January 11, 2017 King Tide at Its Beach
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City of Santa Cruz Beaches

Urban Climate Adaptation Policy Implication & Response Strategy Evaluation Technical Report

June 30, 2020

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Report Prepared for the City of Santa Cruz

Report prepared by the Central Coast Wetlands Group at Moss Landing Marine Labs and Integral Consulting

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1. Introduction

Project Goals

The City of Santa Cruz (City) and Central Coast Wetlands Group, with funding provided by the California Coastal Commission, have drafted a set of long- term strategies aimed at addressing the hazards of coastal climate change in a holistic and strategic manner to achieve the City's future 2100 coastline.

To understand the incremental effects of coastal adaptation actions on coastal resources (beaches, coastal access and use, visual and recreation) the City of Santa Cruz initiated this evaluation of adaptation options for beaches within the city limits to inform a more strategic and iterative approach to coastal climate adaptation. This beaches adaptation and management planning effort includes qualitative, quantitative, socioeconomic and geospatial analysis methods to assess the vulnerability of beach resources from sea level rise and identify policy and strategies to increase resiliency of coastal resources and public access. The evaluation focuses on policies and strategies to support coastal adaptation, (i.e., those called out in the City's Administrative Draft LCP, 2018 Climate Adaptation Plan Update, and those recommended in the Coastal Commission Sea Level Rise Policy Guidance) for identified hazards along City of Santa Cruz coastal beach segments.

This evaluation:

- Supports city staff selection of preferred adaptation strategies and pathways to address projected risks for beaches within the City of Santa Cruz
- Identifies secondary consequences to each of the adaptation strategies selected. (e.g., impacts to recreation, tourism, affordable housing of low income communities, etc.)
- Identifies policy and engineering strategies to mitigate any secondary consequences of the alternative adaptation strategies.
- Recommends triggers/thresholds (e.g.. beach width or repairs frequency) that initiate next phase adaptation strategies within a pathway.
- Evaluates and identifies public finance options and innovative funding to mitigate secondary consequences of adaptation strategies.

These strategies, their costs, tradeoffs, and funding mechanisms will then be presented to decision makers and the public to evaluate equitable cost share strategies. The evaluation will support the integration of policies and programs (seawall mitigation funds, beach nourishment programs, defined coastal retreat areas) needed to maintain beaches, coastal access and recreation for all that live and visit Santa Cruz.

This document outlines the various adaptation strategy alternatives that are applicable to beaches within the City limits, an overview of adaptation pathways, and discusses the importance of triggers when moving from one adaptation strategy to the next. This document also establishes a process by which City staff, the Technical Advisory Committee (TAC), and stakeholders can work to select preferred beach-specific adaptation pathways which support priority coast wide and beach specific management goals.

Planning Context

The City of Santa Cruz has been a leader in coastal climate change resiliency planning. Soon after the 2009 Pacific Institute hazard maps were generated, City staff initiated efforts to integrate this information into City plans. With Federal Emergency Management Agency (FEMA) planning grant funds, the City staff initiated the first LHMP update in California to include sea level rise projections and adaptation strategies. With help from Dr. Gary Griggs and Dr. Brent Haddad at the University of California, Santa Cruz, the City completed a Climate Change Vulnerability assessment (2011). The completed assessment was then reviewed by City department heads and response strategies were identified and integrated into the 2012 Climate Adaptation Plan and LHMP.

In 2016, the City partnered with Central Coast Wetlands Group (CCWG) to update the hazard analysis for use in the City update to the Climate Adaptation Plan. CCWG used the 2012 Coastal Resilience hazard layers to further evaluate future coastal hazards to City infrastructure and identify adaptation actions that could lessen the risks to the City and its businesses and residents. The Climate Adaptation Plan Update also identified successful programs and projects implemented by the City to increase City resiliency to previously identified climate risks. The Climate Adaptation Plan Update also included an analysis of the unique challenges faced by underrepresented sectors of the community that should be considered as part of hazard mitigation and climate adaptation. This work included developing a social vulnerability score identifying vulnerable groups within the community based on incidence of poverty, disability, advanced age, language isolation, and crime by census block group. When climate hazard zones were overlaid onto the socially vulnerably census block groups, the City began assessing how to use the drivers of social vulnerability to tailor adaptation strategies to ensure better outcomes for these underrepresented groups. The Climate Adaptation Plan Update also included initial analysis of sea level rise to various surf spots.

The Climate Adaptation Plan Update was completed concurrently with the 5-year update to the LHMP and both were adopted by the City Council in October 2018. Building on the momentum from the LHMP and Climate Adaptation Plan Updates, the City's Planning Department and Climate Action Program applied for and was successful in receiving funding from the Coastal Commission LCP

grant program to evaluate impacts to beaches and identify policy actions needed to maintain and protect coastal access to City beaches in the face of rising sea levels. The City concurrently received funding from the State of California Department of Transportation (CalTrans) to draft a West Cliff Drive Adaptation and Management Plan. These planning efforts are occurring in parallel, leveraging the expertise of both teams and collaborating on adaptation policy development.

Project Process

This project has been completed in four phases (Figure 1). The first two phases (red and blue in Figure 1), provided the necessary information to select unique adaptation pathways for each beach segment. The third phase (orange in Figure 1) focused on selecting adaptation pathways for each beach segment that best meet the beach specific management goals. This phase also examines secondary consequences, fiscal and policy options for implementing the pathway, and identifies potential triggers to transition from one strategy to the next within the pathway. This report is a culmination of the efforts from the first three phases which are described in more detail below and which will be used to compile a policy guidance document (green in Figure 1) to be integrated into the City's LCP update (Planned for December 2020).

Phase I Resources Completed for Santa Cruz Beaches Adaptation Planning (Fall 2019)

Coastal Resource and Management Goals

The project team, in collaboration with City staff and the California Coastal Commission, developed coastal resource and management goals to guide the selection of adaptation pathways and address sea level rise hazards on each beach segment.

Coastal Resource Goals include:

1. Maintain/protect beach width where feasible.
2. Ensure sufficient city beaches along the length of the city coastline remain accessible in order to minimize increases in visitor densities on specific beaches and preserve public and private visitor serving facilities in collaboration with other agencies holding jurisdiction (e.g., Port District, State Parks).
3. Maintain a distribution of beach access points by encouraging a variety of transportation options along the entire city coastline.
4. Minimize coastal habitat loss and maintain ecological connectivity.
5. Address needs of underserved people of the community, both local residents and visitors with respect to housing, little to no cost access and recreation, day use parking, transportation, cultural and spiritual uses, and jobs.
6. Maintain public safety on beaches and when accessing beaches.
7. Accommodate a diversity of recreational activities for a range of users.

8. Maintain and enhance water quality to the extent feasible.
9. Encourage, enhance and maintain regional sediment supply to the coast.

Coastal Management Goals include:

1. Minimize coastal armoring.
2. Reduce beach area loss from placement footprint of shoreline protection structures.
3. Prioritize living shoreline adaptations.
4. Monitor coastal access infrastructure and beach width long-term and in response to extreme storm events; monitor how coastal change is impacting coastal use.

Beach Profiles and Use Statistics

Site information on each beach segment is found in Chapter 2 of this report and describes historical and existing condition, current visitor serving amenities offered, recreational use statistics (from 2019-2020 survey), and existing level of service provided to underrepresented user groups.

Beach Specific Hazards

Projected future hazard zones for the Santa Cruz coastline were interpreted as areas of the coast where various coastal climate hazards (rising tides, erosion and coastal storm flooding) are likely to occur in the future. These hazard maps are found in Chapter 3 of this report. The future event horizons were expressed for several future time horizons (e.g., 2030, 2060, 2100) and future ocean elevation range (e.g., 0.3 ft, 2.4 ft, 5.2 ft). However, there is uncertainty as to the rate that sea level rise will increase despite the use of best available modeling. Thus, the use of physical triggers (e.g. beach width) is useful rather than associating action with time horizons that are too late or early.

Adaptation Strategy Case Studies

The adaptation case studies (Appendix A) are intended to provide the project TAC, City staff, and other stakeholders with the background information needed to engage in dynamic conversations regarding adaptation applicability and tradeoffs within each of Santa Cruz's four beach areas. Case studies of strategy implementation are intended to provide real world examples of use, costs, benefits, and secondary implications of these strategies, and help stakeholders and decision-makers develop preferred adaptation strategies and integrated, multi-strategy adaptation pathways that transition between current and future climate horizons. Adaptation strategy case studies include:

- Beach nourishment
- Living shoreline
- Groins
- Sea Walls
- Managed Retreat

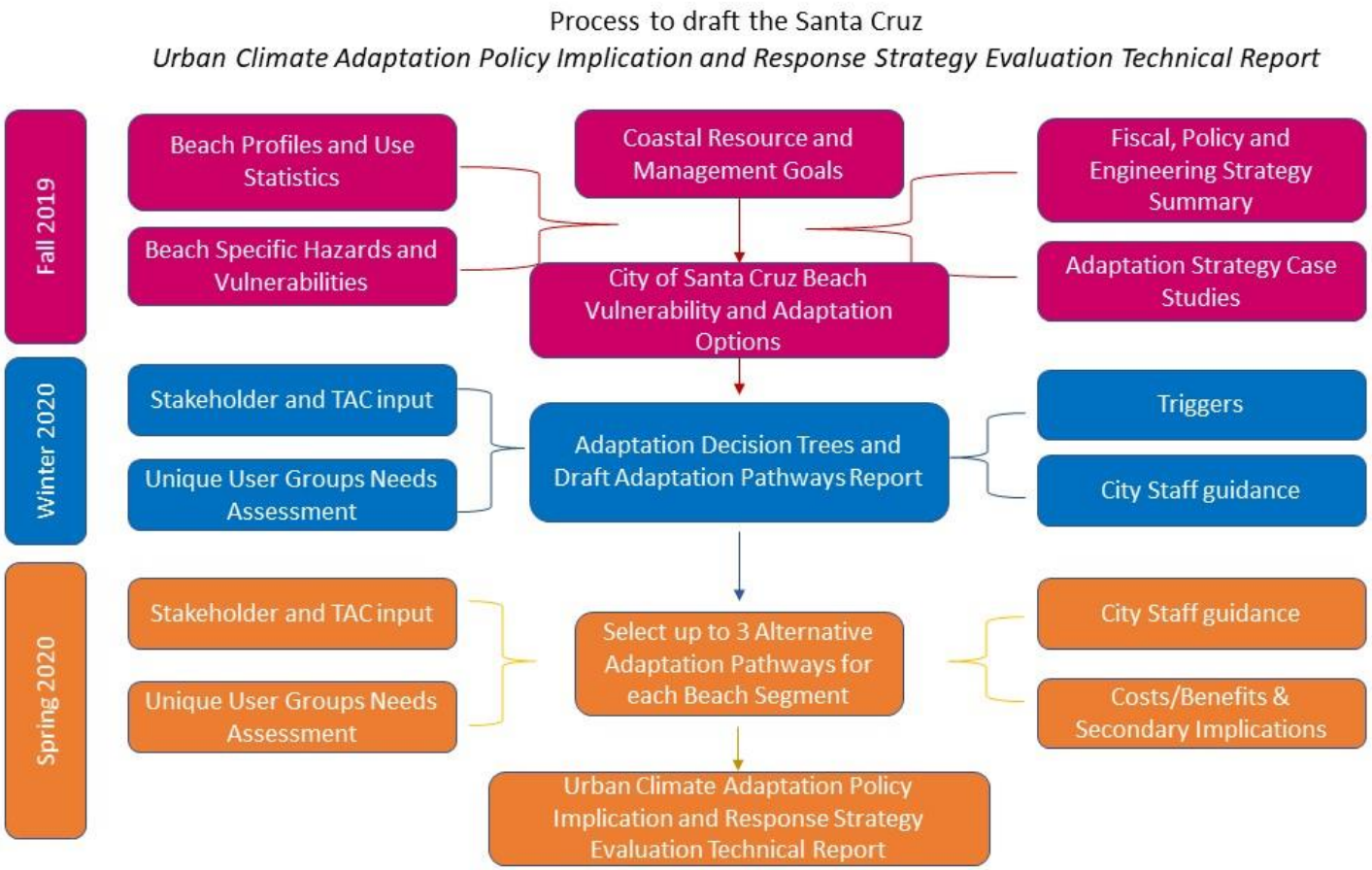


Figure 1. Beach adaptation planning process.

