RINCON ISLAND PHASE 2 DECOMMISSIONING PROJECT

ASSESSMENT OF POTENTIAL PROJECT IMPACTS ON THE SURFBREAK

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Executive Summary

Objective

Phase 2 of the Rincon Island Decommissioning Project includes development of a Feasibility Study and Decommissioning Plan Options comprising planning, public outreach, and development of California Environmental Quality Act (CEQA) documentation. As part of the Rincon Phase 2 Feasibility Study (CSLC 2022), a coastal engineering study assessed the potential offshore impacts resulting from removal of Rincon Island and the causeway connecting Rincon Island to shore. Many comments were received during the subsequent public comment period regarding potential impacts associated with removal of the causeway, specifically related to impacts to the existing surfbreak.

Based on input received from the public and results of the Feasibility Study, the proposed Project includes retention of Rincon Island and the causeway. However, several Project Alternatives are also being considered within the CEQA analysis, including:

- Removal of the causeway including abutment removal and replacement of the revetment;
- Removal of the causeway without abutment / revetment modification; and
- Partial removal of the causeway without abutment / revetment modification.

The objective of this study was to conduct a focused assessment of the potential impacts of the Project Alternatives on the surfbreak.

Methods

By definition, a causeway generally refers to a structure supported mostly by earth or stone, which is not representative of the Rincon Island access structure. The access structure between the shoreline and Rincon Island is better described as a bridge or pier, which are structures supported by pilings. Because a key focus of this investigation relates to the impact of the access structure on waves and sediment movement, which is directly affected by the “hydraulic transparency” or “permeability” of the structure, this report refers to the access structure as the “causeway access pier.”

For clarity, the impacts of removing the abutment (where the causeway access pier connects to the shoreline), completely removing the causeway access pier, and partially removing the causeway access pier are evaluated separately. Assessment methods included the following:

- Potential impacts of abutment removal were evaluated by investigating available literature and historic aerial photography to determine key characteristics of wave breaking and sedimentation patterns before and after construction of Rincon Island and the causeway access pier.
- Impacts of complete or partial causeway access pier removal were assessed by:
    - Detailed analysis of historic aerial photographs supported by site observations and aerial drone photography taken during high quality surfbreak conditions to assess any potential beneficial effect the pier has on surfbreak quality;
    - Analysis of high-definition bathymetric measurements to identify potential signs of structure impact on sediment movement, such as “scour canyons” adjacent to the pier piles; and
    - Review of available technical literature on the impact of pier structures on shorelines.

Conclusions

No Impact from Abutment Removal

Analysis of multiple historic aerial photographs from 1927-1945 clearly show the rock outcrop at Punta Gorda pre-dates the Rincon Island construction in 1959, and this natural rock feature, without the added concrete abutment and riprap constructed as part of the pier structure, is the cause of the wide updrift sand beach. This same natural feature that retains the updrift sand beach also creates the Little Rincon point break. The man-made “abutment” at the landside terminus of the pier is well above an elevation on the headland profile that would have any significant impact on waves and sediment movement, and hence on the surfbreak. Given the fact that the primary “structure” that creates the point break is the natural rocky headland, removal of the abutment and resulting changes to the existing riprap revetment would not be expected to have any significant impact on the surfbreak.

No Impact from Full or Partial Causeway Access Pier Removal

The Little Rincon surfbreak was observed during large west swell conditions on January 6, 2023, and chronicled via aerial drone and ground photos. Three Google Earth® photographs were also identified which captured the surfbreak under other high quality surfing conditions. In all cases, there is no indication of any impacts of the pier pilings on the waves, either in height or direction, nor scattering due to reflection. Furthermore, review of detailed site bathymetric data shows no evidence of a “scour canyon” underneath the pier.

Review of available technical literature on the impact of pier structures on shorelines included a study of 20 piers within the Southern California Bight including the Rincon Island causeway access pier. The study concluded that the Rincon Island causeway access pier had no effect on shoreline processes, citing the relatively slender piles and large spacing.

Based on the analyses described in this study, the Rincon Island causeway access pier has no discernible effect on the Little Rincon surfbreak. Hence, there was no need for further investigation to reduce the pier’s impacts by evaluating partial pier removal.

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1 Introduction

1.1 Study Purpose

Rincon Island is located approximately 3,000 feet to the south-southwest of Punta Gorda in Ventura County, as shown in Figure 1-1. It lies directly offshore of the Mussel Shoals community, in a water depth of approximately 55 feet. A causeway access pier connects the island to the shoreline. A State Coastal Conservancy (SCC) Parcel, managed by the California State Lands Commission (CSLC), is located just east of the abutment at the base of the causeway.

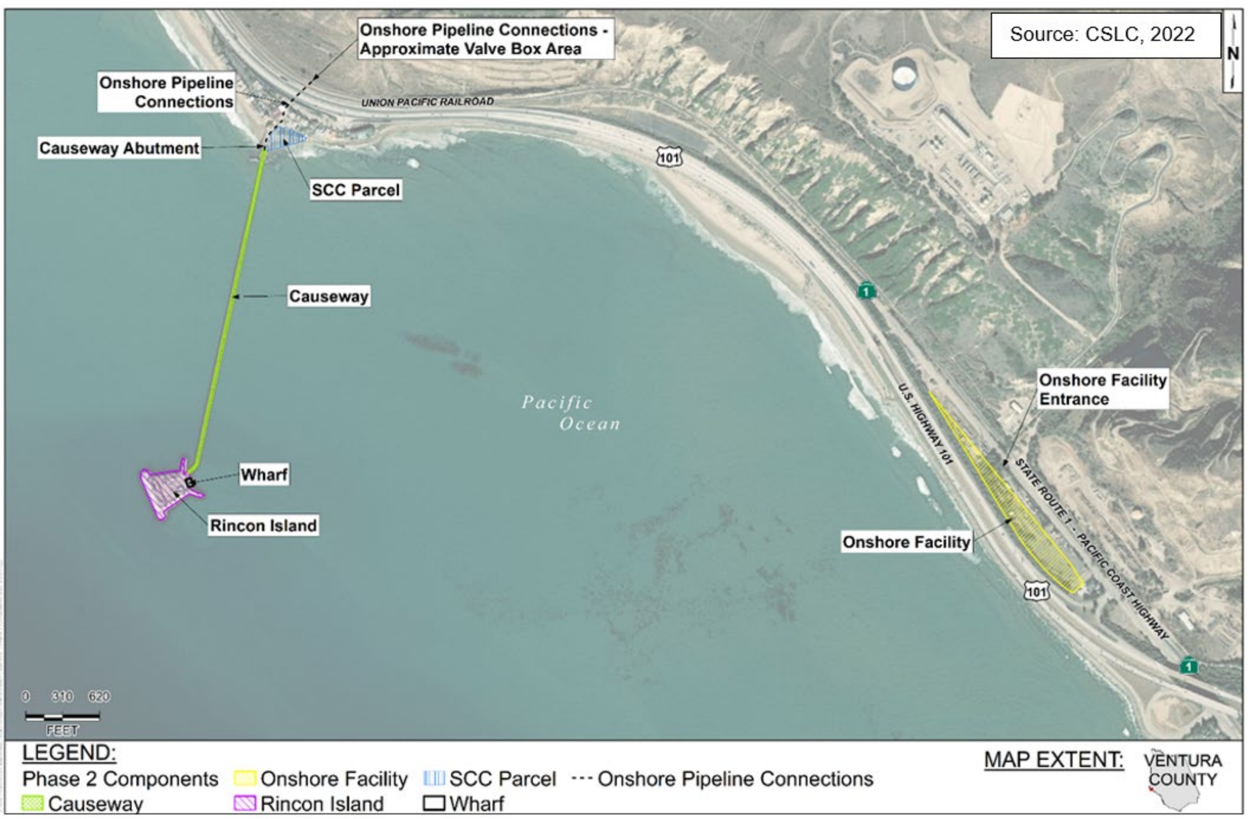

Figure 1-1. Rincon Island – Phase 2 Area and Facilities

Phase 2 of the Rincon Island Decommissioning Project includes the preparation of a Feasibility Study and Decommissioning Plan comprising planning, public outreach, and development of California Environmental Quality Act (CEQA) documentation. The

Feasibility Study (California State Lands Commission, 2022) was completed in July 2022 and preparation of the Draft Environmental Impact Report (EIR) is underway.

A coastal engineering study (NV5, 2021) conducted as part of the Feasibility Study focused primarily on the potential offshore impacts resulting from an Option considering removal of the island and causeway. However, numerous comments regarding the potential impacts of removal on the existing surfbreak, known as "Little Rincon," were received during the public comment period.

The specific objectives of this study are to evaluate whether construction of the causeway access pier and causeway abutment enhanced the surfbreak, and whether modification of these elements in consideration of the Phase 2 Decommissioning Alternatives might alter the quality of the surfbreak that currently exists. In the interest of clarity, the potential impacts associated with removal of the abutment, total removal of the causeway, and partial removal of the causeway are evaluated separately.

1.2 Project Description

Other than the proposed Project, the Rincon Island Phase 2 Decommissioning Project Alternatives that will be carried forward into the Environmental Impact Report (EIR) analysis consist of:

- Removing the causeway and abutment, and replacing the revetment that protected the abutment ("revetment");
- Removing the causeway without modifying the abutment or revetment; and
- Partially removing the causeway without modifying the abutment or revetment.

Figure 1-2 provides a detailed view of the relevant landside features including the abutment and revetment. Figure 1-3 shows a profile view of the causeway. The term "causeway" typically refers to a structure supported mostly by earth or stone, which is not the case with the Rincon Island access structure. The access structure is better described as a "bridge" or "pier," which are structures supported by pilings. Because a key focus of this investigation is the impact of this structure on waves and sediment movement, which are directly affected by the "hydraulic transparency" or "permeability" of the structure, this report will refer to the structure as the "causeway access pier."

1.3 Impact Assessment Methodology

The surfbreak impact assessment consists of three components: (1) describing the general site conditions at the surfbreak; (2) describing the technical aspects of the existing surfbreak; and (3) assessing the potential impact of the project alternatives on surfbreak quality. Key steps in each component are summarized below. A discussion of each component is provided in the subsections that follow.

Figure 1-2. Causeway Access Pier Abutment and Revetment

Figure 1-3. Profile View of Causeway Access Pier

1.3.1 Describe Surfbreak Site Conditions (Section 2)

- *Nearshore Wave Conditions* – Evaluated nearshore wave conditions based on existing studies, including the coastal engineering study prepared as part of the Feasibility Study (CSLC, 2022).
- *Littoral Processes* – Summarized regional shoreline processes based on existing studies and literature.
- *Shoreline History* – Assessed the potential influence of the causeway access pier (including the abutment and revetment) on waves and littoral processes based on available studies and historic aerial photos.

1.3.2 Technical Aspects of the Existing Surfbreak (Section 3)

- *Description of Surf Site Parameters* – Described and illustrated the physical parameters of the surf site, such that potential impacts can be more clearly described and quantified.
- *Surf Site* – Characterization of the existing surfbreak based on a review of existing literature, an analysis of available aerial photos, and detailed observations and aerial video from an unmanned aerial vehicle (UAV), or drone, captured during a fall/winter west/northwest swell event.

1.3.3 Surfbreak Impact Analysis (Section 4)

- *Evaluation of Potential Effects of Abutment Removal on Surfbreak* – Assessed the impact of removal of the abutment at the landside terminus of the causeway.
- *Evaluation of Potential Impacts of Causeway Removal on Surfbreak* – Coastal structures such as pile-supported piers can have impacts on waves and sedimentation processes. Key parameters related to potential impacts include pier orientation relative to predominant wave approach directions, number, size, and density of piles, etc. This evaluation considers the proposed Project Alternatives in relation to the existing causeway access pier structure.

2 Surfbreak Site Conditions

2.1 Water Levels and Wave Climate

2.1.1 Water Levels

Astronomical tides in Southern California are of the mixed, semi-diurnal type, with two highs and two lows of unequal magnitude occurring each lunar day (approximately 24.4 hour [hr]). The nearest tide station is National Oceanic and Atmospheric Administration (NOAA) Station 9411340 in Santa Barbara, CA. Table 2-1 summarizes the key tide levels and water level datums for this site, based on the 1983-2001 National Tidal Datum Epoch. The range between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW) is 5.39 ft. The highest recorded water level at the station is 7.65 ft above MLLW and the lowest is 2.87 ft below MLLW.

