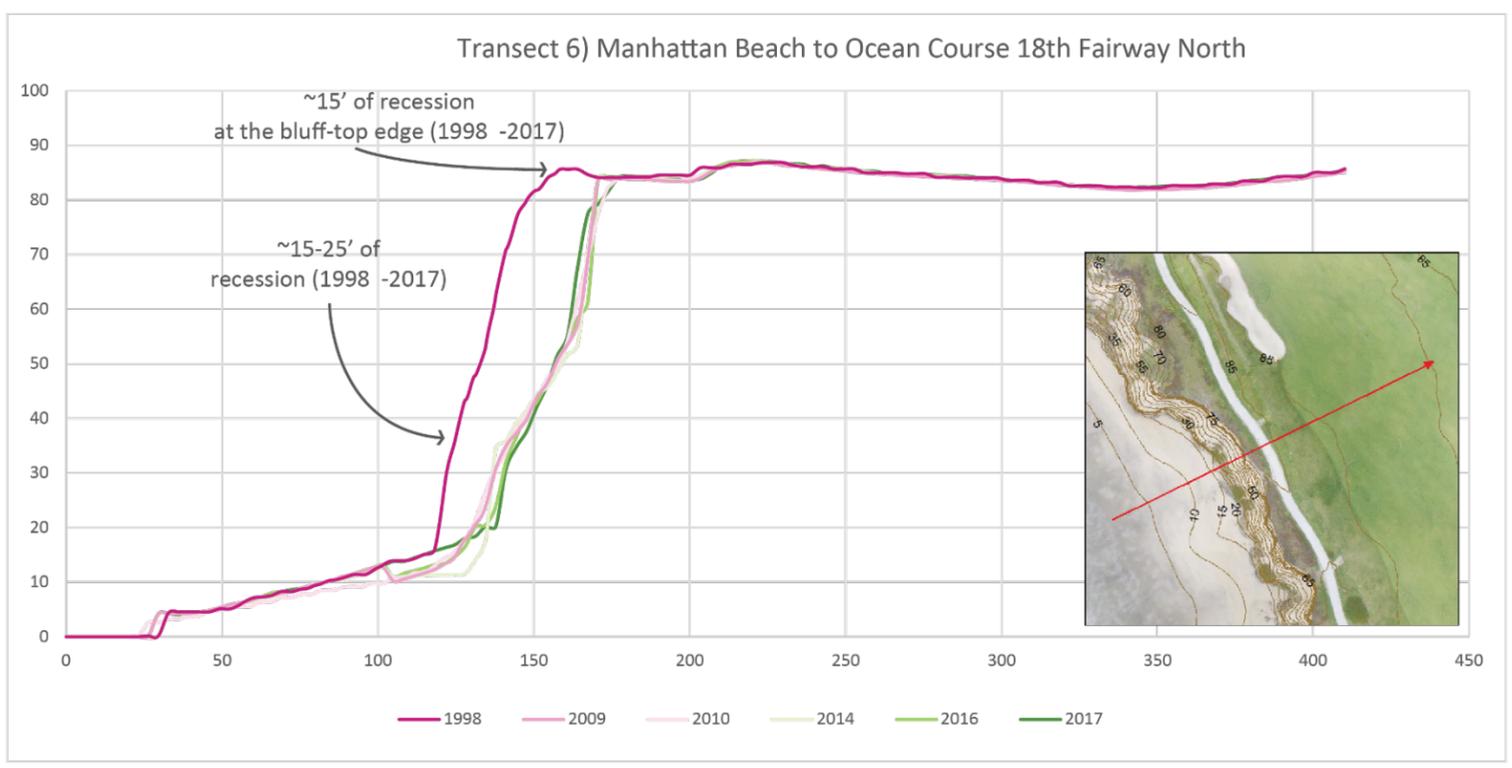


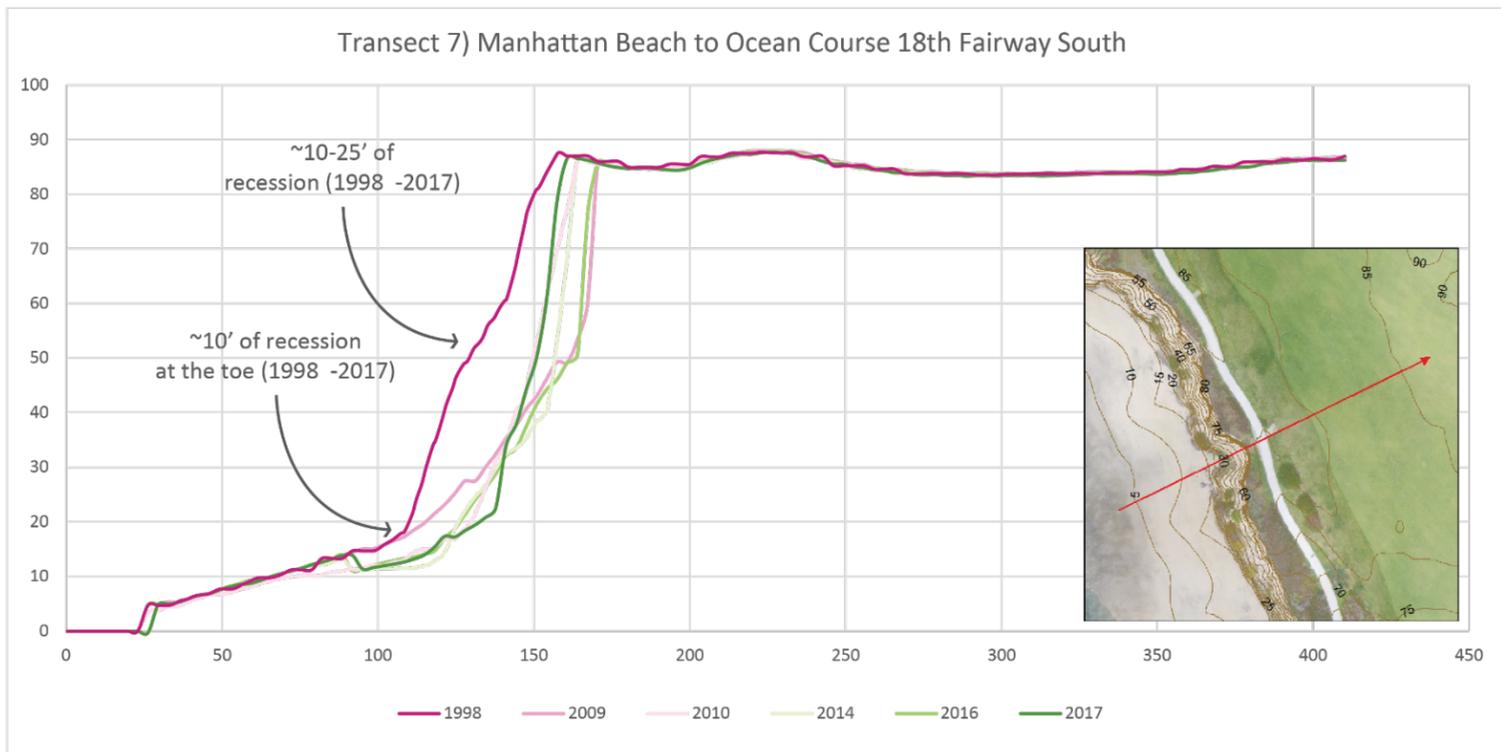


Units in ft (NAVD 88). Horizontal and