Inventory of Adaptation Alternatives

A number of adaptation guidance documents have been developed to help local municipalities link current and future hazards with alternative adaptation strategies. Strategies are often classified as being within one of three categories (accommodate, protect, retreat) with many methods to achieve these objectives.

Several guidance documents selected for use in this adaptation evaluation and prioritization include the Georgetown Adaptation Tool Kit (2011), the Center for Ocean Solutions Coastal California Adaptation Policy Briefs (2018), the ABAG Regional Resilience Toolkit (2019), and the California Coastal Commission Residential Adaptation Policy Guidance (2018). Each of these documents provides valuable information and useful recommendations regarding the applicability, challenges and legal and financial constraints that should be considered when selecting adaptation options.

An adaptation strategy summary matrix (Appendix B) includes reference to hazard response actions (accommodate, protect, retreat) and the needed policies, legal actions, programs and funding mechanisms to implement the described actions. The various actions can be used to address projected hazards. This table was updated during Phase II of the project. Adaptation strategies were selected from these resources for inclusion in the adaptation pathway alternatives for each of the beach segments.

Phase II & III Resources Developed for Santa Cruz Beaches Adaptation Planning (Winter & Spring 2020)

Stakeholder/TAC Adaptation Priorities

To complete an adaptation strategy prioritization effort, the Project Team, TAC, City of Santa Cruz Department Heads, and the public provided input on select preferred adaptation options, beach resource goals, and adaptation selection criteria (Figure 2).

Previous coastal hazard analysis and existing infrastructure information were provided during workshops for evaluation and comment. Preferred alternative strategies were noted by participants to help guide selection of draft alternative pathways for further review and comment. Participants noted the actions they felt best address projected hazards and align with their preferred vision of the future coastline.

Using compiled information from the TAC, City Department Heads, and Community Open House workshops, the Project Team created adaptation decision trees for each specific beach site. Decision trees include a decision point in which one or another strategy is chosen and a list of potential triggers that could be used to move from one strategy to the next. Decision trees have been previously used in climate planning[1] to help manage the uncertainty regarding when and how projected climate effects will manifest. The Decision Trees for this project were intended to be used to select preferred

[11] Ray, P. A., & Brown, C. M. (2015). Confronting climate uncertainty in water resources planning and project design: The decision tree framework. The World Bank.

adaptation pathways for each beach site. Outputs from the TAC, City Department Heads, and Community Workshop, as well as the adaptation strategy decision trees are summarized in Appendix C of this report.

Figure 2. Attendees of the community open house workshop in March 2020 give their input on priority beach resource goals.

Social Vulnerability Needs and Risk Assessment

Group discussions with under-represented groups helped identify how coastal change and adaptation efforts might impact various stakeholders' access to and enjoyment of the coast. This analysis aims to support future project selection and identify stakeholder groups that may be disproportionately impacted by coastal change and selected adaptation strategies.

Needs Assessment: Coastal infrastructure was inventoried to quantify the current level of access for historically under-represented groups that exists within each beach segment (see Appendix D: Social Vulnerability Needs and Risk Assessment). This information was used to characterize the unique infrastructure needs and existing infrastructure available to each historically under-represented stakeholder group. Current level of access is compiled for each beach segment and each stakeholder group interviewed.

Risk Assessment: Using the adaptation strategies developed within this document and the alternate pathways described, information on the unique needs of the surveyed groups were used to understand potential disproportionate impacts of alternate pathways on access to these groups and develop mitigation actions needed to better ensure adaptation pathways maintain or improve coastal access for these stakeholders. This risk assessment is summarized at the end of each proposed pathway in Chapter 5 of this report.

Adaptation Strategy Matrix

Appendix B provides a tabular review of adaptation options including policies recommended and, in some cases, references to policies adopted by other municipalities.

Adaptation Pathways

Using input from City staff, the TAC, and community on adaptation strategy preferences the project team, developed a set of adaptation pathways for each beach segment. These pathways are presented in Chapter 5 of this report.

Monitoring and Triggers

Decisions regarding when to end one adaptation strategy and transition to the next are best done using predetermined endpoint conditions. By selecting future conditions under which a change in strategy is warranted, the community can anticipate future stages of adaptation and track progress (monitoring) towards those conditions (triggers). The project team worked with city staff and stakeholders to identify triggers to initiate the transition from one adaptation strategy to another within an adaptation pathway. Often, these triggers represent a situation that predicts future impacts or infrastructure failure, allowing time for planning and permitting prior to taking action. Information needed to develop a monitoring plan is found in Appendix E. Beach specific triggers are also discussed in Chapter 5 of this report.

Funding Strategies Review

A list of funding strategies for resilience is presented in Appendix F of this report. Funding strategies that may be especially well suited for individual adaptation pathways are presented in Chapter 5. However, funding options are not limited and further consideration could be granted to any item from Appendix F, including less targeted strategies such as a carbon tax. We encourage the City to consider funding resilience measures at the broadest scale that is most feasible to minimize the administrative complexity involved with multiple funds. For instance, a special district along coastal areas may be able to fund multiple necessary actions. Additionally, it may be beneficial to coordinate with other parties, such as State Parks, the County, and the Port District to spread costs of projects that build resilience capacity and provide benefits across multiple jurisdictions.

Implementation Tools Matrix

Appendix G presents regulatory approaches to implementing adaptation strategies. Building code changes, redevelopment regulations, and tax incentives can help achieve more resilient infrastructure, while other policies (e.g., setbacks, transfer development rights, etc.) can aid in facilitating strategic and equitable managed retreat. Tools and their respective implementation programs are listed, along with examples of practice.

2. Site Description

Beach Segments

For this project, the City of Santa Cruz beaches were divided into four segments to aid planning and identify site specific adaptation strategies (Figure 3). These segments are: 1) Natural Bridges State Beach, 2) pocket beaches of West Cliff (divided into zones 1-4), 3) Main and Cowell Beaches spanning from the San Lorenzo River to Bay Avenue, and 4) Seabright Beach between the Santa Cruz Harbor and the San Lorenzo River. For each beach segment, beach descriptions, amenities and recreational use, and historical and existing site conditions are discussed in the following sections.

Figure 3. Beach segments included in evaluation and planning process

Natural Bridges State Beach

Beach Segment Description

Natural Bridges State Beach is a 65-acre California State Park known for its sheltered beach (Figure 4), natural bridge features, and as a monarch butterfly migration viewing location. The State Beach is open to year-round recreation including swimming, surfing, hiking, nature walks and picnics. The beach is sheltered, but afternoon winds attract kite flying and wind surfing. Surfing is busiest during the winter months when the swell is larger. Hiking trails pass through the Moore Creek estuary and the Monarch Butterfly Nature Preserve located north of the beach area. The Moore Creek lagoon is a valuable fresh/brackish water habitat that supports tidewater gobies and other special species.

Figure 4. Natural Bridges State Beach

Vehicular access to the beach is at the end of West Cliff Dr. with the road traversing the eastern bluff before meandering through the park to the parking area north of the beach. Secondary access for parks staff is available from Delaware Avenue.

The Natural Beach State Beach Plan, which is included in the City of Santa Cruz LCP (1992), addresses flooding and beach erosion and outlines habitat restoration activities prioritized for this beach. Natural Bridges State Beach has benefited from a diverse set of restoration activities focused on the dunes and bluffs on the east side of the beach. Groundswell Coastal Ecology has worked with State Parks and the California Native Plant Society Habitat Restoration Team over the past five years to plant native dune species and restore habitat for bluff nesting seabirds. This work has included fencing to focus and enhance access as well as protect dune habitat.

Historical and Existing Condition

Natural Bridges State Beach is named for the naturally occurring mudstone bridges that were carved by the Pacific Ocean into cliffs that jutted out into the sea. Wave erosion carved the arches and then cut away the cliffs, leaving only islands. Of the three original arches, only the middle one remains. The outermost arch fell during the early 20th century and the inner arch collapsed during a storm in 1980. The middle arch is in danger of collapsing as well due to erosion by wind and waves. Visitors were formerly permitted to climb up, walk and even drive from the bridges. Now the arch is closed to public access.

Amenities and Use

The lists of amenities and uses below are compiled from the Friends of Santa Cruz State Parks website, observational surveys conducted by the City of Santa Cruz, and local knowledge of the project team.

Amenities

- Hiking trails
- Bathroom
- Picnic Area
- Visitors Center
- Lifeguard
- There is a free parking lot next to an ocean/beach overlook

Coastal Use

- Tide pooling
- Shallow water play
- Surfing
- Boogie boarding
- Sunbathing
- Kite flying
- Whale watching
- Art

A site and time specific observational survey conducted by the City of Santa Cruz in the summer of 2019 helped to document the numbers of people participating in certain activities at a specific place and time (Figure 5 and Figure 6). A map of amenity locations is shown in Figure 7.

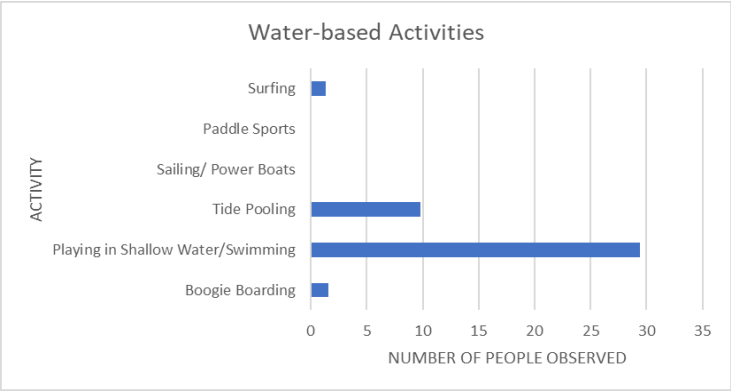


Figure 5. Average numbers of people observed participating in water-based activities at Natural Bridges State Beach

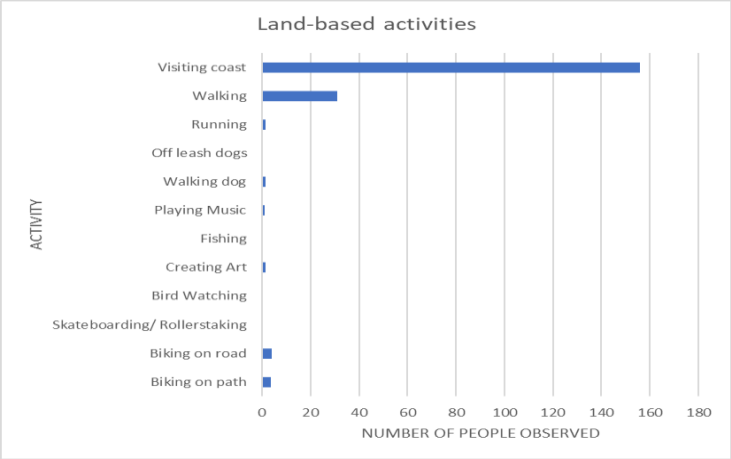


Figure 6. Average numbers of people observed participating in land-based activities at Natural Bridges State Beach

Figure 7. Map of Natural Bridges coastal access amenities

Existing Level of Service to Under-represented User Groups

Natural Bridges State Beach provides ADA access to the sand, ample parking, barbeques and picnic benches. There are numerous ADA view points and a well-used pedestrian path. A bus stop is located on Delaware Ave at the inland edge of the property. There is full access to the beach, surf and coastal viewing. There are no ADA parking spots on the West Cliff point parking area, which is frequented as a sunset viewing location.