Table 2-1. Tidal Levels and Datums for NOAA Station 9411340 Santa Barbara, CA

Description	Water Level (ft, MLLW)
Highest Observed Water Level (12/13/2012)	7.65
Mean Higher High Water (MHHW)	5.39
Mean High Water (MHW)	4.64
Mean Sea Level (MSL)	2.78
Mean Low Water (MLW)	0.97
North American Vertical Datum of 1988 (NAVD88)	0.13
Mean Lower Low Water (MLLW)	0.00
Lowest Observed Water Level (12/17/1933)	-2.87

Notes: 1. Values for the 1983-2001 Tidal Datum Epoch.
2. Source: National Ocean Service (2022)

Planning decisions related to any permanent structure within the coastal zone must consider the potential impacts of future sea level rise (SLR) caused by climate change. In California, the currently accepted planning guidance for SLR is provided in the Ocean Protection Council's (OPC) *State of California Sea-Level Rise Guidance, 2018 Update* (OPC, 2018). The probabilistic projections for SLR over different time frames and high greenhouse emissions scenarios for the Santa Barbara tide station are summarized in Table 2-2.

Table 2-2. Projected Sea Level Rise at Santa Barbara, CA

Year	Probabilistic Projections in feet		
	Likely Range *(66% Probability)*	**1 in 20 Chance** *(5% Probability)*	**1 in 200 Chance** *(0.5% Probability) Medium-High Risk Aversion*
2050	0.4 – 1.0	1.2	1.8
2070	0.7 – 1.7	2.1	3.3
2100	1.2 – 3.1	4.1	6.6

Notes: 1. Values for High Emissions Scenario.
2. Source: OPC, 2018.

2.1.2 Regional Wave Climate and its Relation to Surfbreak Quality

The National Data Buoy Center (NDBC; which is part of the NOAA's National Weather Service) provides the best source of long-term wave measurements in the project area. The most representative buoy for the project site is NDBC Buoy #46053, which is located 24 miles west-southwest of Rincon Island (Figure 2-1). As shown in the figure, the Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa) shelter the site from waves from the south, whereas Point Conception shelters the site from the north. Hence, the only "window" through which large, long-period waves, or swell, can reach the site lies to the west. Although a wave buoy was first deployed at the NDBC site in 1994, a *directional* wave buoy was not deployed until 2007 (directional wave data provide information on the direction of wave approach). High quality data are available for the entire 15-year period from 2007 to 2022, and include over 75,000 measurements of wave height, period and direction.

Analysis of the NDBC Buoy #46053 data provides valuable insight into the frequency of high-quality surf conditions at Little Rincon. Figure 2-2 presents both a three-dimensional and contour "heat map" plot of the probability of occurrence for the various combinations of wave height and direction. The plots show spectral significant wave height versus mean wave direction (in degrees as measured clockwise from true north). Both plots confirm that most waves that reach the buoy arrive through the window bound by 230° and 280° (*i.e.*, the "window" of wave approach between Point Conception and the Channel Islands as shown in Figure 2-1). A very minor portion approach from 85° to 120°, indicating that these waves were generated locally by offshore winds. Under such conditions, one would expect "flat" surf at Little Rincon, because the winds that likely generated these waves would be blowing from the land.

As the best surfing at the Project site is likely to result from large, long-period swell approaching from the west-southwest, Figure 2-3 presents two plots of the physical parameters that generally represent the quality of a surfing wave. These are wave height and wave steepness, where wave steepness is defined as H_{mo}/L_o[1]. Assuming that "good" surfing conditions can occur when the significant wave height is greater than or equal to 5 ft, and the wave steepness is less than or equal to 0.015, it was found that approximately 16% of the over 75,000 wave data measurements have the potential to produce "good" surfing conditions at Little Rincon (not accounting for local water level and wind conditions that can influence surf quality). "Epic" wave conditions were assumed to occur when the significant wave height was 12 ft or greater and the wave steepness was less than or equal to 0.015. Such "epic" events occurred only about 0.15% of the time (again, not accounting for local water level and wind conditions).

[1] Where H_{mo} is the spectral significant wave height, L_o is the deepwater wavelength ($L_o = g\,T_p^{\,2}/2\pi$), *g* is gravity acceleration, and T_p is the peak energy wave period.

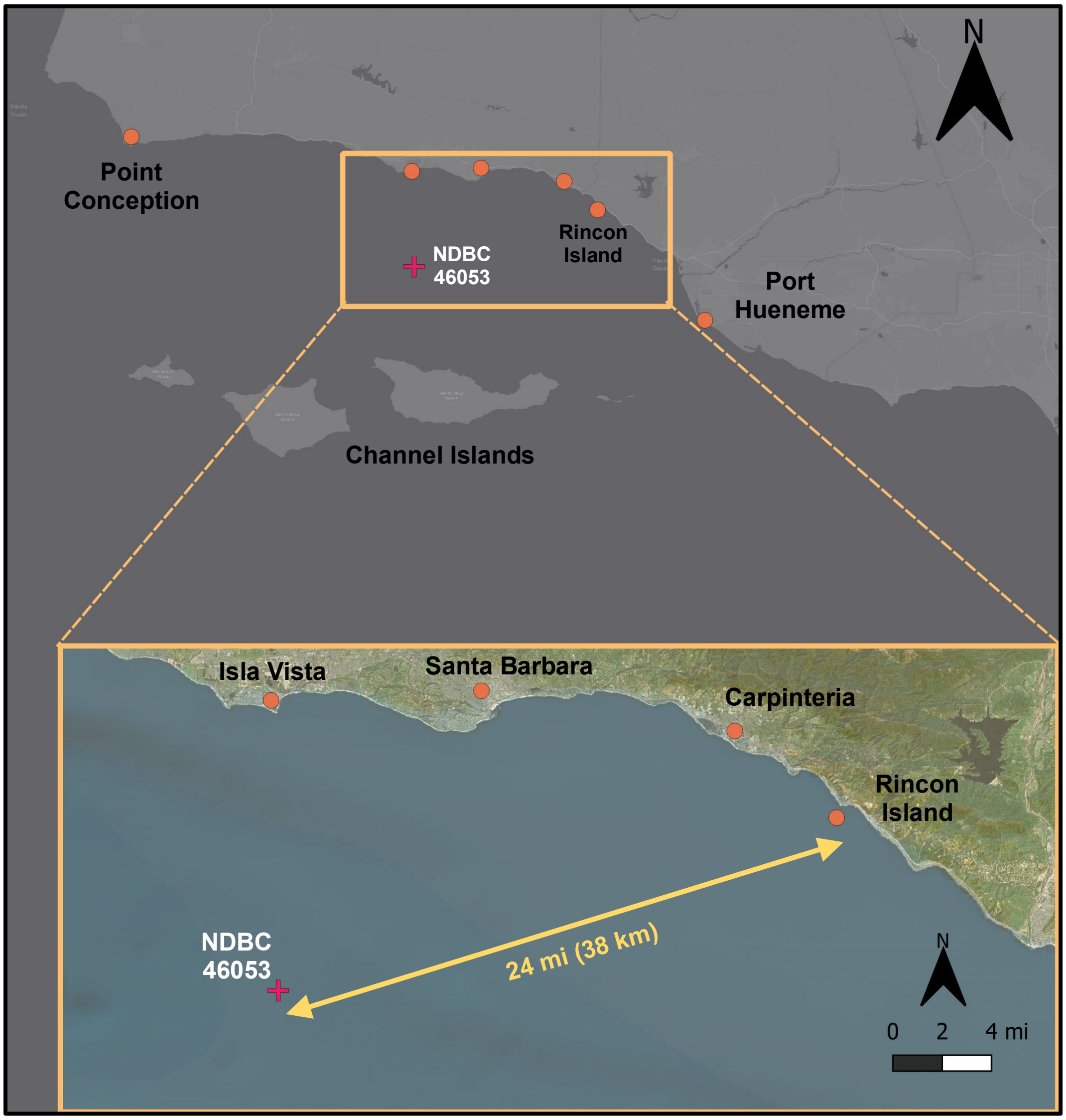

Figure 2-1. Location of NDBC Wave & Weather Buoy #46053

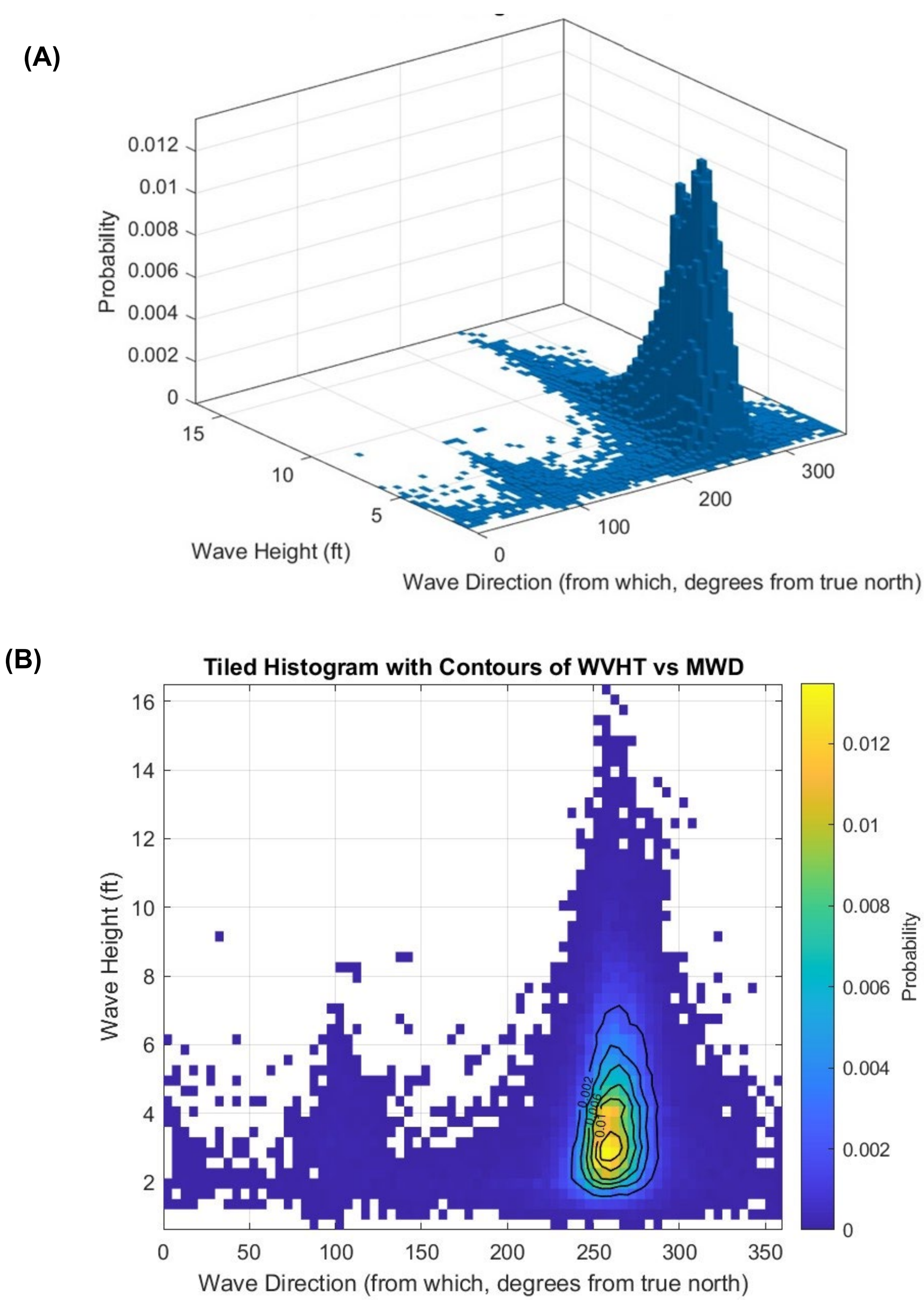

Figure 2-2. Joint Histogram (A) and Probability Tile Plot (B) of Significant Wave Height and Mean Wave Direction from NDBC Wave Buoy #46053