vertical distances vary.

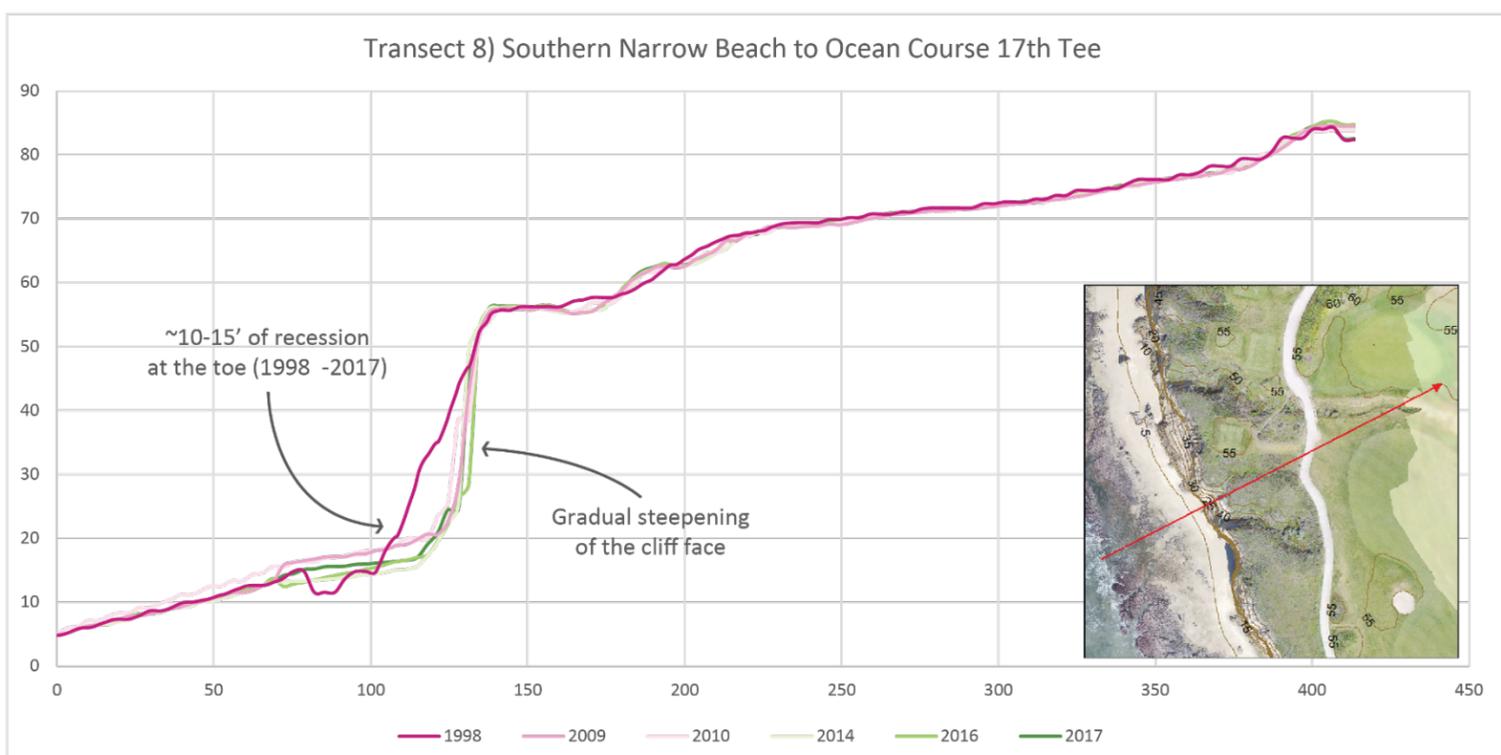


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