This section of the coast provides a high level of service for all unique user groups. Elderly needs are well supported. This section of coast does not provide fire pits (although BBQs at picnic areas are available), fishing is restricted west of the beach, and there are no concessions within the park. Existing level of service is shown in Table 1. The full social vulnerability needs assessment is found in Appendix D.

Table 1. Natural Bridges State Beach: Priority amenities and level of access for under-represented user groups.

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low X Identified during interview as being a coastal resource used by group

West Cliff Pocket Beaches

Beach Segment Description

Santa Cruz's west side coastline is studded with a number of small to mid-size beaches distributed along the 2.7 miles of coastline. For this planning effort, West Cliff pocket beaches have been divided into four zones that correspond to the zones being used in the forthcoming West Cliff Drive Adaptation and Management Plan (Figure 8). Beaches of note include (from large to small), Its (Lighthouse) Beach (within Zone 3), Mitchell's Cove (within Zone 2), and Pyramid Beach (within Zone 1) (Figure 8). Several smaller beaches are found between Fair and Swift streets within Zone 1.

Its Beach is a south-facing beach below the bluff on the west side of Lighthouse Field. The City Parks and State Parks share management of the beach. The City manages Lighthouse point and State Parks manages the adjacent open space park across West Cliff Drive from the beach. There is a stairway providing safe access to the beach, which is frequented by dog owners and boogie boarders.

Figure 8. Popular pocket beaches along West Cliff Drive

Mitchell's Cove is located below the bluff between Woodrow Avenue and Almar Avenue. There is a parking lot right above the beach and a stairway that provides safe access down to the beach. During high tides and during the winter stormy months there isn't much dry sand exposed in Mitchells Cove. Rip rap has been piled up in the pockets of the bluff to minimize erosion from winter storms.

Pyramid Beach (also known as 222 Beach or Nude Beach) is located at Auburn Avenue. This beach has steep walls and is susceptible to erosion. The back of the beach has been filled with rip rap that currently has displaced some of the beach area. In the winter the sand is eroded away. In the summer, once the sand has built back up, a small secluded beach can be found. There is no stairway down to Pyramid Beach, so it is accessed using informal trails.

Restoration opportunities within the pocket beaches along West Cliff are somewhat limited due to intense winter swell. However, small restoration projects have been implemented along the first terrace of the bluff and along the coast recreation trail at several locations along West Cliff.

Historical and Existing Condition

West Cliff Drive's coastline consists primarily of 25 to 40-foot high bluffs that front an uplifted marine terrace. The bluff backed coastline is broken up by small pocket beaches, with Its Beach and Mitchell's Cove being the largest. Many of the smaller pocket beaches are backed by riprap so that as sea level continues to rise, these narrow beaches will gradually be lost (Griggs and Haddad, 2011) (Figure 9).

Figure 9. Rip rap backs many of the West Cliff pocket beaches

Its Beach is the most intensively used beach along West Cliff during the summer months. During the winter, storm waves lower the beach sand level and attack the bluffs at high tides. Monitoring of Its Beach during the 1997-98 El Niño documented that the 150-foot wide beach present in October was completely eroded by February and the sand had dropped about eight feet in elevation (Griggs and Haddad, 2011), demonstrating the dynamic fluctuations in beach width and elevation. There is limited armor backing the beach so as sea level has risen historically, the bluffs have gradually retreated, maintaining a narrow and heavily used beach. Overall, the low bluffs have changed very little over the past century. Riprap on the west side of Its Beach has reduced recreational use of this portion of the beach and limited lateral access west of the armoring to low tides. Rising seas will progressively narrow the summer beach and lead to more frequent and severe winter wave impacts, which even now overtops the bluff (Griggs and Haddad, 2011).

West Cliff Coastal Infrastructure and Armoring

The City has already begun adapting to large storm erosion events by armoring the coastal cliffs with rip-rap rock revetments. Where a shoreline is armored, wave energy is dissipated or reflected away from the cliff, thereby reducing erosion. However, there are secondary consequences and impacts such as burying of small pocket beaches and influences on coastal recreation, habitats, and access. As sea levels rise, waves will break with more energy and more frequently and higher on the revetments. This may increase the potential for more damage to the rock revetments along West Cliff, and more influences on other coastal recreational amenities.

Visitors enjoy a variety of coastal access opportunities along West Cliff Drive that include both lateral blufftop access as well as direct access to the beach. A 2019 survey of existing coastal access along West Cliff Drive documented 52 coastal access areas along West Cliff Drive (comprised of either a single trail or stairway, or a network of access routes including trails, paved walkways, stairways, or overlooks) that provide access to unique areas. In addition to the 2.7 miles of paved Recreational Trail, three miles of informal access trails exist. Access trails were designated as either "formal" or "informal." Formal access areas support amenities (e.g., stairs, benches, signage, maintained trail, maintained overlook) that encourage coastal access and recreational use. Informal access areas are characterized by unmaintained goat trails, often behind a fence with unsafe access conditions, and lacking visitor serving amenities (signs, benches, railing, etc.).

While formal designated paths, trails, stairways, and overlooks provide safer access to coastal resource areas, informal dirt trails exist along most of West Cliff, which in some cases provide unique access opportunities, but may also contribute to cliff erosion. Often these informal trails or networks of small goat trails are located on steep slopes. In some cases, the only access to the beach is down existing revetments.

Continued use of these types of informal trails can increase erosion. Furthermore, informal access continues to be a safety concern. The City has reported multiple water rescues and or drownings along West Cliff in past years due to the public using informal trails to access the bluff, beach, or water in unsafe areas.

Of the 52 access areas identified, with 25 documented as solely informal access areas. These informal pathways can increase erosion through damage to vegetation, trampling of fragile bluff deposits, and channeling storm run-off during rain events. Opportunities exist to encourage use of the formal access areas and reduce the impact of the informal trail pathways, including through establishment of native planting areas and removal of iceplant. Where formal access ways do not exist, installation of such infrastructure can provide new, safe coastal access opportunities while also reducing cliff erosion.

Coastal surveys also documented storm drain infrastructure that is in disrepair and is adding to cliff top erosion.

Amenities and Use

The lists of amenities and uses below are compiled from the City of Santa Cruz website, observational surveys conducted by the City of Santa Cruz, and local knowledge of the project team.

Amenities

- Overlooks
- Walking/Bike path
- Benches

Coastal Use

- Tide pooling
- Fishing
- Art
- Dog walking
- Off leash dog
- Surfing
- Walking
- Sunset viewing
- Boogie Boarding

A site and time specific observational survey conducted by the City of Santa Cruz at Its Beach during the summer of 2019 helped to document the numbers of people participating in certain activities at a specific place and time (Figure 10 and Figure 11). Maps of amenity locations are shown in Figure 12 through Figure 15.

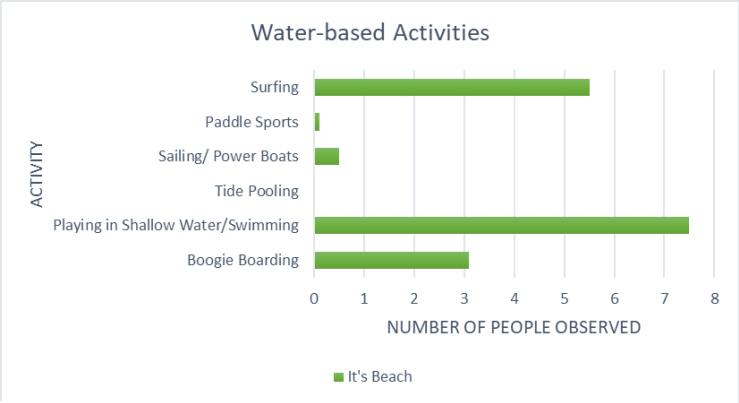


Figure 10. Average numbers of people observed participating in water-based activities at Its Beach

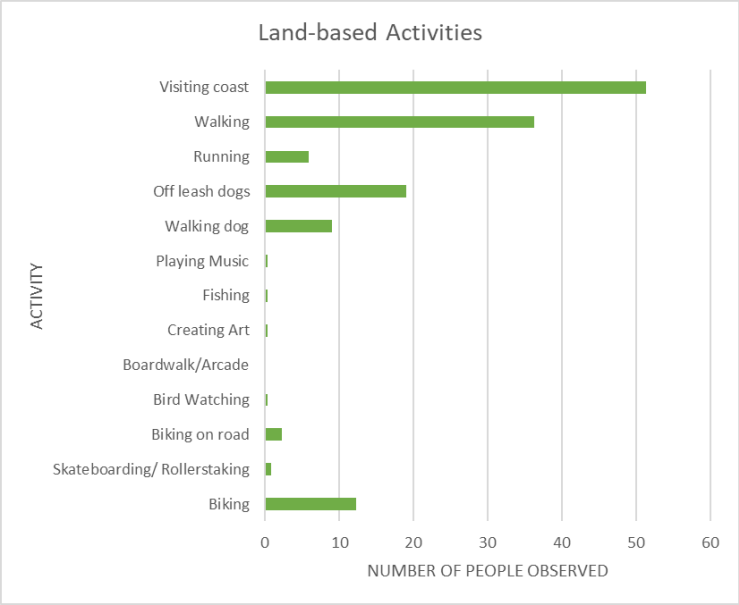


Figure 11. Average numbers of people observed participating in land-based activities at Its Beach

Figure 12. Map of West Cliff Drive Zone 1 (Pyramid Beach and adjacent clifftop access) coastal access amenities

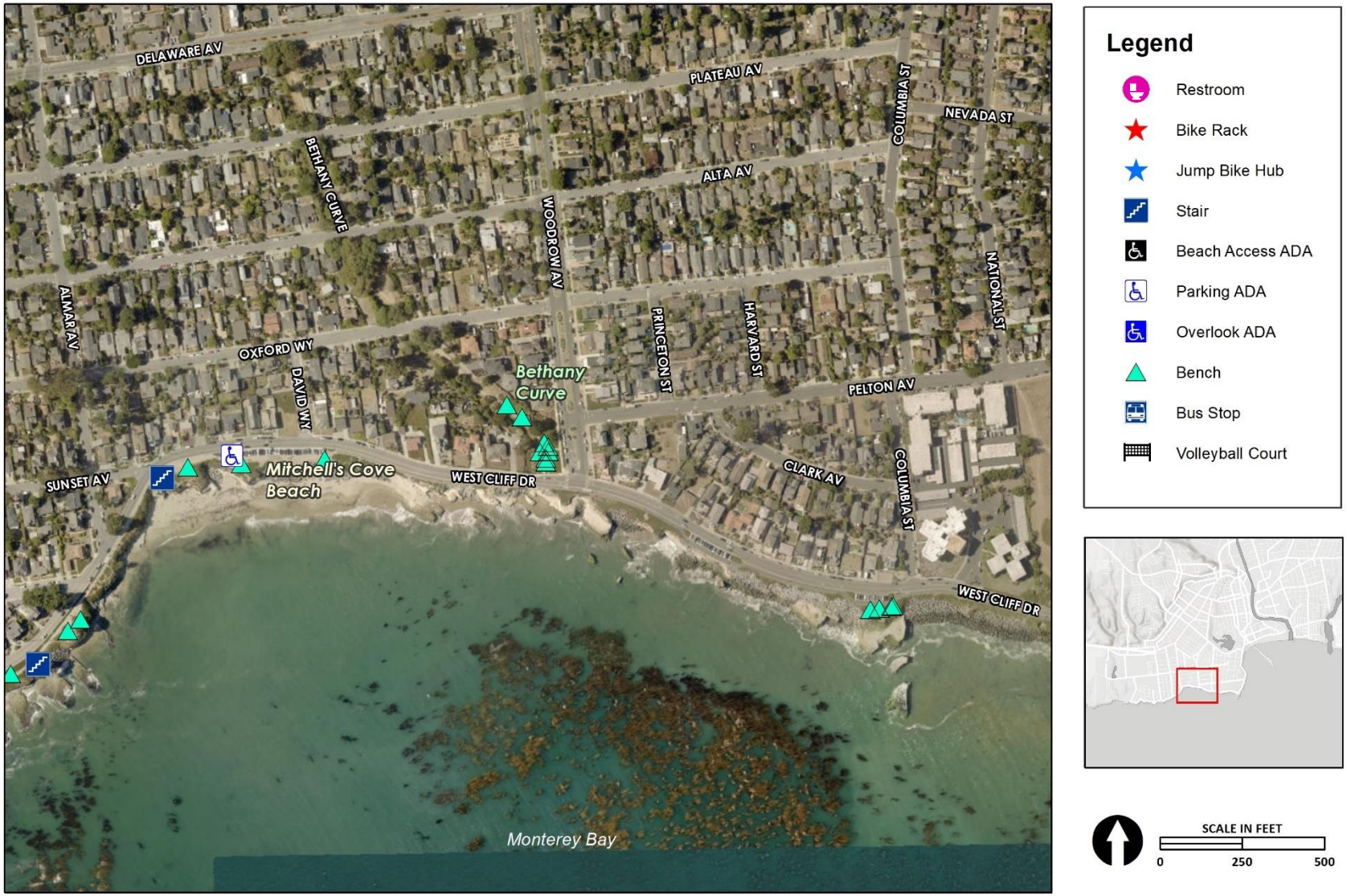


Figure 13. Map of West Cliff Drive Zone 2 (Mitchell's Cove) coastal access amenities