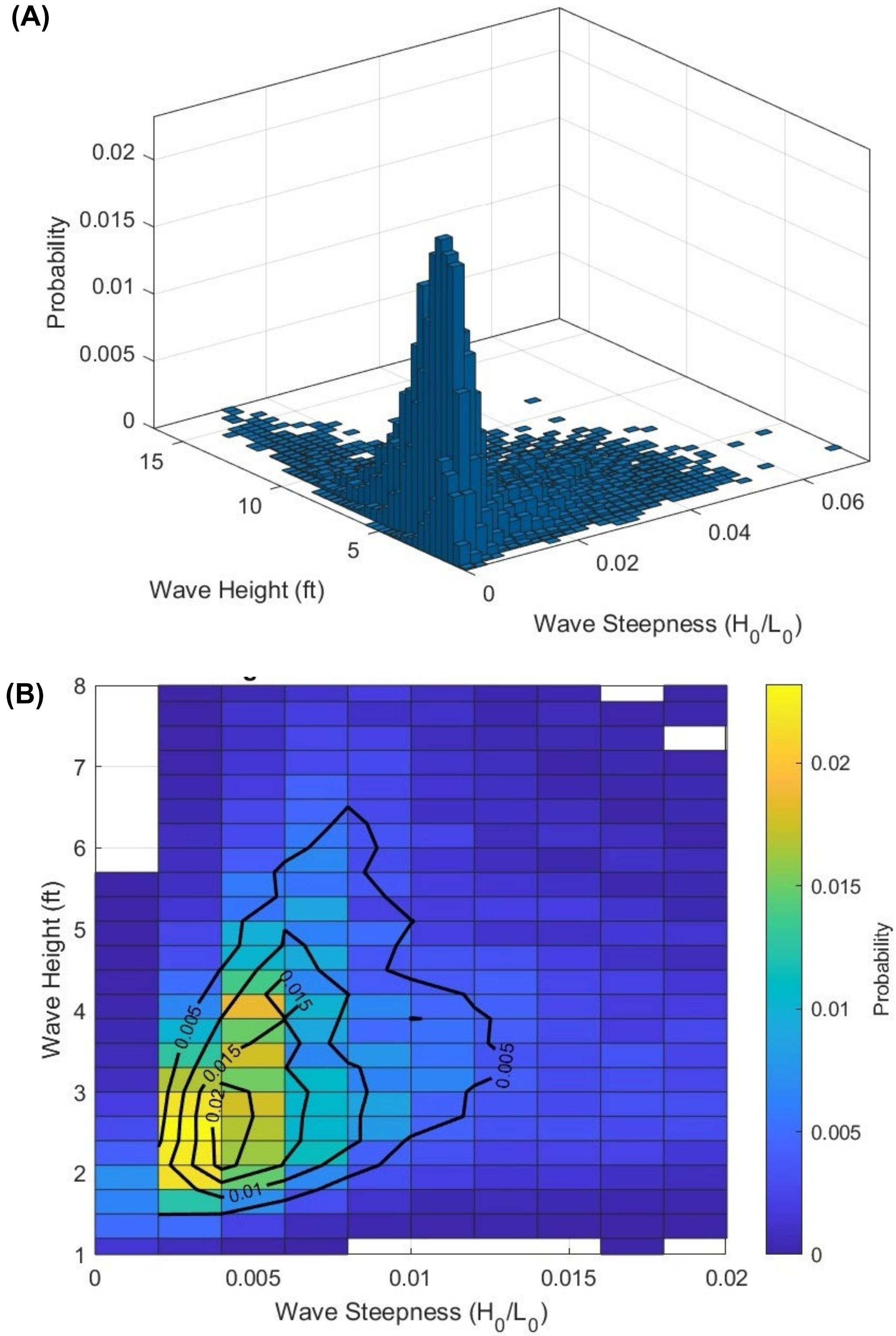

Figure 2-3. Joint Histogram (A) and Probability Tile Plot (B) of Significant Wave Height and Wave Steepness from NDBC Wave Buoy #46053

2.2 Littoral Processes

Griggs (2022) evaluates the impacts of the proposed project and alternatives on the shoreline and beaches. Because the wave climate and sand transport processes that affect shorelines and beaches are much the same as those that create a surfbreak and impact its quality, his study provides a valuable resource for this investigation.

Understanding the littoral process known as the “river of sand” is valuable in any shoreline impact study, because sand movement and patterns of deposition and erosion directly affect nearshore wave processes. Any modification to physical coastal features, either natural or man-made, that affects the movement of sand either by blocking its transport directly or altering the waves (via re-directing or blocking) that drive the transport may exert an impact on the quality of a surfbreak.

A littoral cell is a closed or quasi-closed coastal compartment or physiographic unit that contains sediment sources, transport paths, and sediment sinks (Inman and Chamberlain, 1960). A budget of sediment may be developed for a littoral cell to evaluate and interpret coastal sedimentation. This conceptual model applies the principle of conservation of mass to the fluxes of sediment into and out of the cell. Accretion occurs if the balance is positive (*i.e.*, more sand entering the cell than leaving), while erosion occurs if the balance is negative (*i.e.*, more sand leaving the cell than entering).

The Project site is located in the middle of the 144-mile-long Santa Barbara Littoral Cell, which extends from the mouth of the Santa Maria River to the Mugu Submarine Canyon. The net littoral drift volume along the Punta Gorda shoreline is approximately 300,000 cy/yr toward the southeast (Griggs, 2022). Griggs discusses how littoral drift can be impounded by natural and/or man-made features to create beaches, and how these features can create high-quality surfbreaks by bending or refracting the waves as they approach the shoreline. Punta Gorda is identified as a major “salient,” or bulge in the shoreline, on an otherwise nearly linear shoreline that extends into the nearshore zone to such an extent that it traps sediment moving to the east to form a long beach on its north (updrift) side (Figure 2-4). Griggs (2022) indicates that the seaward protrusion of the shoreline at Punta Gorda exists in part because of the resistant bedrock that outcrops along the shoreline (Figure 2-5).

Figure 2-4. Aerial View of Study Area

Figure 2-5. Nearshore Bedrock Outcrops Forming Punta Gorda Adjacent to Updrift Side of Abutment

2.3 Shoreline History

Task 2.3 of this study includes an assessment of the influence of the causeway access pier, abutment, and revetment on waves and littoral processes based on available studies and historical aerial photos. It is clear from the preceding discussion that the bedrock outcrop that provides the foundation for the abutment plays an important role in stabilizing the updrift sand beach. A key question is whether the abutment structure enhances the sediment-trapping function of this bedrock. As discussed in Griggs (2022), there was a pre-existing bedrock "point" at Punta Gorda prior to construction of Rincon Island in 1959. He found that the rock outcrop in the surf zone was visible in many of the pre-1959 island construction photographs, and clearly acted as a natural groin retaining sediment on its updrift side. Figure 2-6 shows a 1945 aerial photograph illustrating this phenomenon. Figure 2-7 shows the Pico Formation outcrop in November 1945, with the identical bedrock appearing in 2013 in Figure 2-5.

Figure 2-6. Wide Sand Beach Retained Upcoast of Punta Gorda (October 1945)

Figure 2-7. Punta Gorda in November 1945 Showing Pico Formation Bedrock

As Griggs (2022) presents, vertical aerial photographs taken prior to Rincon Island construction were compared to numerous post-construction photographs to determine the extent of any shoreline and beach changes that occurred in the subsequent years. Although the concrete abutment extended seaward of the pre-existing shoreline and was protected with armor stone, it extended only as far as the bedrock outcrop in the surf zone and did not significantly lengthen the original natural groin at Punta Gorda. Griggs (2022) concluded that *while this beach does change in width seasonally and from year to year due to differences in wave climate, there has not been any consistent increase or decrease apparent in the adjacent beach width in the 63 years since abutment and rip rap construction*.

Based on the foregoing analysis, it is concluded that: (1) the natural rock outcrop at Punta Gorda is responsible for the existence of the wide sand beach that exists to the north; and (2) the abutment that was constructed on the bedrock in 1959 does not materially affect the existence or configuration of this beach.

3 Technical Aspects of a Surfbreak

3.1 Surfing Background and Surfbreak Parameters

The intent of this section is to describe the physical parameters that contribute to the quality of a surfbreak. With an understanding of these physical parameters, the conditions that contribute to the quality of the Little Rincon surfbreak, and how these conditions may be affected by the Project or its alternatives, can be evaluated and quantified.

3.1.1 Basic Wave Parameters and Processes

The most basic parameters used to characterize a water wave are its *height* (H), *length* (L), and *direction* (θ) (measured in degrees clockwise from true north), the shoreline orientation, or the orientation of a coastal structure (Figure 3-1). In turn, the wavelength depends upon the wave *period* (T), which represents the time elapsed between the passage of two wave crests, the local *water depth* (h) and, for shallow water waves suitable for surfing, the wave height.

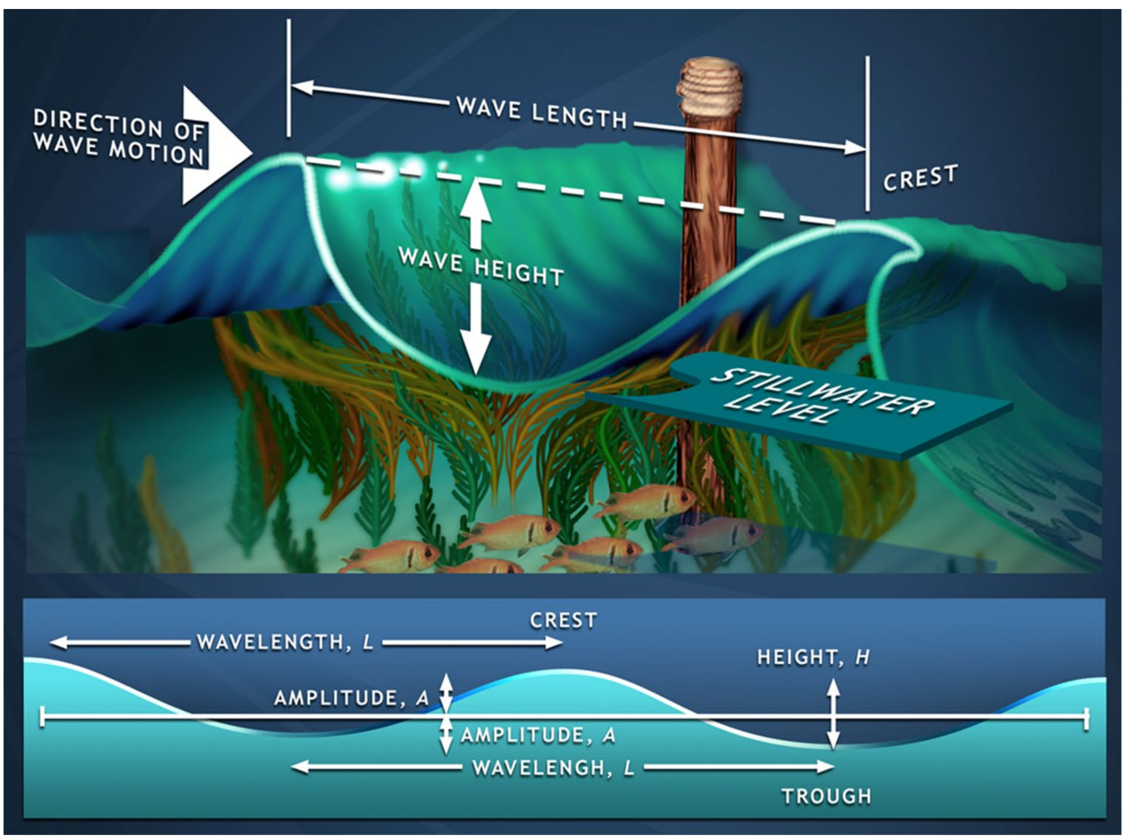

Figure 3-1. Definition of Basic Wave Properties

Wave *shoaling* is the process by which the wave height increases as the wave enters shallow water and approaches breaking. If waves approach shallow water at an angle to the local bottom contours, the wave direction will rotate in an attempt to approach perpendicular to the bottom contours (see Figure 3-2). This process is called *refraction*, and a line drawn which traces this changing direction as the wave moves onshore is referred to as a *wave ray*. On an idealized open coast that has straight and parallel bottom contours, the refraction process tends to reduce the height of the waves, but, the increase in height due to shoaling eventually wins out and causes the waves to start breaking. However, as shown in Figure 3-3, in the presence of a headland the wave rays converge and consequently focus the wave energy and increase the breaker height. Conversely, an embayment (e.g., an indentation) in the shore will cause the wave rays to diverge, decreasing the height of waves before they begin to break.