Figure 14. Map of West Cliff Drive Zone 3 (Lighthouse Point and Its Beach) coastal access amenities

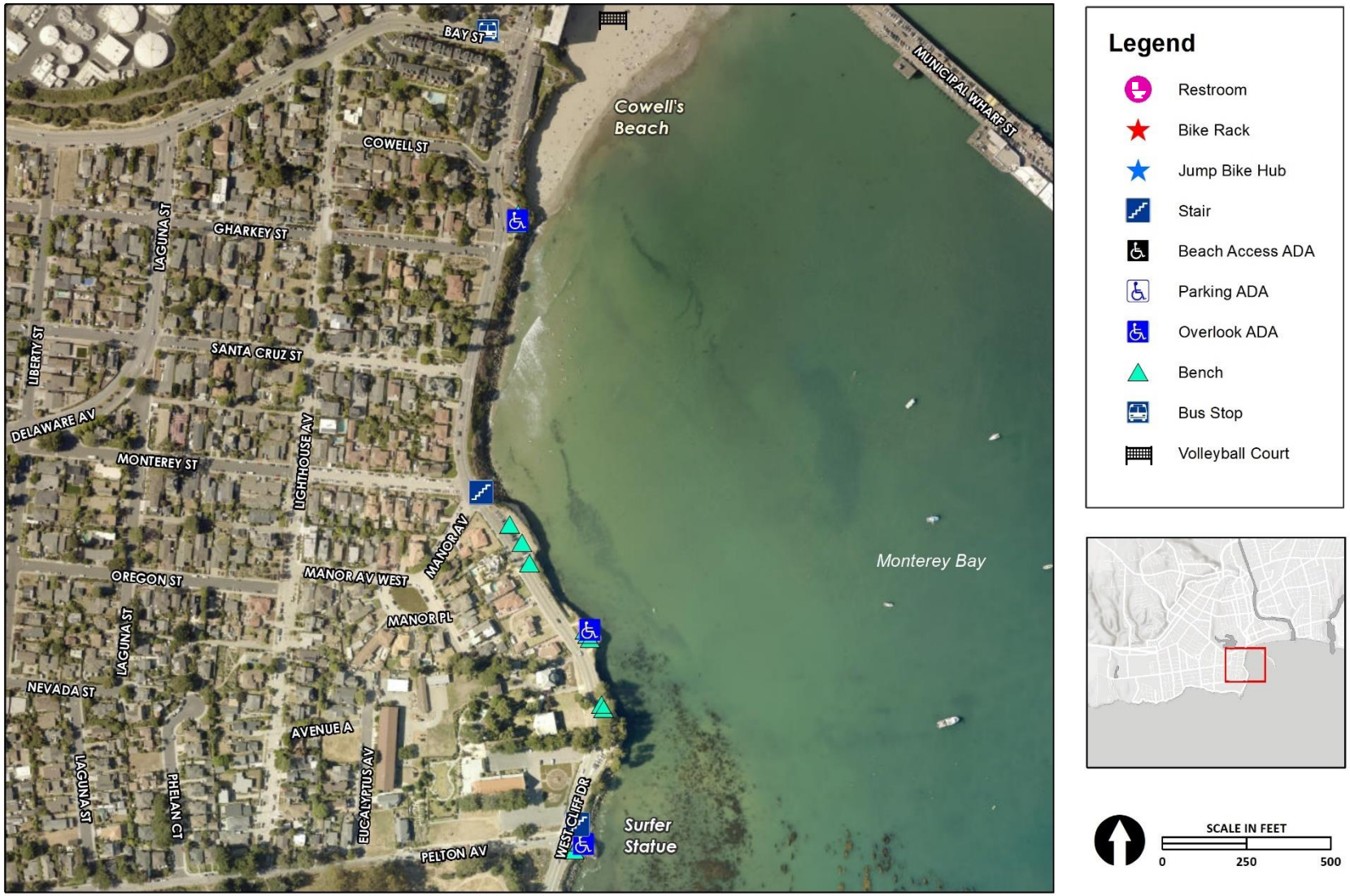


Figure 15. Map of West Cliff Drive Zone 4 (from Bay Street to Pelton Ave) coastal access amenities

Existing Level of Service to Under-represented User Groups

Lighthouse Point managed by the City, provides views of the Monterey Bay to many locals and visitors. Stairs at Its Beach and Mitchell's Cove provide easy (non-ADA) access to the beach and are frequented by boogie boarders and dog owners.

The coastline extending along West Cliff Drive is bisected by small pocket beaches. Many of the smaller pocket beaches are backed by riprap that limits access to many user groups and restrict use of the beach during high tides. Access to the numerous beaches is provided by a variety of sanctioned infrastructure including stairs (Its and Mitchell's) and overlooks, and informal dirt pathways and trails that the public uses to scramble down the cliff to gain access to the open terrace areas (fishing, picnicking and ocean watching) and to the beach and ocean (sand and surf access).

There are no wheelchair accessible pathways to the beach or ocean along West Cliff Drive. Access to many small beaches and water entry locations requires a scramble down the cliff and over rock revetment that is unsafe for many user groups, restricting their access to these areas. These informal accessways lead to further erosion of terrace and bluff deposits. Some pocket beaches are only usable at low tide and are flooded during high tide periods. Public restrooms along West Cliff are only available at Lighthouse Field.

The greatest level of access and service for underrepresented groups is provided near Lighthouse Point and Its Beach. Other zones of West Cliff drive provide much fewer safe access and beach recreational opportunities. For most under-represented groups, the greatest access and recreational opportunities provided by West Cliff Drive are the bike and pedestrian pathway and other cliff top viewing amenities (Figure 16). Steep natural cliffs and substantial riprap reduce water and beach access along Zones 1 and 2 to most of the surveyed groups. Existing level of service for each zone is shown in Table 2 through Table 5. The full social vulnerability needs assessment is found in Appendix D.

Figure 16. West Cliff Drive offers many cliff top viewing amenities

Table 2. West Cliff Drive Zone 1 (Pyramid Beach and adjacent cliff top access): Priority amenities and level of access for under-represented user groups. West Cliff Zone 1 offers the lowest level of access and service for these user groups.

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on West Cliff*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low **X** Identified during interview as being a coastal resource used by group

Table 3. West Cliff Drive Zone 2 (Mitchell's Cove): Priority amenities and level of access for under-represented user groups.

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on West Cliff*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low **X** Identified during interview as being a coastal resource used by group

Table 4. West Cliff Drive Zone 3 (Lighthouse Point and Its Beach): Priority amenities and level of access for under-represented user groups. West Cliff Zone 3 offers the highest level of access and service for these user groups.

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on West Cliff*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low X Identified during interview as being a coastal resource used by group

Table 5. West Cliff Zone 4 (Bay Street to Pelton Ave): Priority amenities and level of access for under-represented user groups

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on West Cliff*	*Water Access*	*Businesses / Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low X Identified during interview as being a coastal resource used by group

Main and Cowell Beaches

Beach Segment Description

Cowell Beach is located west of the Municipal Wharf pier (Figure 17). It is a popular beach for both locals and tourists and is known as a good beginner's surf spot. The Dream Inn is located behind Cowell Beach. The beach can be accessed from a stairway along West Cliff Drive or by the entrance to the Wharf.

On the other side of the pier is the larger and more popular Santa Cruz Main Beach (Figure 18). Main Beach is also known as Boardwalk Beach because of the amusement park that spans most of the length of this beach. Main Beach stretches from the mouth of the San Lorenzo River to the Santa Cruz Municipal Wharf wooden pier. Volleyball is popular here and there are many sand courts available. This beach is also frequented by locals and tourists and can get quite crowded on a warm summer day. The shops and attractions along Beach Street and the Santa Cruz Boardwalk are a popular place for tourists to visit. Lifeguards are commonly on hand at Main Beach making it a safer place for families to play in the waves. Parking is available on the streets nearby and on the Santa Cruz Wharf. The San Lorenzo River mouth has a sand bar that periodically closes the river mouth and creates a lagoon at the east end of the beach where a narrow rock fin wall extends into the surf.

Little restoration activity has occurred on Main Beach despite ample open space. The city recently installed a small bioswale near the Cowell Beach parking lot and an unknown entity planted coastal species adjacent to the east side of the Dream Inn foundation.

Figure 17. Cowell Beach

Figure 18. Main Beach

Historical and Existing Condition

Before the Santa Cruz Harbor was completed in 1965 the average width of Main Beach in the early 1960s was about 220ft (Griggs 2012). After completion of the harbor jetties, which helped trap sand at both Seabright Beach and Main Beach, the beach slowly widened and is now on average about 450 ft wide.

Figure 19. Historical fluctuation of width of Main Beach at end of Raymond Street, at end of the Boardwalk seawall, and near San Lorenzo Point. (From Griggs 2012)

The entire 3,700 feet of shoreline from the Dream Inn to the San Lorenzo River mouth, including the Boardwalk, has been protected for decades with a low concrete support wall. During large storm events winter waves can reach the beach edge of Cowell Beach and the concrete support wall along Main Beach. The top of the wall is at an elevation of about 14 feet; so while the beach itself may gradually narrow as sea level rises in the decades ahead, erosion risk is lessened because of the presence of the concrete support wall. A significant change in the storm wave climate and the rate of sea level rise could lead to the overtopping of these walls (Griggs and Haddad, 2011).

Several times a year, a sand bar builds at the mouth of the San Lorenzo River, creating a lagoon that pools water in front of the Boardwalk, threatening the historic site (D. Revel per com) (Figure 20).

Figure 20. Flooding in front of the boardwalk due to large winter storm in 2012. Source: Santa Cruz Sentinel, Dan Coyro.

Amenities and Use

Main and Cowell beaches provide a variety of coastal recreational opportunities including swimming and surfing, beach volleyball, and a summer junior guards' program. These beaches are also a primary tourist destination and visitors often enjoy the Wharf and Beach Street businesses. Evening concerts and beach movies occur throughout the summer months in front of the Boardwalk. The lists of amenities and uses below are compiled from the City of Santa Cruz website, observational surveys conducted by the City of Santa Cruz, and local knowledge of the project team.