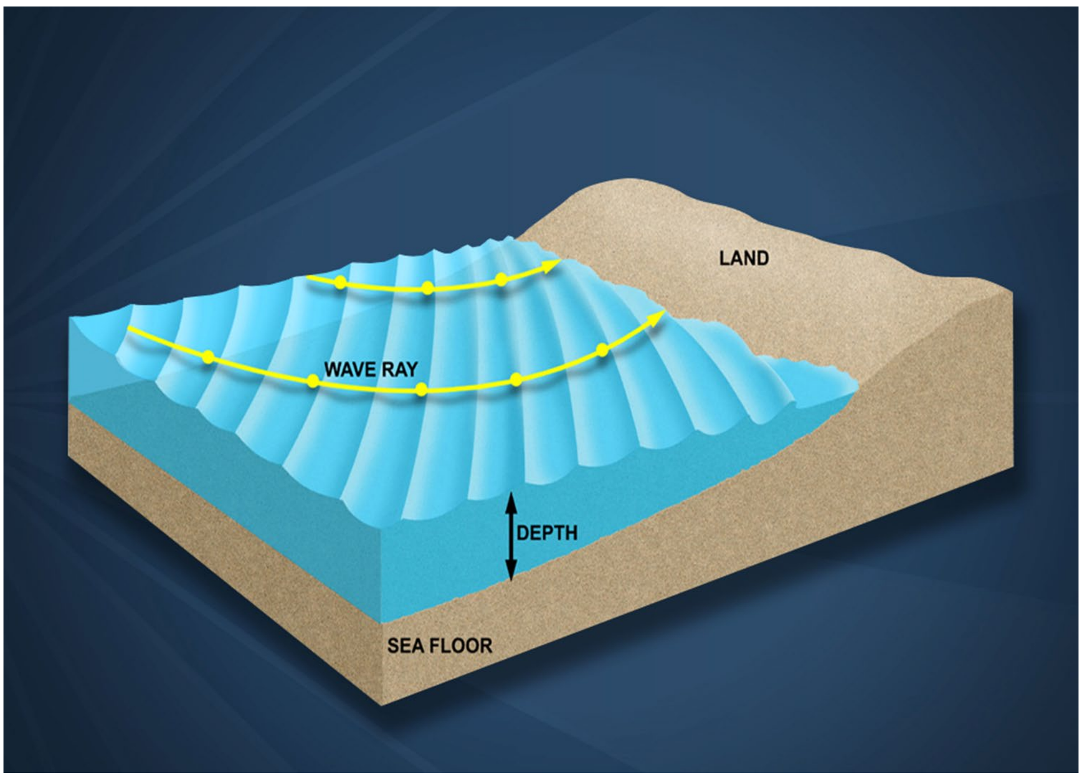

Figure 3-2. Illustration of Wave Refraction

Wave *reflection* is the process that occurs when waves encounter a barrier, such as a seawall or beach scarp, and "bounce" back out to sea. This process often occurs on steep beaches, where a portion of the incoming wave energy may be dissipated by breaking and by the turbulence and friction associated with the runup of the wave on the beach, resulting in *partial* reflection. On an open-coast sandy beach, reflection tends to be detrimental to surfing conditions because the interference that occurs when a reflected wave passes through an incoming wave renders the incoming wave difficult to catch.

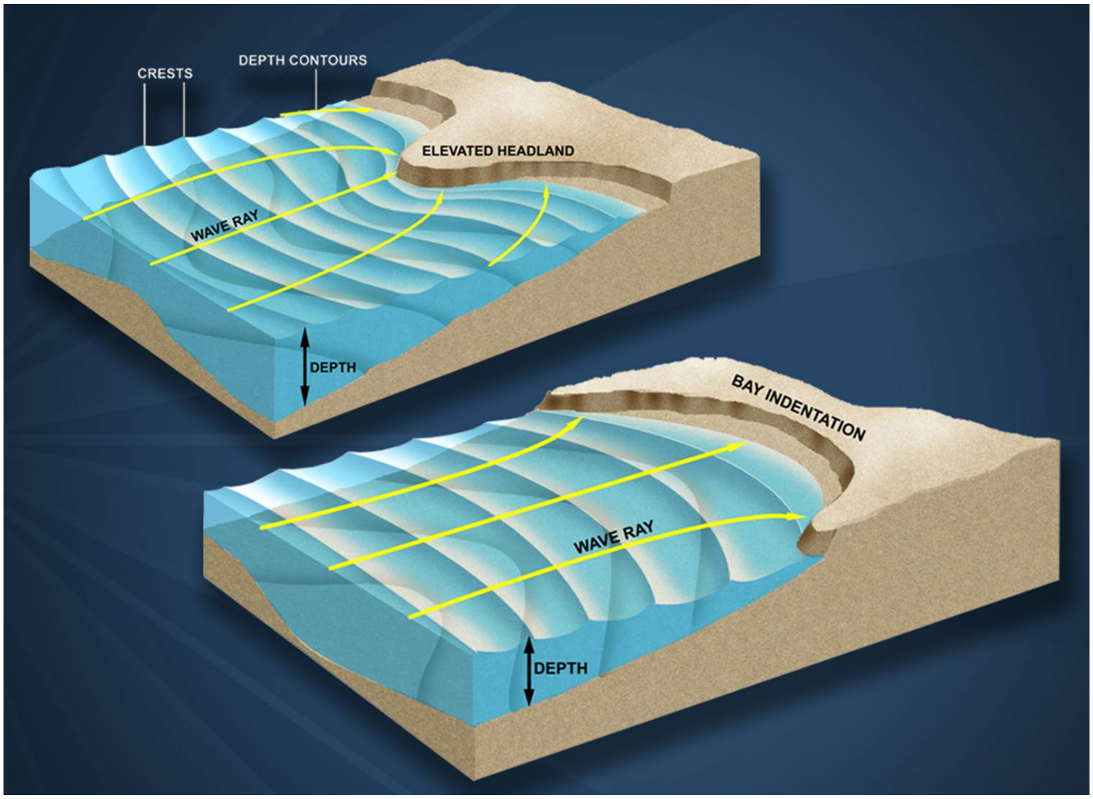

Figure 3-3. Illustration of Wave Refraction Near Headlands and Embayments

3.1.2 Breaker Type

There are three types of breaking waves found on natural beaches – *spilling*, *plunging*, and *collapsing*/*surging* (Figure 3-4), with plunging breakers generally preferred by surfers. Breaker type can be predicted by computing the Iribarren Number[2] (ξ) defined as

$$\xi_b = \frac{m}{\sqrt{\frac{H_b}{L_o}}} \qquad \text{(Equation 1)}$$

in which m is the local bottom slope under the wave, H_b is the breaker height, and L_o is the wave length in deep water, which is in turn is computed as

$$L_o = \frac{gT^2}{2\pi} \qquad \text{(Equation 2)}$$

in which g is gravitational acceleration (32.2 ft/s^2) and π is the mathematical constant equal to approximately 3.14. If $\xi_b \leq 0.4$, breakers are generally of the spilling type, and when $0.4 \leq \xi_b \leq 2$, the breakers are generally of the plunging type. When $\xi_b \geq 2$, the waves will be of the collapsing or surging type, with much of the wave energy reflected out to sea, rendering the waves unsurfable as discussed above.

[2] Also referred to as the Surf Similarity Parameter.

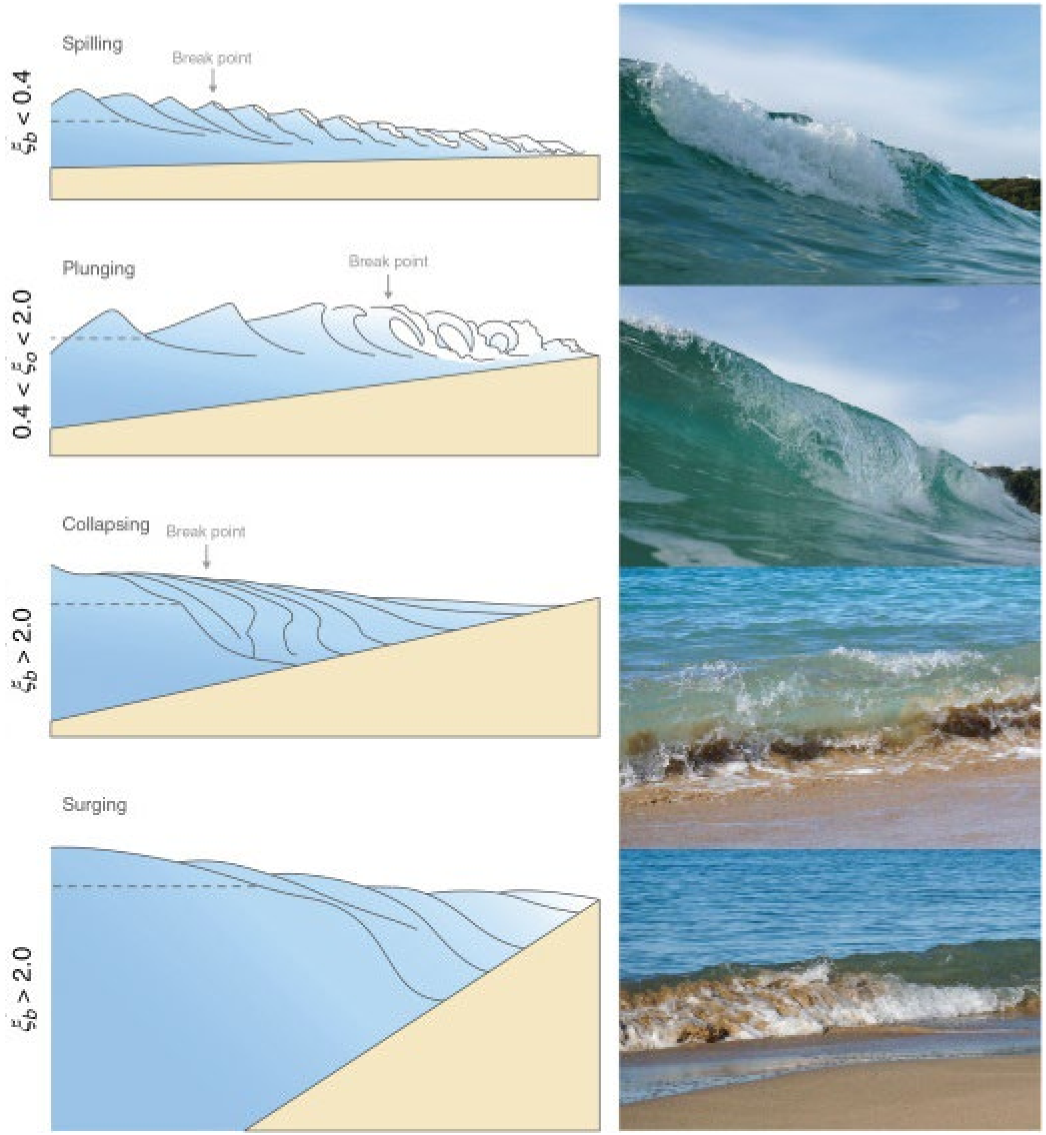

Figure 3-4. Breaking Wave Types and Associated Iribarren Numbers

Surfers tend to prefer plunging breakers for several reasons. Firstly, in order to catch a wave, the surfer must paddle the board to gather as much forward speed as possible until the face of the near-breaking wave tilts the nose of the board sufficiently far down to cause strong acceleration. The surfer then must match (or slightly exceed) the wave celerity and make a 'bottom turn' before the breakpoint overtakes him/her. The slope of the wave face, and therefore the acceleration imposed on the board by a breaker that is about to plunge, is significantly greater than that of one that is about to spill, thereby improving the surfer's chance of successfully catching the wave. Another reason that surfers tend to prefer plunging breakers is that for a given wave height, the speed attained by the surfer on a plunging wave is generally greater than that on a spilling wave, making the ride more thrilling.

3.1.3 Parts of a Plunging Breaker

Figure 3-5 shows a surfer riding a plunging breaker along with the nomenclature associated with different sections of the wave. If the wave were of the spilling type but still surfable (discussed below), there would be no clearly defined *Lip* or *Tube/Barrel/Pocket/Curl*. Also, the *Face/Wall* would not be as steep as in the case shown.