Amenities

- Public bathrooms
- Public transit nearby
- Lifeguards
- Beach and water sport rentals
- 16 Volleyball Courts

Coastal Use

- Surfing and surf schools (Cowell Beach)
- Volleyball
- Boardwalk and arcade
- Boogie boarding
- Sunbathing
- Shallow water play

A site and time specific observational survey conducted by the City of Santa Cruz in the summer of 2019 helped to document the numbers of people participating in certain activities at a specific place and time (Figure 21 and Figure 22). Maps of amenity locations at Cowell and Main Beaches are shown in Figure 23 and Figure 24.

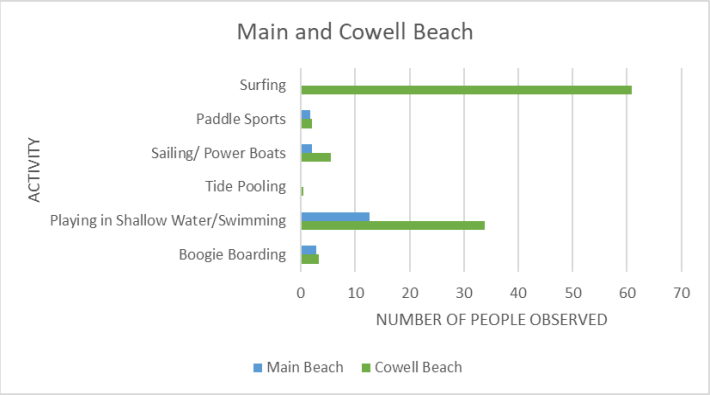


Figure 21. Average numbers of people observed participating in water-based activities at Main Beach and Cowell Beach

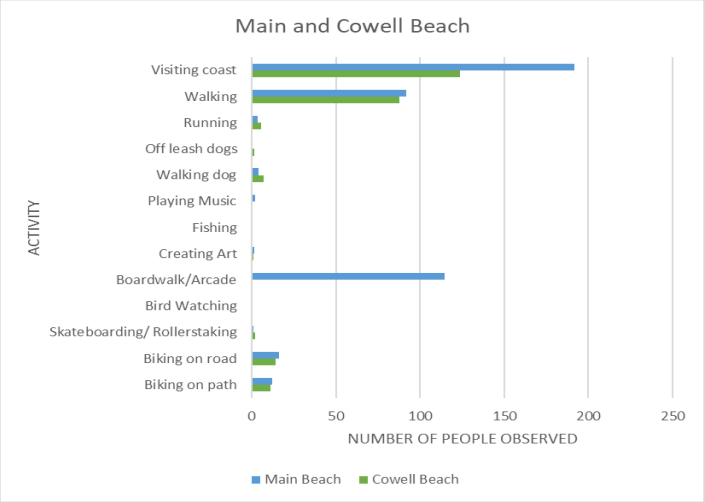


Figure 22. Average numbers of people observed participating in land-based activities at Main Beach and Cowell Beach

Figure 23. Map of Cowell Beach coastal access amenities of importance to under-represented user groups.

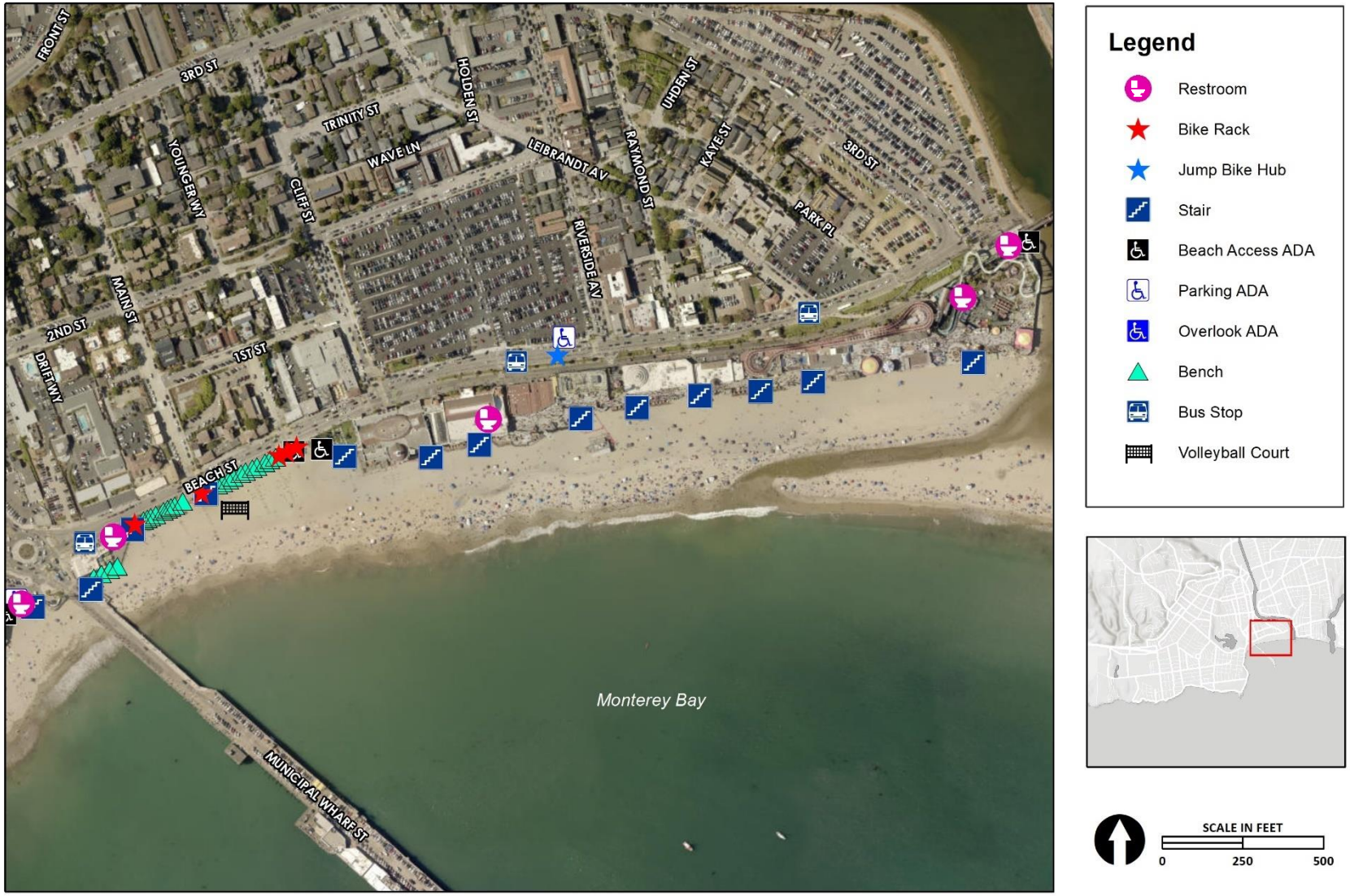


Figure 24. Map of Main Beach coastal access amenities of importance to under-represented user groups.

Existing Level of Service to Under-represented User Groups

Main and Cowell Beaches are primary coastal destinations for out of town visitors. The Main Beach area provides numerous hotels and motels, parking, and restaurants. The Santa Cruz Beach Boardwalk and the Santa Cruz Wharf provide unique visitor experiences and access to the coast. ADA amenities are numerous, providing many coastal and beach access opportunities. Wooden pathways are installed every summer allowing wheelchair access to Cowell and Main beaches. Valued visitor access amenities include overlook benches, bike racks, a Jump Bike hub, and a roadway separated bike path.

Main and Cowell beaches provide a variety of coastal recreational opportunities including swimming and boogie boarding, beach picnicking and numerous volleyball courts. The Boardwalk provides access through the park to the beach at no cost, making restrooms and other amenities available to all. The Boardwalk provides summer movies and concerts on the beach and partners with City Parks department and other venues to sponsor numerous coastal events from chili and chowder cookoffs to an annual marching band competition. Summer activities include surfing schools, city junior guard program, and numerous other sporting events.

Free parking is limited and vehicle access can be problematic during summer weekends. While numerous access points are available, transport of water sports equipment and vehicles is difficult through the Boardwalk but made possible near the Wharf entrance. Access ways through the Boardwalk to the beach are safe but do not provide ADA accessible access to the beach. Fires are prohibited as is overnight camping.

The overall level of access and service is high along Main and Cowell's beaches for most of the unique user groups surveyed (Table 6). The full social vulnerability needs assessment is found in Appendix D.

Table 6. Main Beach and Cowell Beach: Priority amenities and level of access for under-represented user groups.

MAIN BEACH

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

BEACH STREET

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

COWELL BEACH

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High | Moderate | Low | X Identified during interview as being a coastal resource used by group

Seabright State Beach

Beach Segment Description

Seabright State Beach (also known locally as Castle Beach) is part of Twin Lakes State Beach and managed by State Parks staff. It is a popular beach that spans a wide stretch of sand from the Santa Cruz Yacht Harbor entrance and West Jetty to a narrow natural rock wall that juts out into the surf at the mouth of the San Lorenzo River (Figure 25). At the bottom of this rock wall is a small rock arch opening that lets river water pass through. Shifting sand sometimes closes up the arch, but at times it's possible to crawl through and wade the river water to reach Main Beach. People are no longer allowed to walk the trail on top of this narrow fin, but many locals jump the fence and go out on the rock wall despite the "area closed" signs.

The Walton Lighthouse is located at the end of the Santa Cruz Harbor's West jetty where a paved walking path allows residents and visitors to walk out and look back at Seabright Beach. Parking and beach access are available at the west end of East Cliff Drive near Alhambra Avenue, Mott Avenue, and at the end of 3rd Avenue.

Restoration efforts, spearheaded by Groundswell Coastal Ecology, were initiated in 2011 to enhance back dune and jetty habitat (Figure 26). Most of this work has occurred on CA State Parks and Port District properties with a small portion on City of Santa Cruz land.

Figure 25. Seabright State Beach looking East towards Walton Lighthouse

Figure 26. Dune restoration efforts by Groundswell Coastal Ecology along Seabright State Beach

Historical and Existing Condition

Prior to the construction of the jetties at the Santa Cruz Small Craft Harbor in 1963, the 2,500 foot length of Seabright Beach was very narrow, even in the summer months. Based on historical imagery (UCSC Commons), average beach width was approximately 150 ft (Figure 26). Waves often attacked the bluffs during the winter months, and sometimes even during summer high tides (Figure 28).

Figure 27. 1953 historical photo shows narrow beach width and bluff erosion at Seabright Beach. source: UCSC Digital Commons

Figure 28. Waves breaking up against the bluffs and old castle at Seabright State Beach in 1953.

Seabright beach is backed by bluffs that are 35 to 40 feet in height consisting of Purisima Formation capped by up to 15 feet of weaker terrace deposits. Erosion rates determined from aerial photographs averaged 6 to 18 inches/yr during the decades prior to harbor construction (Griggs and Haddad, 2011). A number of private seawalls and bluff stabilization structures were constructed by private land owners prior to construction of the harbor.

The harbor jetties, constructed in 1963, began to trap littoral drift sands moving down coast and Seabright Beach gradually widened (Figure 29). Over the next 20 years, beach width reached 300 feet at the west end near San Lorenzo Point and about 600 feet next to the jetty (Griggs and Haddad, 2011). With this wide sandy buffer, wave attack and erosion of the bluff has been reduced significantly. Bluff

failure at the west end of Seabright Beach occurred during the Loma Prieta earthquake.