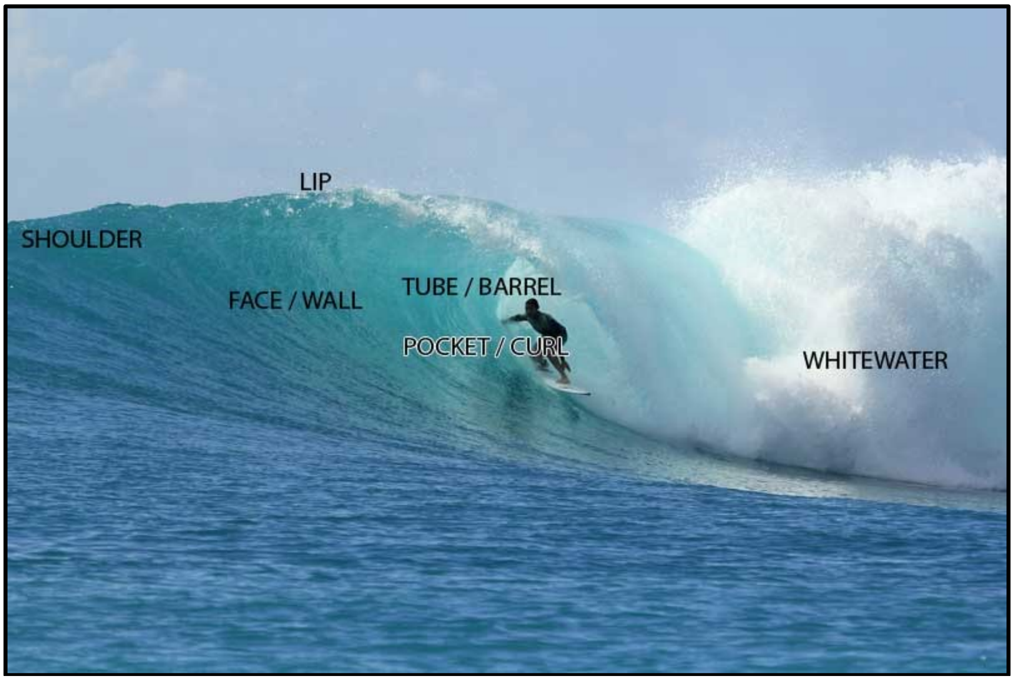

Figure 3-5. Surfbreak Nomenclature for Plunging Breaker

3.1.4 Peel Angle, Wave Celerity, and Peel Rate

Based on a coastal engineering survey of popular surfing beaches in Hawaii, Walker (1974) first identified and studied many of the parameters material to the evaluation of waves for recreational surfing. Arguably the three most important are (1) the *peel angle* (α_b), which is the angle between the wave crest and the path of the point of incipient breaking; (2) the *wave celerity* (c_b), which is the forward speed of the wave at the point of incipient breaking; and (3) the *peel rate* (P), which is the speed of the point of incipient breaking along the wave crest. The peel angle, as depicted in Figure 3-6, is illustrated on an aerial photograph taken on April 12, 2018 during prime surfing conditions at the Little Rincon site. Based on simple trigonometry, if the peel angle and wave celerity are known, the peel rate can be computed using the relationship[3]

[3] To clarify semantics, in Dally (1990a) the *peel rate* was defined as Eq. (1), whereas Walker originally defined the peel rate as the speed of the break point *along the wave crest*, which in the present context would be $\frac{c_b}{\tan(\propto_b)}$.

$$P = \frac{c_b}{\sin(\propto_b)} \qquad \text{(Equation 3)}$$

If the wave period is known, and the wavelength can be accurately extracted from a source that may consist of an aerial photograph or video of a breaking wave, then the wave celerity (c_b) can be estimated using the simple expression

$$c_b = \frac{L_b}{T} \qquad \text{(Equation 4)}$$

which is utilized below in the analysis of several GoogleEarth® photographs. If only the height of the breaking wave is known, Walker (1974) suggested computing/estimating the breaker celerity based upon

$$c_b = 1.25\sqrt{gH_b} \qquad \text{(Equation 5)}$$

in which H_b is the wave height at the local point of incipient breaking.

Figure 3-6. Definition Sketch of Peel Angle, Wave Celerity, and Peel Rate

3.1.5 Board Speeds

Dally (1990a, 2001b) applied the basic concepts of Walker (1974) in the development of stochastic (probability) models for evaluating the "surfability" of random waves, with the goal of rigorously quantifying the percentage of waves that were surfable during a selected time period such as a particular day or even a single surfing session. In this regard, the term *board speed* (S) is defined as the hypothetical *maximum* speed that a surfer could sustain on a particular wave, and so a wave was deemed surfable if S ≥ P. If not, the wave is classified as a *close-out*, during which the surfer would be overtaken by the break point and therefore unable to continue his/her ride.

An important distinction must be made between the maximum sustainable board speed (S) and the average board speed (S_{av}) experienced during a particular ride. If the maximum sustainable speed is significantly greater than the peel rate of the wave, the surfer could momentarily outrun the break point to the extent that the board stalls out on the shoulder of the wave (Figure 3-5), the surfer cannot regain speed quickly enough, and is overtaken by the break point thereby ending the ride. In fact, in the situation where S is significantly greater than P, the surfer must purposely either slow the board by maneuvering up and down the face of the wave, or *cut back* to reestablish him- or herself in the *pocket* (Figure 3-5). This results in the average board speed, S_{av}, always being less than or equal to the maximum sustainable board speed, S, on a particular section of a particular ride.

Using aerial photographs of the Hawaiian surfing sites, Walker (1974) estimated the break rates of individual waves, computed from the photographed peel angles and estimates of wave height at breaking (Eq. 5). For several waves that were ridden by surfers, Walker (1974) measured the average surfer speed, $S_{av,}$ by triangulating the surfer's position using shore-based surveying transits. The greatest average speed estimated was nearly 27 mph (39 ft/s), and at least a few of the rides documented are believed to have been at maximum speeds, *i.e.,* the surfable limit before the wave closed-out.

However, regarding the hypothetical maximum sustainable board speed, S, no data were available until Dally (2001a) developed a photogrammetric method that utilized land-based, commercially available surfing videos. Particular rides were selected in which the surfer was judged to be at the maximum speed attainable on a particular wave, dictated by the fact that the surfer could not slow down, cut-back, or perform acrobatics without being overtaken by the break point. Based upon 29 rides deemed to be at the surfable limit, with H_b ranging from 4 – 40 ft and maximum sustainable board speeds ranging from 12 – 40 mph (1.6 – 59 ft/s), the following empirical expression was established:

$$S = \beta \sqrt{g H_b} \qquad \text{(Equation 6)}$$

for which the best-fit value of β was found to be 1.93 (dimensionless).

It should be noted that Dally (2001a) did not find conclusive evidence that the maximum sustainable board speed was dependent on breaker *type*. This is somewhat counterintuitive, except that long-period waves tend to shoal to greater breaker heights than short-period waves, and therefore are inherently more likely to plunge than to spill (Eq. 1 and 2), and therefore are easier to catch.

3.1.6 Ride Length

In general, the longer the ride, the more enjoyable the surfing experience. Based upon the discussion above, if a wave is *catchable*, in principle the ride can continue until one of two conditions are encountered. Firstly, if the peel rate exceeds the maximum sustainable board speed, the wave will close out, which generally is due to the peel angle being too small, either at the very beginning of the attempted ride, or else becoming too small during the ride as the wave continues to refract through the surf zone (Eq. 3). Secondly, if the local breaker height becomes too small, or the wave stops breaking altogether[4], the necessary board speed is no longer available (Eq. 6) and the ride ends, often with the surfer *kicking out* over the shoulder of the wave. The second condition is strongly related to any longshore gradient in the height of the breaking waves which, even when waves approach directly to the beach (*i.e., shore-normal*), can create a non-zero peel angle that lies within the surfable range.

3.1.7 Categories of Surfbreaks

Figure 3-7 presents photographs of several of the most common categories of surfbreaks. Figure 3-7a shows a *beach break*, which relies upon either irregular sandbar formations or the interaction of waves approaching from different directions to create peel angles large enough to promote surfing. On a sandy beach devoid of irregular sandbars or without intersecting wave trains, refraction will cause the large, long-period swell waves usually preferred by surfers to align themselves nearly parallel to the beach, resulting in a preponderance of close-outs. This situation is referred to as the “surfer’s paradox,” which is common on the Atlantic coast when long-period swell from a distant hurricane arrives at an open sandy beach with somewhat straight and parallel bottom contours.

Figure 3-7b depicts a *point break*, created by a rocky headland or other naturally occurring, protruding feature that presents bottom contours sufficiently oblique to the incoming waves to create large peel angles and surfable waves. As mentioned above, refraction can cause wave energy to focus on the headland, thereby locally increasing the wave height at the tip of the headland. The resulting gradient in height along the wave crest helps to promote even larger, more surfable peel angles and longer rides.

Another naturally occurring surfbreak category is the reef break (Figure 3-7c), in which waves approach a submerged coral or rock reef system at an angle that is sufficiently oblique to create large peel angles and surfable waves. Because the reef bottom is fixed and generally flat, the quality of these breaks is sensitive to the stage of the tide and the incident wave height.

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[4] Usually breaking abates when the breaker height becomes less than approximately 40% of the local water depth.

Figure 3-7. Categories of Surfbreaks

Finally, many favored surfbreaks are the result of “unintended consequences” created by the interaction of waves with coastal structures built for other purposes such as navigation or shoreline management, *e.g.,* jetties and groins. For example, an accumulation of sediment off the end of a groin can act as an artificial (submerged) headland, which often occurs at Surf City, New Jersey. Also, when waves reflect off a structure within a certain range of sharp angles (20^{o} to 30^{o}), a surfable break can be created from waves that would otherwise not be surfable. This phenomenon, known as *mach-stem reflection* and depicted in Figure 3-7d, is responsible for “The Wedge” at the west jetty at Newport Harbor in southern California, and “First Peak” at the north jetty of Sebastian Inlet, Florida.

3.2 Little Rincon Surfbreak

This section characterizes the existing surfbreak at Little Rincon based on existing information that includes web-based sources and aerial photographs. The section that follows (Section 3.3) provides a summary of site observations and an analysis of aerial drone photography to establish a pre-Project baseline against with which the impacts of components of the Project alternatives on the surfbreak can be assessed.

The characteristics of the surfbreak for purposes of the Project impact analysis are summarized in Table 3-1.

Table 3-1. Little Rincon Surfbreak Characteristics[5]

Characteristic	Description
Surfer Experience	Intermediate to advanced
Surfbreak Type	Point Break – first outer peak at pier, second inner peak in front of hotel
Direction	Right
Power	Fast, fun
Ride Length	Normal 150-500 ft, good day 500-1000 ft
Good Swell Direction	WSW, W and WNW – best in fall, winter
Swell Size	Starts working at 3-5 ft, holds up to 10 ft plus
Tide	Best at low to mid-tide
Ideal Wind Direction	East to northeast

The favored wave conditions for surfing at Little Rincon occur when large, long-period swell approach from the west-southwest through west, resulting in a "right-handed" point break. Of the 27 aerial photographs available of the Little Rincon site on Google Earth® from 2009 to 2021, only three captured conditions that were favorable for surfing, with large peel angles and potentially long rides due to large wave heights. Figure 3-8, Figure 3-9, and Figure 3-10 present these photographs. Because the exact time each photo was taken is not available, the characteristic wave conditions during daylight hours on these dates, extracted from the record measured at NDBC 46053 as described in Section 2.1, are provided along with the wave lengths and peel angles estimated from each photograph. Figure 3-8 and Figure 3-10 appear to have been taken under "near-epic" conditions, with wave breaking starting under the pier off the tip of the abutment and continuing uninterrupted far into the embayment to the east. In Figure 3-9, it appears that breaking does not start until the wave has passed the abutment, providing only a short ride at this outer break. However, approximately 1,200 ft to the east an inner break appears that offers rides up to 1,000 ft long under smaller wave conditions.

These aerial photographs confirm that the favored surfbreak at Little Rincon is a "one-sided point break" that produces only right-handed breaks that are surfable. The break is created by the abrupt change in shoreline orientation that occurs at the pier abutment. In fact, in each of the three photographs of surfable conditions, the waves along the beach north of the abutment are approaching essentially normal to the shoreline (*i.e.,* from a direction of 270^{o}) and consequently close out. At the abutment, the shore-normal direction changes abruptly from 270^{o} to 232^{o}, creating the favorable surfing conditions

[5] Sources include Collins (2005), https://www.wannasurf.com/spot/North_America/USA/California/Ventura/little_rincon/index.html, https://www.surf-forecast.com/breaks/Little-Rincon, https://www.yeeew.com/listing/north-america/california-south/ventura-county/ventura-west/little-rincon-mussel-shoals/ .

associated with westerly waves. Under such conditions, wave refraction cannot turn the waves quickly enough to significantly affect their surfability, and consequently they do not close out. It is not until approximately 2,600-3,000 ft farther to the east, where the shoreline orientation rotates clockwise to the extent that the waves again become roughly shore-normal, that surfing conditions deteriorate. Consequently, the rides during epic conditions can be quite long.

Figure 3-8. Little Rincon Surf Conditions on April 12, 2018

Figure 3-9. Little Rincon Surf Conditions on April 14, 2017

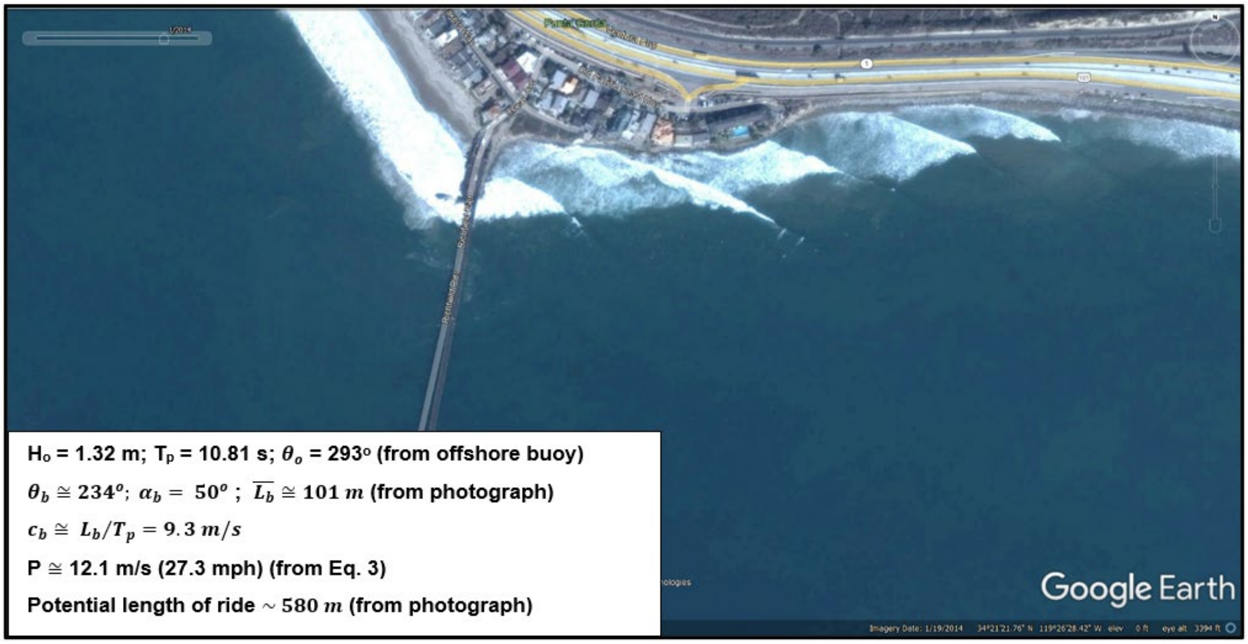

Figure 3-10. Little Rincon Surf Conditions on January 9, 2014

3.3 Analysis of Surfbreak During January 6, 2023 Large Wave Event

On January 5th and 6th, 2023, a strong weather system passed, sending large, long-period swell into the study area. As indicated in Table 3-2, the wave energy measured at Buoy #46053 increased throughout the afternoon and into the evening of the 5th, reaching a maximum energy-based significant wave height (H_{mo}) of 6.3 m at midnight[6]. At that time, the peak wave period (T_p) reached 19 s, and the mean wave direction (θ_m) was 268°. Thereafter the wave energy began to gradually decline.

A field crew mobilized by Coastal Frontiers reached the site before dawn on January 6th, set up two land-based video cameras, and began unmanned aerial vehicle (UAV/drone) flights at approximately 7:00 AM. By this time, H_{mo} at the buoy was nominally 4.8 m, T_p was 17 s, and θ_m was 268°. The wind and wave characteristics during the period in which field observations were obtained are presented in Table 3-2 in **bold** (time 6:50 through 8:50).

The UAV hovered at an elevation of 400 ft (the maximum altitude allowed) with its video camera looking directly downward. It was positioned so that the favored take-off location of the surfers was in the upper-right-hand corner of the video frame. This configuration maximized the chances of capturing the full duration of any long rides that might occur.

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[6] Note that the maximum significant wave height of 6.3 m is larger than any recorded measurement taken at NDBC #46053 between January 1, 1994 and December 31, 2021.

Table 3-2. Wave and Wind Conditions at NDBC #46053; January 5-6, 2023

Date	Time	H_{mo} (m)	T_p (s)	θ mean (°T)	Wind Dir. (°T)	Wind Speed (m/s)
1/5/2023	16:50	2.8	19	248	230	4.0
1/5/2023	17:50	3.6	19	258	230	3.0
1/5/2023	18:50	4.0	19	264	230	3.0
1/5/2023	19:50	4.8	17	268	240	6.0
1/5/2023	20:50	4.5	19	281	240	5.0
1/5/2023	21:50	4.3	19	279	250	7.0
1/5/2023	22:50	5.9	19	265	250	7.0
1/5/2023	23:50	6.3[7]	19	268	270	7.0
1/6/2023	0:50	5.7	17	257	280	6.0
1/6/2023	1:50	5.5	16	270	280	6.0
1/6/2023	2:50	5.9	17	266	280	7.0
1/6/2023	3:50	5.8	17	274	300	6.0
1/6/2023	4:50	5.3	17	277	280	4.0
1/6/2023	5:50	5.5	15	262	270	6.0
1/6/2023	**6:50**	**4.8**	**17**	**268**	**280**	**8.0**
1/6/2023	**7:50**	**4.6**	**17**	**263**	**280**	**7.0**
1/6/2023	**8:50**	**4.4**	**16**	**260**	**290**	**6.0**
1/6/2023	9:50	3.8	17	256	300	6.0
1/6/2023	10:50	4.4	16	262	280	7.0
1/6/2023	11:50	4.3	17	258	300	6.0
1/6/2023	12:50	3.7	16	241	340	2.0
1/6/2023	13:50	3.6	16	235	300	4.0
1/6/2023	14:50	3.7	16	246	300	5.0
1/6/2023	15:50	3.3	14	244	50	2.0
1/6/2023	16:10	3.3	15	238	50	3.0
1/6/2023	16:50	3.3	16	232	50	4.0
1/6/2023	17:50	3.2	15	249	110	2.0

[7] Peak storm wave height

Figure 3-11 presents three partial frames from a video clip taken by the hovering UAV as a surfer progresses through a long ride. The frames also include the local orientation of the wave crest and the direction of the path of the break point, thereby defining the peel angle. When the surfer catches the wave, the peel angle is approximately 55^o. In the second frame, about halfway through the ride, the peel angle increases to about 70^o, slowing the peel rate to the extent that the surfer performs a cut-back (evident in the foam trail left by the surfer in third frame) to allow the break point to catch up. In the third frame, the peel angle returns to approximately 55^o. The duration of the ride is 13 s, and its total length is estimated to be 500 ft, yielding an average surfer speed of 38 ft/s (26 mph). Based upon the video footage, the average wave celerity[8] is 30 ft/s, which, when combined with an average peel angle of 55^o, yields an average peel rate of 37 ft/s. This value is almost identical to the average surfer speed, as expected for a good surfbreak (Section 3.1.5).

To document the breaker type and estimate the breaker height as a surfer caught a particular wave, one land-based camera was positioned near the pier abutment, with its operator concentrating on the surfers' favored take-off location (Figure 3-12). The second camera was positioned on the shore approximately 500 ft (150 m) to the south for the purpose of tracking the surfer during his or her ride, with the intent of capturing footage that would allow estimation of the local wave height as the ride progressed (Figure 3-13).

The video footage obtained by the UAV also was analyzed to determine if the characteristics of the waves changed when they passed through the causeway access pier. As illustrated in Figure 3-14, no changes were evident.

[8] Speed at which an individual wave advances.