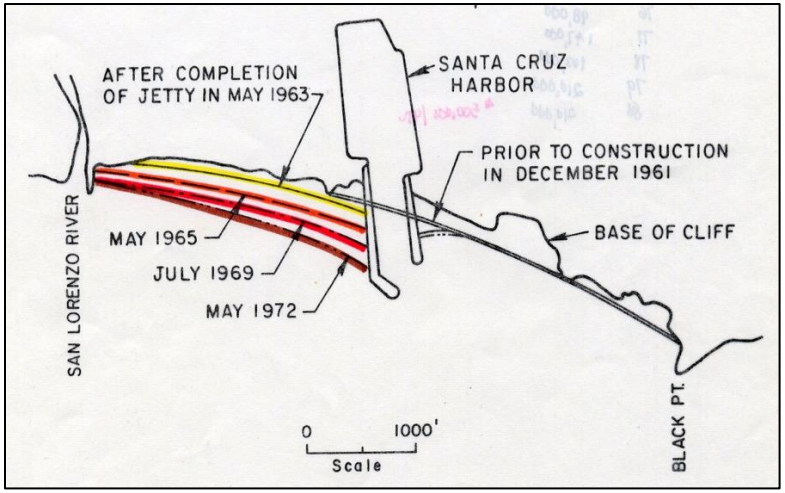


Figure 29. Progressive widening of Seabright Beach following jetty completion (from Moore, 1972).

Depending upon the rate and magnitude of future SLR, Seabright Beach will gradually narrow and the waves will again reach the base of the bluffs in the winter, contributing to erosion.

The lowest elevation along this stretch of coastline is at the main access path to Seabright Beach at the end of Cypress Avenue. High tides and storm waves do occasionally wash this far inland, carrying logs and other debris.

Habitat restoration efforts that include native plantings have been incredibly effective at improving coastal dune habitat condition adjacent to the Seabright Beach entrance (Pilkington Creek) and adjacent to the harbor jetty.

Amenities and Use

Seabright Beach provides a variety of coastal recreational opportunities including swimming and boogie boarding, beach picnicking and evening bonfires. Most beach access and amenities are managed by State Parks staff. The lists of amenities and uses below are compiled from the Friends of Santa Cruz State Parks website, observational surveys conducted by the City of Santa Cruz, and local knowledge of the project team.

Amenities

- Public bathrooms
- Public transit nearby
- Lifeguards (1 lifeguard tower active during summer months)
- Firepits
- Free parking in the neighborhood surrounding the beach.

Coastal Uses

- Shallow water play
- Sunbathing
- Boogie boarding
- Surfing (river mouth and jetty, sandbar dependent)
- Fishing
- Volleyball
- Dog walking
- Harbor access
- Jetty/lighthouse access
- Sunset viewing
- Walking
- Kite-flying

A site and time specific observational survey conducted by the City of Santa Cruz in the summer of 2019 helped to document the numbers of people participating in certain activities at a specific place and time (Figure 30 and Figure 31). A map of amenity locations at Seabright State Beach is shown in Figure 32.

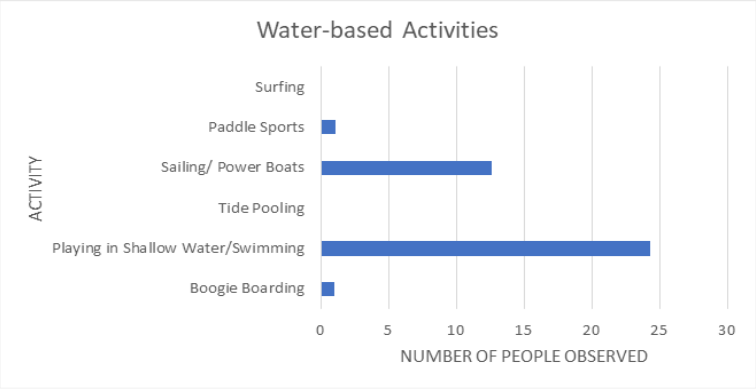


Figure 30. Average of numbers of people observed participating in water-based activities at Seabright Beach.

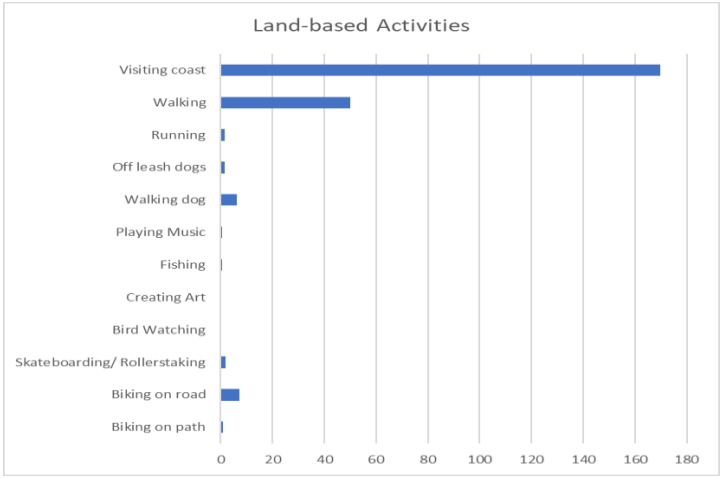


Figure 31. Average of numbers of people observed participating in land-based activities at Seabright Beach.

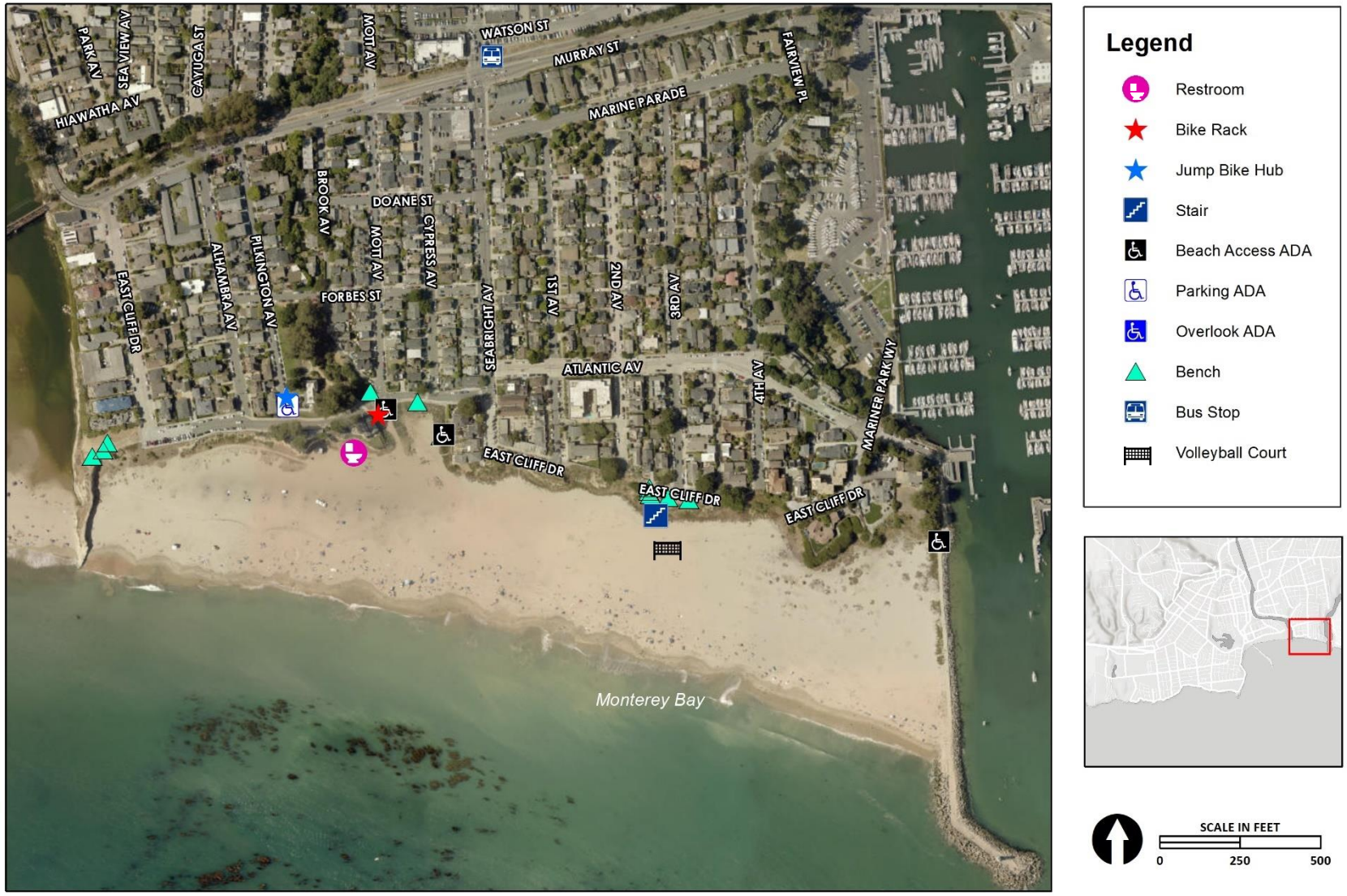


Figure 32. Map of Seabright Beach coastal access amenities

Existing Level of Service to Under-represented User Groups

Seabright State Beach provides a diverse assortment of public amenities and access opportunities. These include one ADA parking spot, numerous overlook benches (Figure 33), bike racks and a Jump Bike hub, three ADA access ways and use of a beach wheelchair if scheduled in advance of arrival. There are four gender neutral bathrooms near the Pilkington entrance as well as an exterior shower and sink. Access to the bathrooms requires travel across sand which may limit bathroom accessibility to some individuals. There are a large number of fire pits that are used frequently (Figure 34).

Access limitations for surveyed groups include limited access to the sand from ADA access ways, limited number of wheelchair sidewalk cuts (ADA coastal trail) along East Cliff and only one ADA parking spot. Safe transit down the cliff is not available in several frequented locations leading to informal access trails, risking injury and cliff erosion. The East side of Seabright beach offers fewer amenities (specifically ADA parking and bathrooms) identified as valuable to the surveyed groups. Overall level of service to most groups is high for both sections of Seabright Beach (Table 7). The full social vulnerability needs assessment is found in Appendix D.

Figure 33. A bench overlooking Seabright Beach at the end of Seabright Drive

Figure 34. Firepits are provided at Seabright Beach

Table 7. Seabright State Beach: Priority amenities and level of access for under-represented user groups. Seabright State Beach offers a high level of access and service for most of these user groups.

SEABRIGHT WEST

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

SEABRIGHT EAST

Interviewed Under-Represented Groups	Beach and Coastal Access Ways			Cliff Top Access and Coastal Viewing				Transportation			Recreation			Coastal Habitats		Overall Level of Service
	Safe/ADA Beach Access	*Beach Wheelchair Available*	*Fire Pits*	*ADA Overlooks*	*ADA Coastal Trail*	*Available Bathrooms*	*Benches*	*Bus Stop Proximity*	*ADA Parking*	*Jump Bikes*	*Camps & Special Events on Beaches*	*Water Access*	*Businesses/ Jobs*	*Stormwater Protection*	*Natural Habitat Areas*	
Elderly	X			X	X	X	X		X							
Youth	X						X			X	X	X	X		X	
People with Disabilities	X	X		X	X	X			X							
Low Income Residents													X	X		
Tribal	X														X	
Homeless			X			X									X	
LGBTQ+						X										
Fishers	X						X					X		X	X	

Level of Service Provided to Group

High Moderate Low X Identified during interview as being a coastal resource used by group

New State SLR Guidance

State guidance (Ocean Protection Council, 2018) suggests that "a Bayesian probabilistic framework" can support improved decision making and probabilistic projections represent consensus on the best available science for sea-level rise projections through 2150. With continued advances in sea-level rise science, it is expected that probabilistic projections will change in the future. However, within the Monterey Bay, probabilistic models are not yet available. To respond to state guidance, the Coastal Resilience hazard models (developed by ESA in 2014) were cross-walked with the probabilistic based-scenarios referenced within the most recent guidance (Table 8). For clarity, this report focuses the hazard analysis on a subset of those scenarios (red text in Table 8).

State guidance recommends evaluating the impacts of the highest water level conditions that are projected to occur in the planning area. In addition to evaluating the worst-case scenario, planners need to understand the minimum amount of sea level rise that may cause impacts for their community, and how these impacts may change over time, with different amounts of sea level rise.