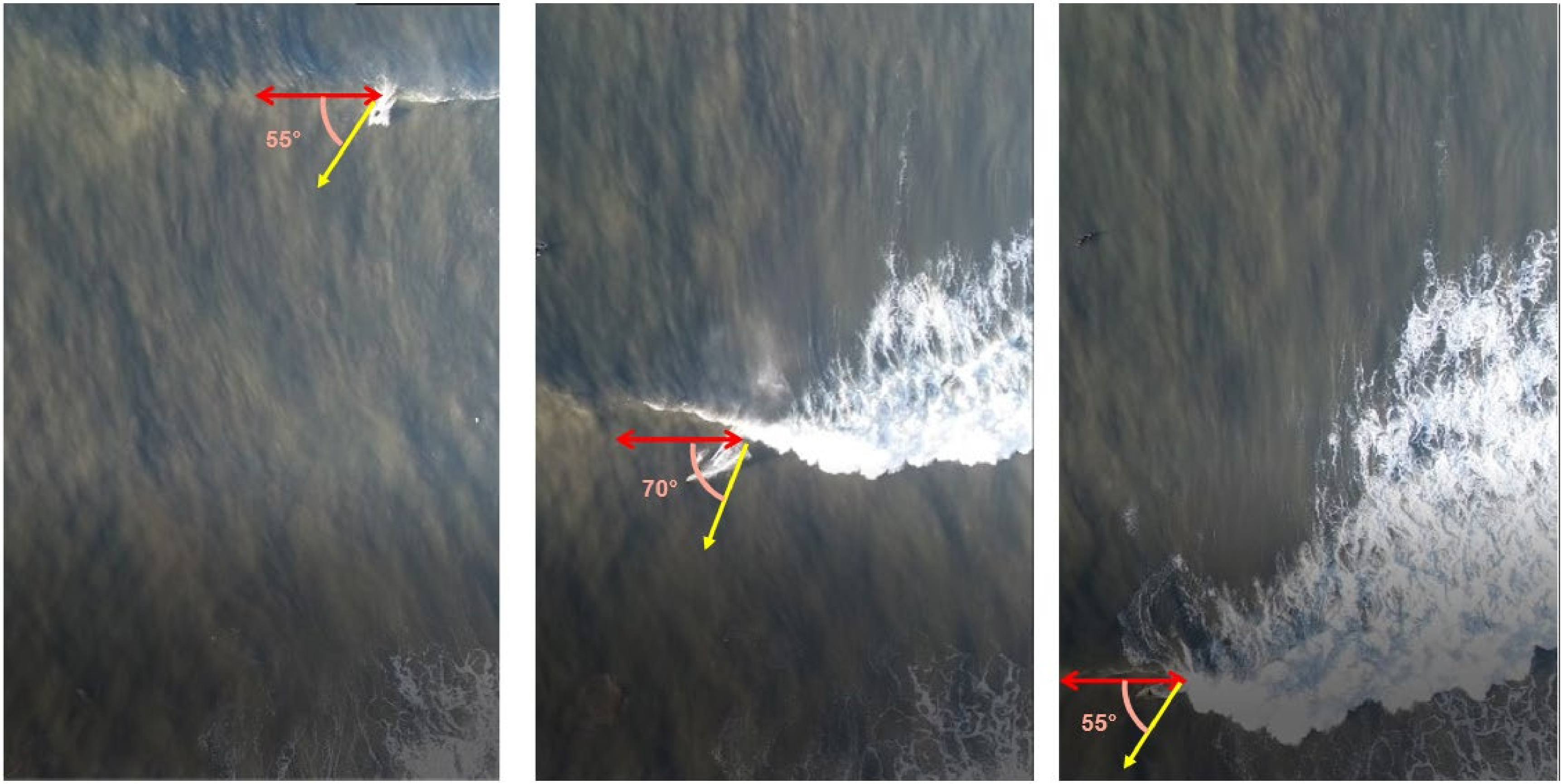

Figure 3-11. Sequence of UAV Video Frames from Long Ride at Little Rincon

Figure 3-12. View from Ground Camera #1 Showing Surfer Paddling to Catch a Wave

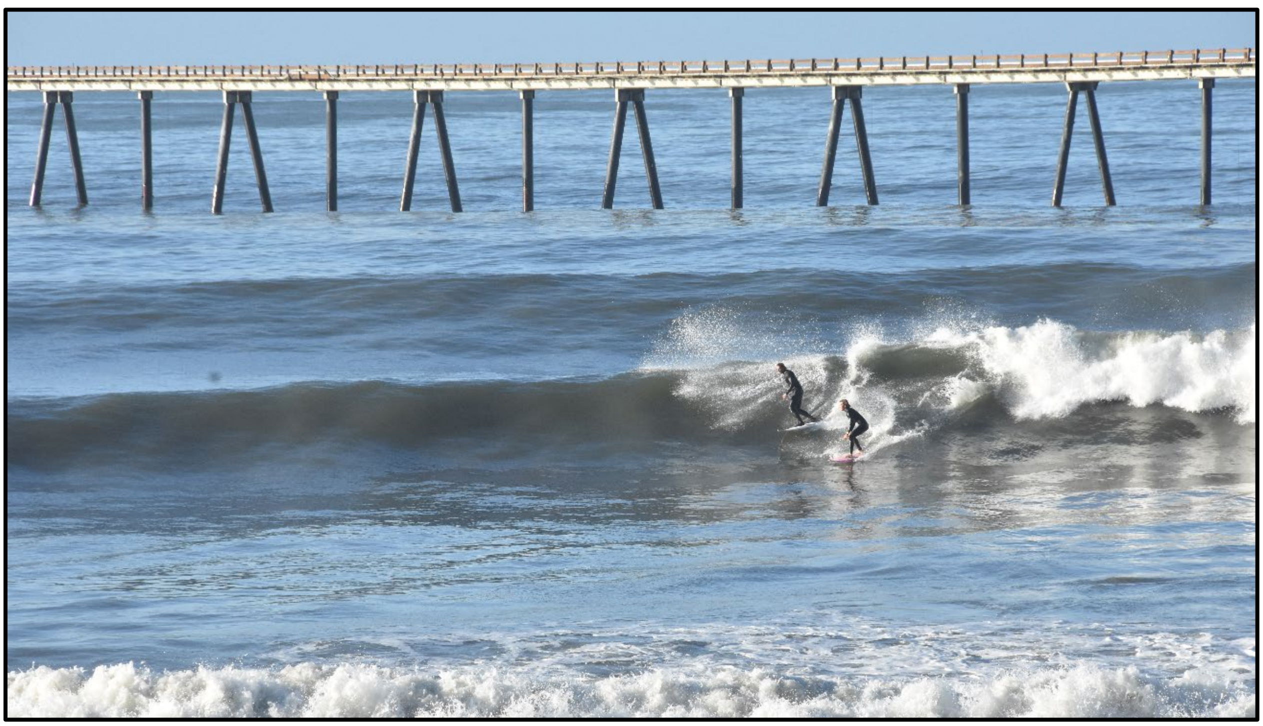

Figure 3-13. View from Ground Camera #2 Showing Two Surfers Riding the Same Wave

Figure 3-14. Frame from UAV Video Showing Waves Passing through Pier

4 Potential Impacts of Rincon Phase 2 Decommissioning on Surfbreak

This section addresses the potential impacts of the three Rincon Island Phase 2 Decommissioning Project alternatives on the Little Rincon surfbreak:

- Removal of the causeway including abutment removal and replacement of the revetment;
- Removal of the causeway without abutment / revetment modification; and
- Partial removal of the causeway without abutment / revetment modification.

4.1 Removal of Causeway Including Abutment Removal and Replacement of the Revetment

For clarity, the impacts of (1) removing the causeway access pier and (2) removing the abutment and replacement of the revetment are evaluated separately.

4.1.1 Removal of Causeway Access Pier

Coastal structures can cause significant impacts on adjacent sandy shorelines, either by modifying the incident wave conditions or by blocking the transport of sand. A key question for the decommissioning of Rincon Island is whether the causeway access pier currently alters the nearshore wave conditions and associated sediment movement. If the pier does not materially alter these phenomena, it can be concluded that its removal will not impact the surfbreak.

The potential effect of removing the causeway access pier is assessed by (1) analyzing site-specific aerial photographs and high-resolution, multi-beam sonar bathymetric survey data to identify possible impacts of the pier piles on the nearshore sea bottom, waves, and sediment movement; and (2) reviewing prior research of a more general nature on the possible impacts of pier structures coastal processes.

4.1.1.1 Analysis of Aerial Photographs and High-Resolution Bathymetric Survey Data

None of the aerial photographs obtained from Google Earth®, including the three taken during prime surfing conditions, show any indication that the pier piles are altering the wave conditions. On the contrary, the waves appear to pass underneath the pier without alteration. This outcome is consistent with the fact that the piles are both slender, with a diameter of 16 inches, and widely-spaced, with a separation of 12 ft in each pile bent (*i.e.*, row of piles perpendicular to the structure orientation) and 40 ft between bents.

Figure 4-1 presents the results of a high-resolution, multi-beam sonar survey of the sea floor extending offshore from the nearshore region to beyond Rincon Island. The survey was conducted by eTrac, Inc. on March 24 and 26, 2021 (Longitude 123, Inc. 2021). Figure 4-2 provides a detailed view of the nearshore region associated with the surfbreak. Note that there is no evidence of a "scour canyon" beneath the pier, a feature typically found at piers whose pilings are of large diameter and closely spaced (*e.g.,* the U.S. Army Corps of Engineers research pier at Duck, North Carolina). Figure 4-3 presents a three-dimensional ("3D") image of the landward end of the causeway access pier and abutment (viewed from the northwest) that was created by combining UAV LiDAR data from the subaerial region with multi-beam sonar data from the submerged region. Figure 4-4 presents a 3D view from the nearshore looking toward the island. In all cases, evidence that the causeway access pier is altering the nearshore bathymetry is conspicuously absent.

4.1.1.2 Coastal Structures' Effects on Shorelines

Noble (1978) conducted a study of the effects of coastal structures on shorelines in southern California that included the impacts of piers. Case histories of existing piers were investigated, and a review of analytical and model studies was performed. Twenty piers in the Southern California Bight (from Point Conception south to San Diego) were analyzed, including the Rincon Island causeway access pier. Factors evaluated for each pier structure included the following:

- Environment
    - Location of structure
    - Wave exposure
    - Physiographic setting
    - Pier configuration
    - Net longshore sediment transport
- Structural characteristics
    - Pile diameter
    - Number of piles per bent and pile spacing
    - Bent spacing
    - Length and width of structure
- Effects on adjacent shoreline

Each of the 20 piers was a pile-supported structure with evenly spaced pile bents. The foot of each pier was located shoreward of the mean high-water level, and the pier extended seaward through the zone of wave breaking. Pile diameters were uniform over the length of the pier as were the bent spacings. With few exceptions, the number of piles per bent was consistent over the pier length.

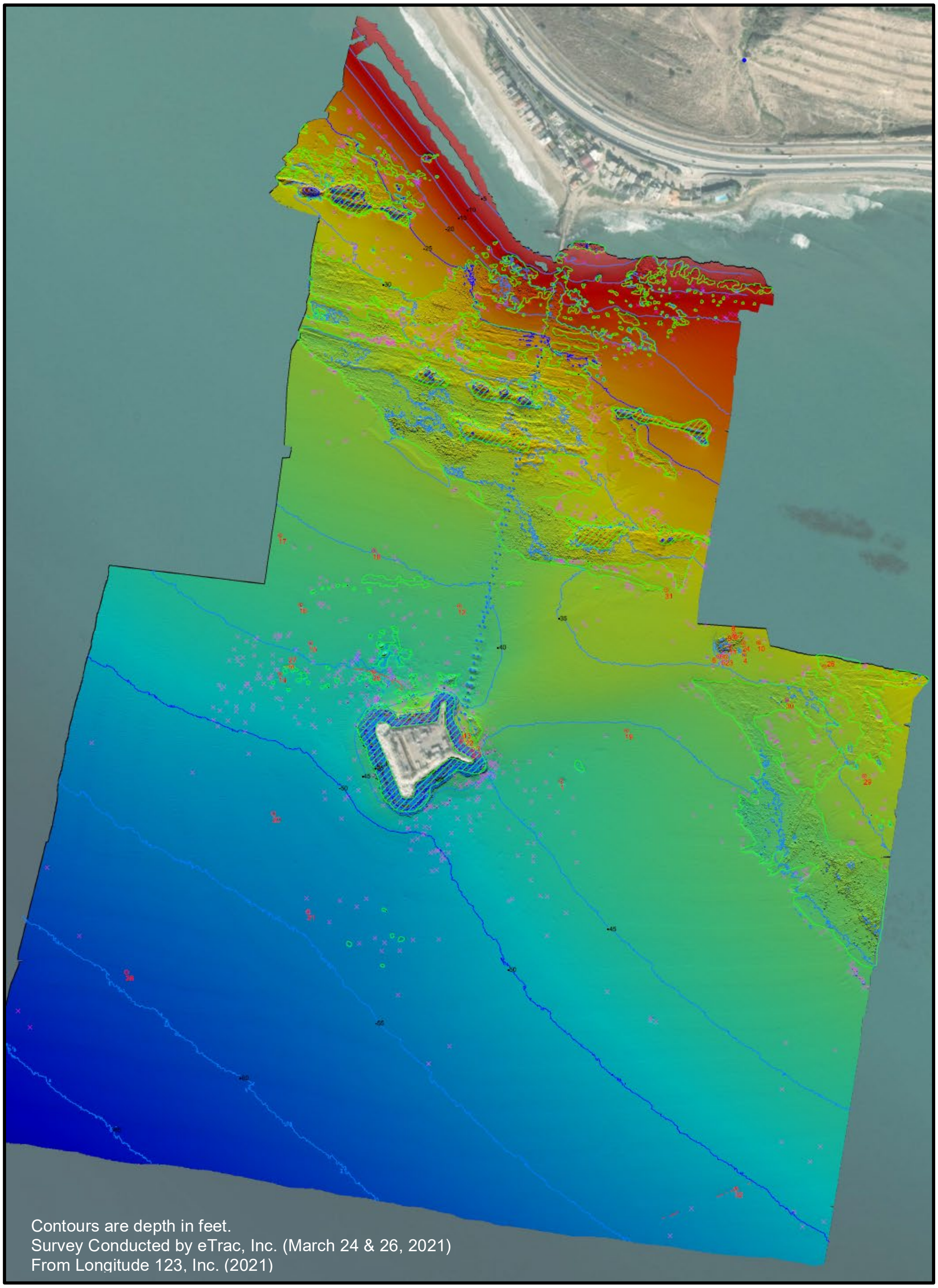

Figure 4-1. Bathymetry in the Study Area

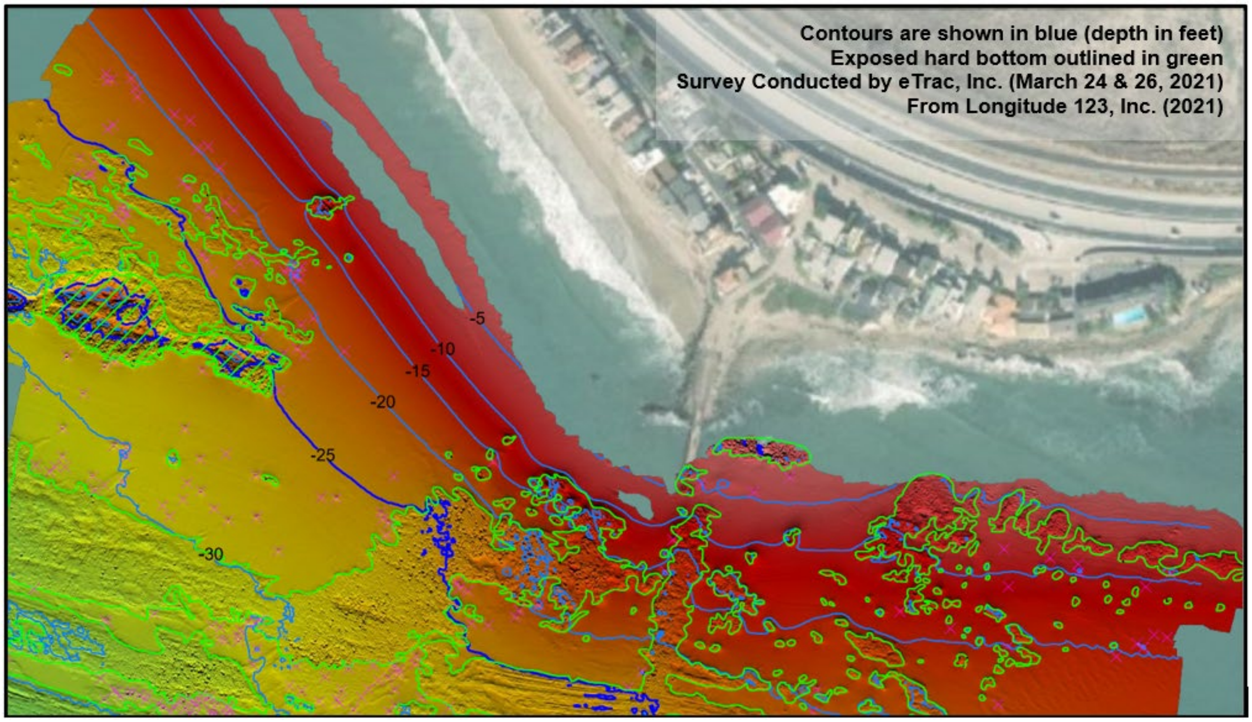

Figure 4-2. Bathymetry and Areas of Hard Bottom at Project Site

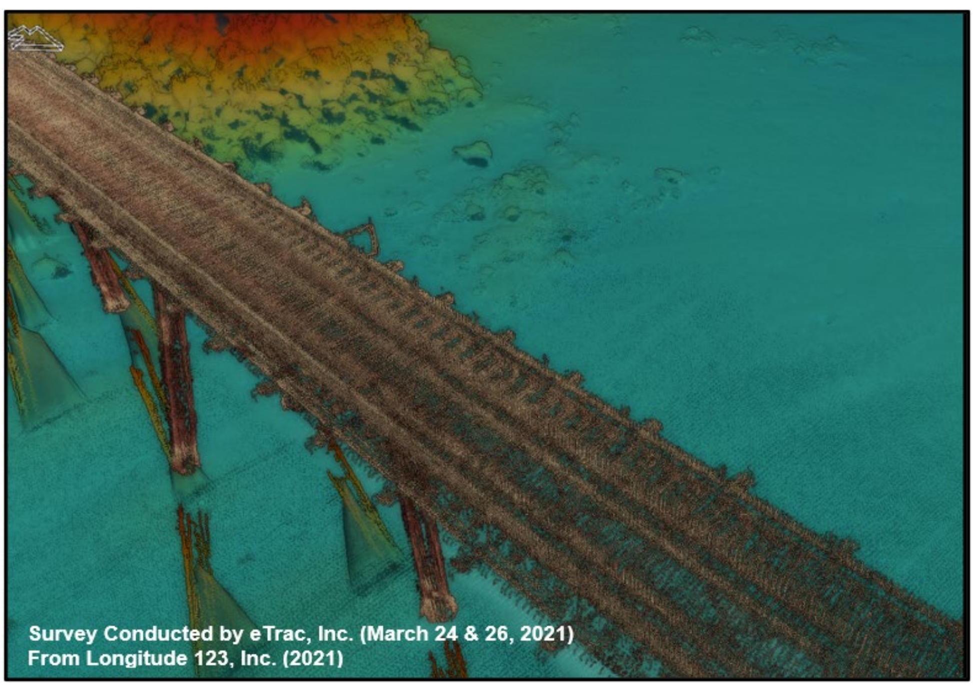

Figure 4-3. Multi-Beam and LiDAR Survey Data Showing Rincon Pier near Favored Take-off Point

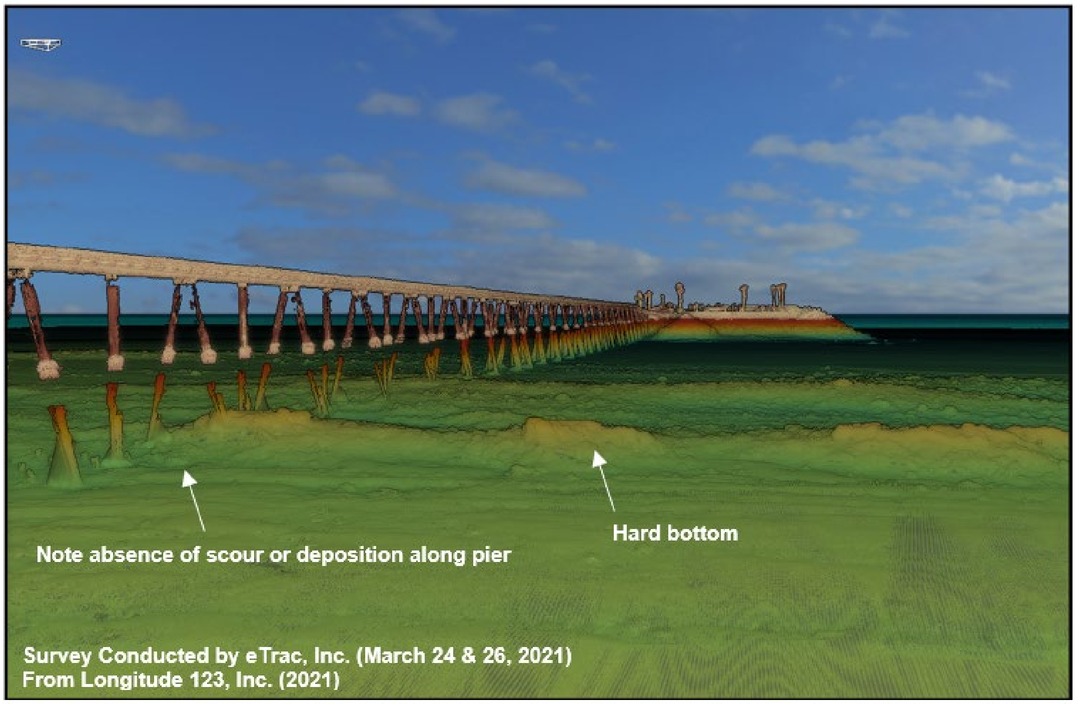

Figure 4-4. Sea Bottom at Rincon Pier

The study cites field inspections and historical aerial photographs used to evaluate the impact of each pier on sand transport in the adjacent littoral zone. The study concluded that the 20 piers, including the causeway access pier, had no effect on shoreline processes. Although two of the piers were located in areas that had experienced accretion, the gains were attributable to the presence of structures other than the piles supporting the piers. The study also cited findings of prior studies of pile-supported piers on coastal processes. Noble (1978) cited a study by J.W. Johnson (no reference provided) in 1973 that included 34 piers on the California coast and found no discernible effects on the adjacent shorelines resulting from pier construction.

Noble (1978) also researched theoretical/analytical studies that had been conducted to assess the effects of pile-supported structures on the transmission of wave energy. Most of the cited studies attempted to identify the factors that controlled or strongly influenced the transmission losses that occurred when waves passed through pile structures. The studies investigated longitudinal and transverse pile spacings, along with pile diameter and the number of piles. Considerations were given to the incident wave height and steepness and diffraction effects as the waves passed through the pile arrays. The findings of these studies indicated that for a range of incident wave steepness, when the pile spacing (both transverse and longitudinal) exceeds four times the pile diameter, reflection and eddy losses are of minor importance and the ratio of transmitted wave height to incident wave height should approach unity. Noble (1978) confirmed that the predominant swell conditions in the Southern California Bight fell well within the range of wave steepness parameters investigated in the cited studies.

As indicated previously, the causeway access pier has 16-inch diameter piles spaced 12 ft apart within each transverse bent, and pile bents that are spaced 40 ft apart in the longitudinal (shore-perpendicular) direction. Hence, the pile spacing is 10 times the pile diameter in the transverse direction and 33 times the pile diameter in the longitudinal direction – values that exceed the four-diameter pile spacing cited above by wide margins. Hence, the highly permeability causeway access pier has an insignificant effect on wave characteristics as they propagate through the structure.

4.1.1.3 Comparison with Mobil Seacliff Oil Piers Decommissioning

The Mobil Seacliff Oil Piers, aka "Oil Piers," were located just east of Punta Gorda and Rincon Island. Originally constructed in the 1930s, the piers were decommissioned and demolished in 1998. Concerns were raised by the local surfing community during the regulatory process for decommissioning regarding potential degradation of surfbreak quality if the pier structures were removed. While there were differing professional opinions regarding the impact of Oil Piers removal on surfbreak quality, there was consensus that the small diameter pier pilings had negligible effect on wave attenuation and sedimentation. However, the offshore pier structures at Oil Piers included large caisson structures that were cited as the features that "disrupt waves and the longshore current and create scour and deposition features (sandbars/shoals) that support surfing at Seacliff" (California Coastal Commission, 1997). There are no such caisson structures at the Rincon Island causeway access pier, and review of historical photographs of Oil Piers indicates the pier pilings were more closely spaced than those supporting the Rincon Island causeway access pier.

4.1.2 Removal of Abutment and Replacement of the Revetment

The right-handed point break at Little Rincon/Mussel Shoals is caused by two natural features: (1) the protruding bedrock outcrop at the landside terminus of the causeway access pier, and (2) the abrupt change in shoreline orientation that occurs at this location (Figure 2-5). The outcrop also is responsible for the wide, sandy beach that exists to the north, which predated the addition of the abutment and associated revetment (Figure 2-4).

The abutment and revetment (Figure 1-2) are located well above the elevation on the headland profile that would exert a significant impact on waves and sediment movement, and hence on the surfbreak. As a result, it is anticipated that removal of the abutment and associated reconfiguration of the riprap revetment would not exert a significant impact on the existing surfbreak.

4.2 Removal of Causeway without Abutment / Revetment Modification

For the reasons cited in Section 4.1.1, full removal of the causeway access pier will not impact the surfbreak.

4.3 Partial Removal of Causeway without Abutment / Revetment Modification

For the reasons cited in Section 4.1.1, partial removal of the causeway access pier, like complete removal, will not impact the surfbreak.

5 Conclusions

The local surfbreak, known as Little Rincon or Mussel Shoals, is a right-handed point break induced by the protruding natural bedrock outcrop where the landside terminus of the causeway access pier is founded, and the sudden change in shoreline orientation induced by this natural headland. Analysis of multiple historic aerial photographs from 1927-1945 clearly show the rock outcrop at Punta Gorda pre-dates the Rincon Island construction in 1959, and this natural rock feature, without the added concrete abutment and riprap, is the cause of the wide updrift sand beach. This same natural feature that retains the updrift sand beach also creates the Little Rincon point break. The man-made "abutment" at the landside terminus of the pier is well-above an elevation on the headland profile that would have any significant impact on waves and sediment movement, and hence on the surfbreak. Given the fact that the primary "structure" that creates the point break is the natural rocky headland, removal of the abutment and reconfiguration of the adjacent rock revetment would not be expected to have any significant impact on the surfbreak.

The Little Rincon surfbreak was observed during large west swell conditions on January 6, 2023 and chronicled via aerial drone and ground photos. Three Google Earth® photographs were also identified which capture the surfbreak under high quality surfing conditions. In all cases, there is no indication of any impacts of the pier pilings on the waves, either in height or direction, nor scattering due to reflection. The waves appear to simply pass underneath the pier as if it were transparent to the waves. This is to be expected, given the slender pilings and their large spacings. Furthermore, review of detailed site bathymetric data shows no evidence of a "scour canyon" underneath the pier, which can be found at piers whose pilings are very large in diameter and closely spaced.

As surfers ourselves, the study authors also took care to observe possible nuanced effects that the causeway access pier structure may have on the surfbreak (e.g., the quality of the takeoff). In addition to our observations on January 6, 2023, we reviewed multiple on-line videos of the surfbreak under varying conditions and found no evidence of a beneficial effect of the pier on surf ride quality.

Available technical literature on the impact of pier structures on shorelines was reviewed because shoreline shape and configuration can have a direct impact on surfbreak quality. Noble (1978) conducted a study of coastal structures' effects on shorelines in southern California. The study focused on the effect of (1) shoreline piers; and (2) offshore structures (artificial island and breakwaters). A total of 20 piers within the Southern California Bight (from Point Conception south to San Diego) were analyzed, including the causeway access pier. The study concluded that the causeway access pier had no effect on shoreline processes, again citing the relatively slender piles and large spacing.

Regarding potential similarities with the 1998 Mobil Seacliff Oil Piers removal, there was consensus of professional opinions that the slender pier pilings had no impact on surfbreak quality. However, in the case of Oil Piers, large caisson structures were cited as potential reasons for surf enhancement; no such caissons exist at Rincon Island.

Based on the analyses described in this study, the causeway access pier has no discernible effect on the Little Rincon surfbreak. Hence, there was no need for further investigation to reduce the pier's impacts by evaluating partial causeway pier removal.

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