Table 8. Comparison of OPC 2013 Guidance Document and 2018 Update's Probabilistic SLR projections

SCENARIO BASED PROJECTION: TIME HORIZON	SCENARIO BASED PROJECTION: EMISSIONS SCENARIO	SCENARIO BASED PROJECTION: SLR	PROBABILISTIC PROJECTION: EMISSIONS SCENARIO	PROBABILISTIC PROJECTION: LIKELY RANGE*: 66% PROBABILITY SLR IS BETWEEN…	PROBABILISTIC PROJECTION: 1-IN-200 CHANCE**: 0.5% PROBABILITY SLR MEETS OR EXCEEDS…	H++ SCENARIO***
2030	Med	4 in	High	**3.6 – 6 in**	9.6 in	12 in
2060	High	28 in	Low	6 – 14.4 in	**27.6 in**	45.6
			High	8.4 – 16.8 in	31.2 in	
2100	High	63 in	Low	10.8 – 27.6 in	**66 in**	121.2
			High	18 – 39.6 in	82.8 in	

*Notes: * low risk aversion projection, **Medium-high risk aversion projection, ***Extreme risk aversion projection*

Scenario Selection for Planning

Projected future hazard zones can be interpreted as areas of the coast where various climate impacts (rising tides, erosion and coastal storm flooding) are likely to occur in the future. The expected future event horizon can be expressed as a predicted time horizon (e.g., 2030, 2060, 2100) or for a future ocean elevation range (e.g., 4 in, 28 in, 63 in). Therefore, future adaptation pathway triggers can be either based on a future predicted date or other financial (e.g., inability to meet costs of a certain strategy) or physical (e.g., projected sea elevation) triggers. The use of physical

triggers like sea level rise is useful because they don't initiate but actions prematurely, but rather wait for the particular financial or physical phenomena to occur.

For ongoing management of beach and coastline resources, considerations regarding predicted time horizons should be taken when decisions as to if and how to adapt are made. Specifically, new infrastructure built within hazard zones should be designed to withstand the projected hazards while accommodating the appropriate level of uncertainty regarding the scale of the hazard (i.e. water elevation) and the predicted time horizon when these hazards will occur (i.e. 2030 through 2060). Red text (Table 8) highlight corresponding probabilistic sea level rise predictions with those used for modeling coastal and beach hazards (scenario-based model). Because such probabilistic projections (66% and 0.5%) have not yet been integrated with predictions for storm intensity and wave height and for changes in rainfall, and future emissions scenarios are extremely uncertain, it is likely inaccurate to assume the projected impacts have less than a 1% chance of occurrence by 2060.

Coastal Climate Change Hazards

The 2017 coastal climate change vulnerability analysis, conducted by CCWG for the City of Santa Cruz, uses the Coastal Resilience hazard model developed by Environmental Science Associates (ESA) and funded by the State Coastal Conservancy.[2] An important limitation of the original ESA hazard layers was addressed within the 2017 focus effort for the City of Santa Cruz. CCWG modified the hazard layers to account for reductions in potential hazards provided by current coastal protection infrastructure. This refinement of this coastal hazard analysis helped to better understand the future risks Santa Cruz may face from each individual coastal hazard process.

The 2017 vulnerability analysis evaluates the impacts of each individual coastal climate change hazard process (rising tides, coastal storm flooding, and erosion) for time horizons 2010 (existing), 2030 (.3ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR) on beach resources. Definitions of each of these hazards are discussed below. More information about the method used and the 2017 SLR assessment can be found in the City of Santa Cruz 2018 Climate Adaptation Plan Update (City of Santa Cruz, 2018a).

Rising Tides

These hazard zones show the area and depth of inundation caused simply by rising tides and ground water levels (not considering storms, erosion, or river discharge). The water level mapped in these inundation areas is the Extreme Monthly High Water (EMHW) level, which is the high water level reached approximately once a month.

[2] The Coastal Resilience model developed by ESA in 2014 mapped hazard zones at various sea level rise scenarios for each of the individual coastal hazards (rising tides, coastal storm flooding, and coastal erosion). The Coastal Resilience hazard layers are available for viewing through the online mapping viewer at www.coastalresilience.org.

Coastal Storm Flooding

The coastal storm flooding hazard zones depict the projected flooding caused by future coastal storms. The processes that drive these hazards include (1) storm surge (a rise in the ocean water level caused by waves and pressure changes during a storm), (2) wave overtopping (waves running up over the beach and flowing into low-lying areas, calculated using the maximum historical wave conditions), and (3) additional flooding caused when rising sea level exacerbate storm surge and wave overtopping. These hazard zones also take into account areas that are projected to erode, sometimes leading to additional flooding through new hydraulic connections between the ocean and low-lying areas.

Coastal Erosion

The coastal erosion hazard layers represent future cliff and dune (sandy beach) erosion hazard zones, incorporating site-specific historic trends in erosion, additional erosion caused by accelerating sea level rise and (in the case of the storm erosion hazard zones) the potential erosion impact of a large storm wave event. The inland extent of the hazard zones represents projections of the future crest of the dunes, or future potential cliff edge, for a given sea level rise scenario and planning horizon. The extents of these hazard zones were modified by CCWG to take into account existing coastal armoring through the year 2030.

Figure 35 provides examples of each of the three coastal hazards evaluated within this report.

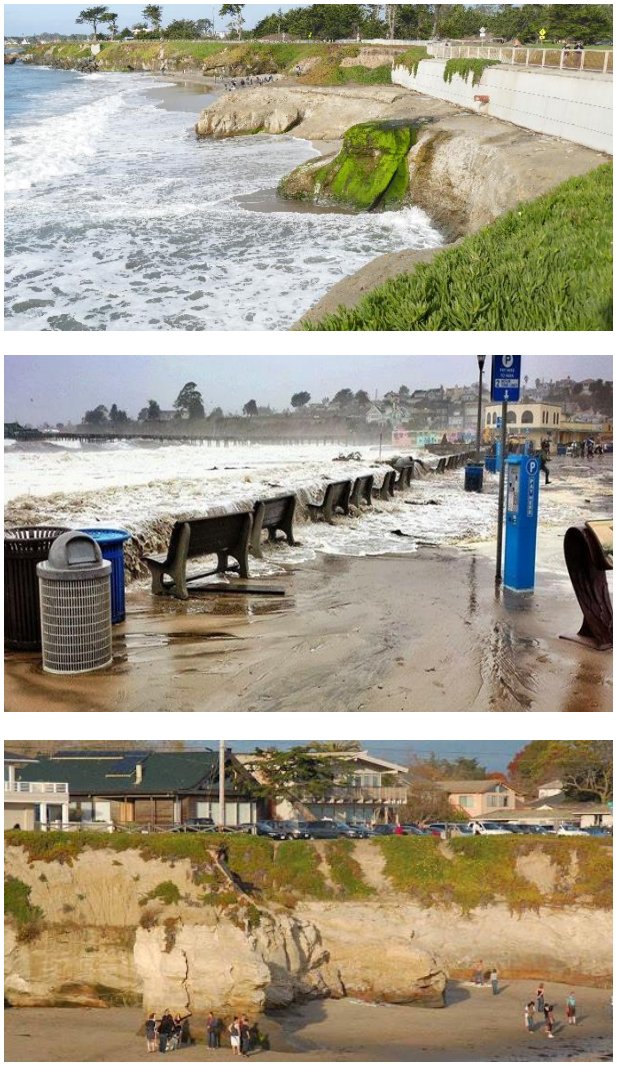


Figure 35. Loss of beach area at Its Beach due to King Tide in Jan 2020 (top), Wave overtopping of the Esplanade wall in Capitola Village during a storm event (middle), cliff erosion along West Cliff (bottom).

Natural Bridges State Beach Projected Coastal Hazards

The projected coastal hazard zones for Natural Bridges Beach for rising tides, coastal storm flooding, and bluff erosion can be found in Figure 36, Figure 37, and Figure 38 below.

Projected Impacts of Focus for this Report

- Coastal Flooding (CF): By 2030 all of the beach is projected to be inundated during large storm events
- Rising Tides (RT): By 2030 beach width may be reduced by 10%, by 2100 the beach width may be reduced by 30-50%.
- Bluff Erosion (ER): Erosion is projected to impact coastal access ways and habitat areas as early as 2030.

A summary of assets that are projected to be impacted by future coastal hazards is shown in Table 9.

Problem Statement

Natural Bridges State Beach is a large beach area at the west end of the City that provides beach access to many residents and visitors. The eastern bluff and adjacent parking and access road are vulnerable to coastal erosion and sea level rise is projected to flood large portions of the beach. Back bluff erosion may lead to loss of parking and picnic areas and may impact coastal habitat areas including Moore Creek lagoon.

Table 9. Assets projected to be impacted by coastal hazards at Natural Bridges Beach.

Severity characterized as Low-short term impacts with minimal rebuild required, Moderate-some infrastructure replacement required, High- significant impact to infrastructure requiring significant replacement.

Asset	Hazard	Time horizon	Severity
Access Driveway	CF ER	2030 2060	Moderate Severe
Habitat: Intertidal	CF ER	2030 2030	Moderate Moderate
Habitat: Lagoon	CF ER RT	2030 2060 2060	Low Moderate Severe
Habitat: Nesting bird	ER	2030	Moderate

Management and Resource Goals

Beach resource and management goals identified for Natural Bridges State Beach include

- Maintain or increase beach area for public recreation
- Work with State Parks on managed retreat plan that meets beach width goals, considers unique aquatic habitat (e.g., tidepools, lagoon etc.), and supports habitat restoration objectives.
- Investigate alternative access ways to Natural Bridges outside of erosion and flood hazard zones, so as to maintain multimodal access
- Focus on living shoreline adaptations.

Figure 36. Rising tides hazard zones at Natural Bridges Beach for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

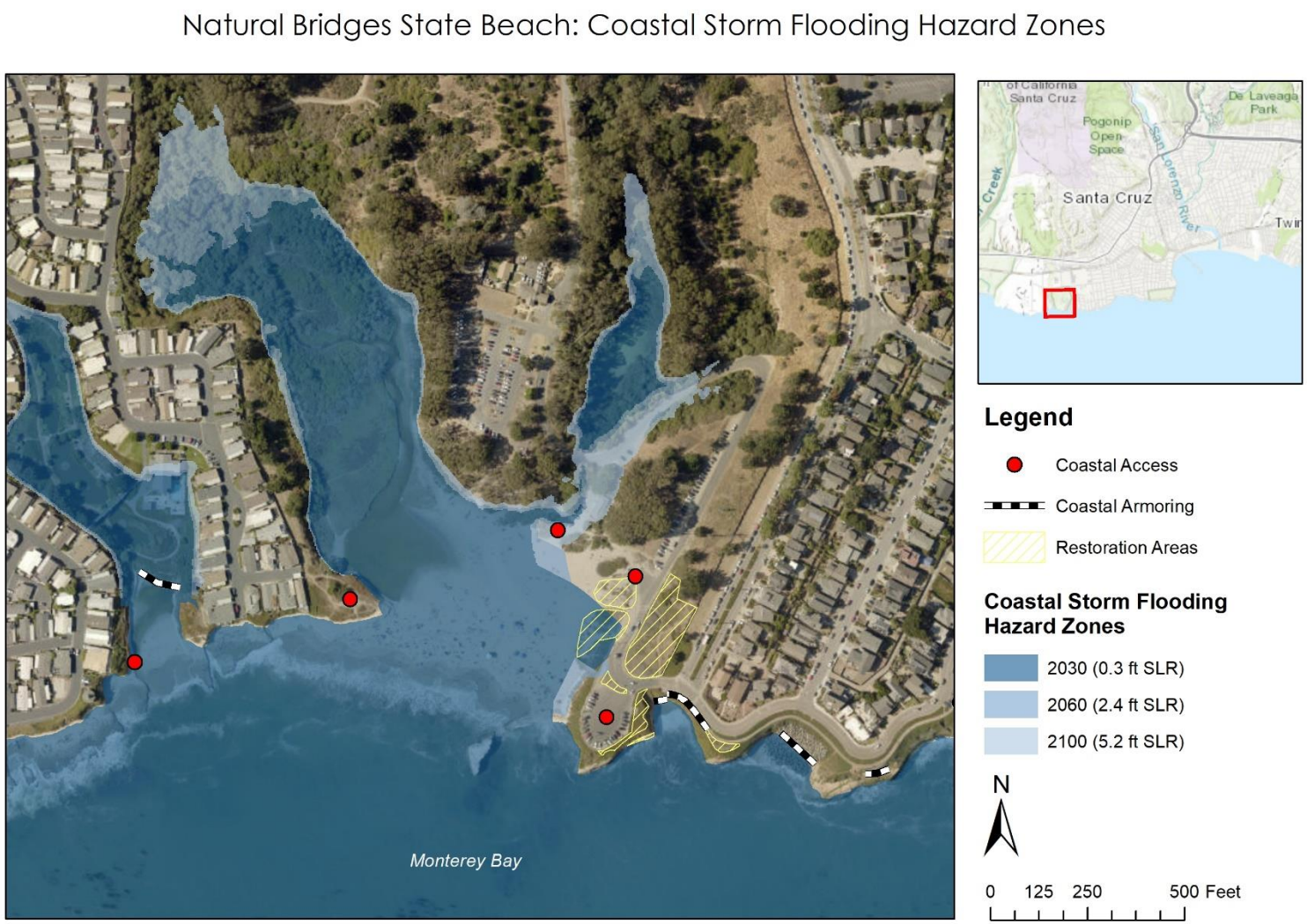


Figure 37. Coastal storm flooding hazard zones at Natural Bridges Beach for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

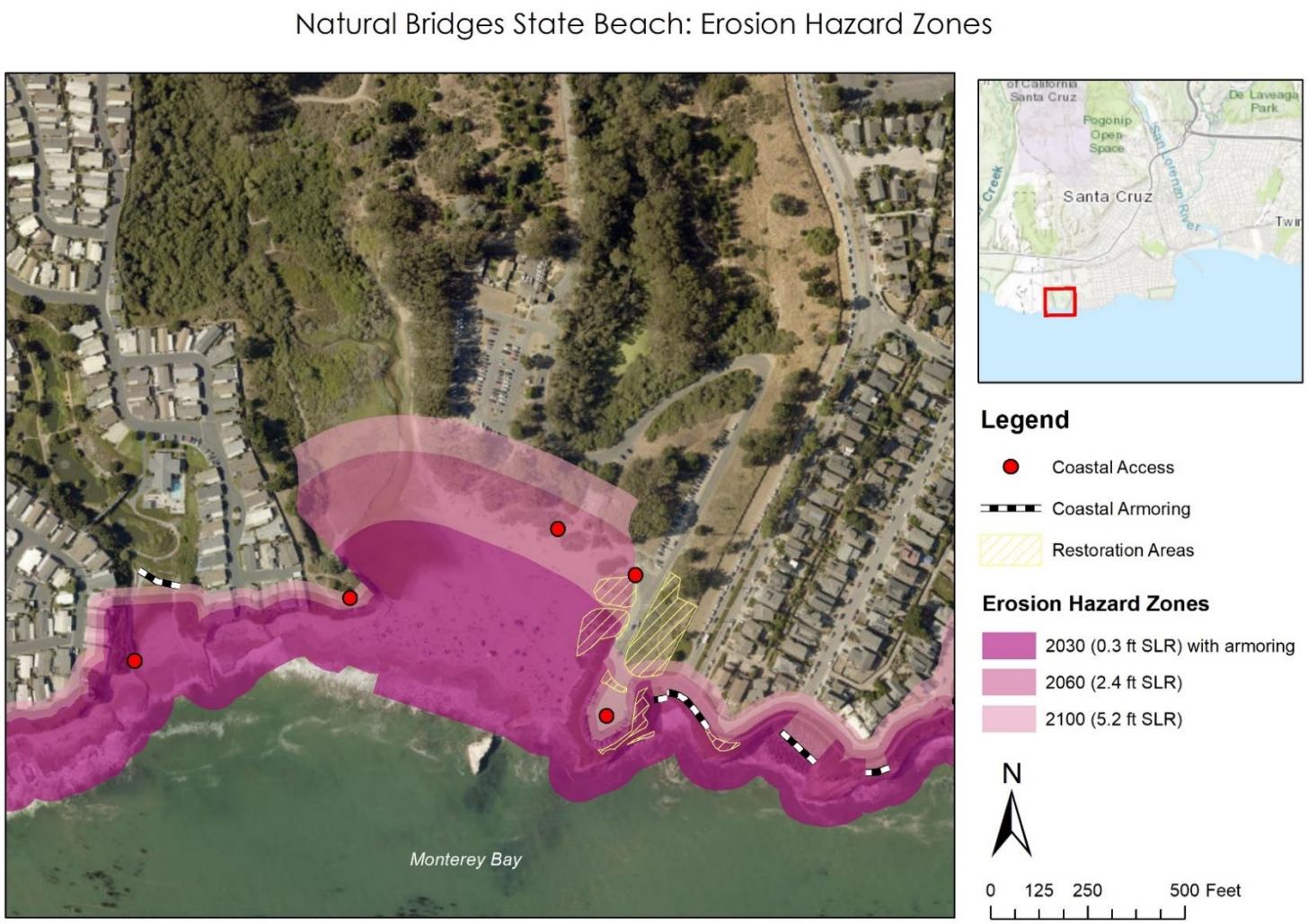


Figure 38. Coastal erosion hazard zones at Natural Bridges Beach for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR). Existing armoring is accounted for (restricting erosion) through 2030 but assumed to fail to restrict erosion past that time horizon.

West Cliff Projected Coastal Hazards

The projected hazard zones for West Cliff pocket beaches for rising tides, coastal storm flooding and bluff erosion can be found in Figure 39, Figure 40, and Figure 41.

Projected Impacts of Focus for this Report

- Coastal Storm Flooding (CF): By 2030 all pocket beaches are projected to be inundated during large storm events
- Rising Tides (RT): Between 2010 and 2060 pocket beaches around West Cliff are projected to be reduced up to 30%
- Bluff Erosion (ER): Erosion is projected to continue to impact coastal access ways, Lighthouse Point, and bluff habitat by 2030.

A summary of assets that are projected to be impacted by future coastal hazards is shown in Table 10.

Problem Statement

Many of the smaller pocket beaches along West Cliff have already been lost, or partially lost, due to the deposit of riprap to protect the Rec Trail, roadway, and other infrastructure along West Cliff Drive. The remaining pocket beaches (including Its Beach and Mitchell's Cove) are vulnerable to significant loss of area due to SLR as early as 2030. Pyramid beach and the smaller pocket beaches at the end of Swift Street are projected to be lost by 2030 due to sea level rise interacting with coastal armoring and the cliff face. By 2060 all pocket beaches may be lost except for Mitchell's and Its Beach, which may retain some of their beach area.

Table 10. Assets projected to be impacted by coastal hazards at West Cliff pocket beaches.

Severity characterized as Low-short term impacts with minimal rebuild required, Moderate-some infrastructure replacement required, High- significant impact to infrastructure requiring significant replacement.

Asset	Hazard	Time Horizon	Severity
Access ways	ER	2030	Moderate
Bird nesting habitat	CF ER	2030 2030	Moderate Moderate
Intertidal habitat	RT	2060	Low
Lighthouse Point	ER	2030	Severe

Management and Resource Goals

Beach resource and management goals identified for West Cliff pocket beaches include:

- To the extent possible, retain access to some pocket beaches including Lighthouse and Mitchell's Cove through 2100.
- Manage public safety (on beach and bluff) with respect to bluff failure and access ways
- Retain level of multi modal beach access adjacent to priority pocket beaches.
- Identify options for continued access along the coast and to the ocean even where beaches are lost (through blufftop trails, parks, etc. and/or access features along seawalls)

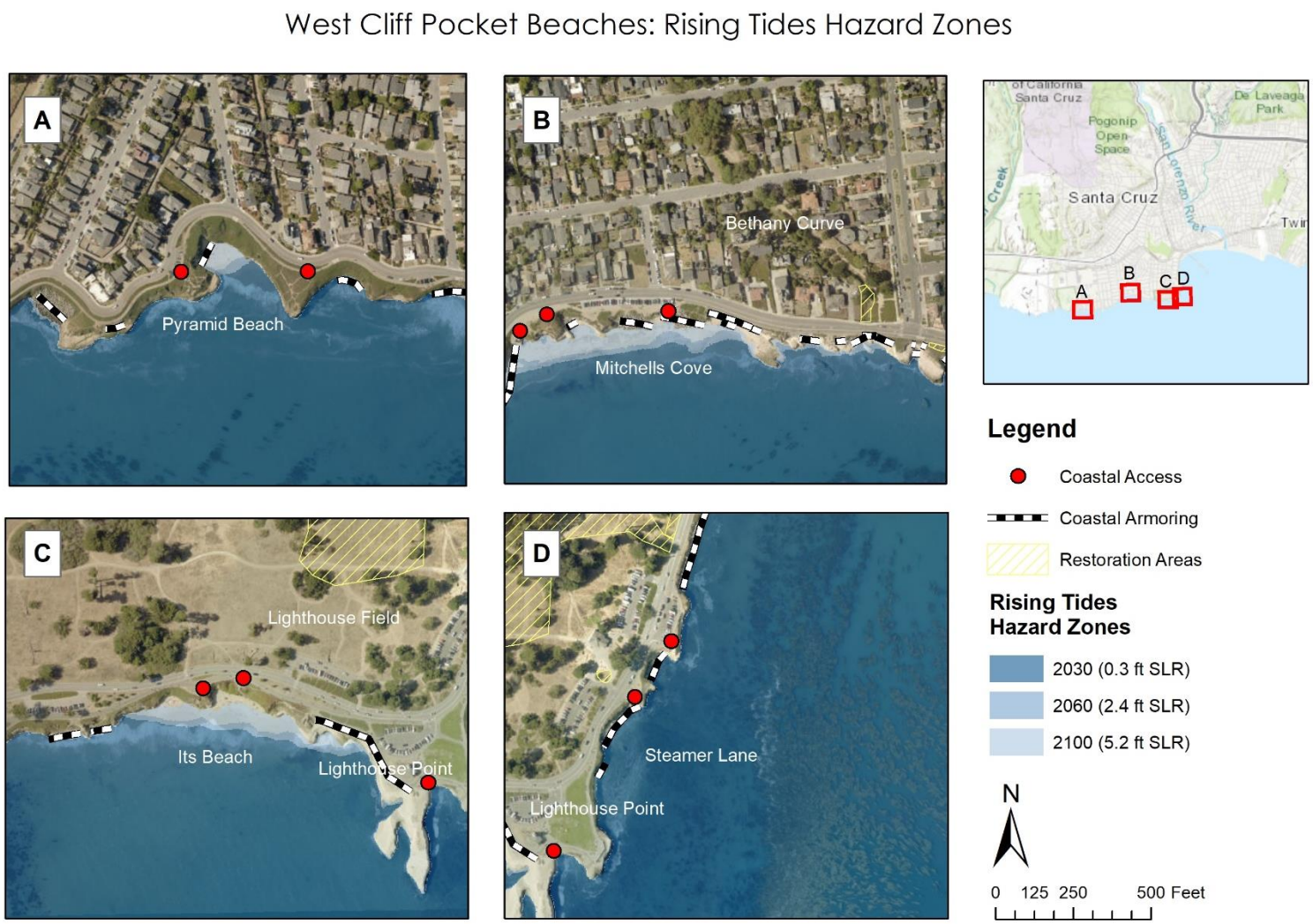


Figure 39. Rising Tides hazard zones at along West Cliff pocket beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

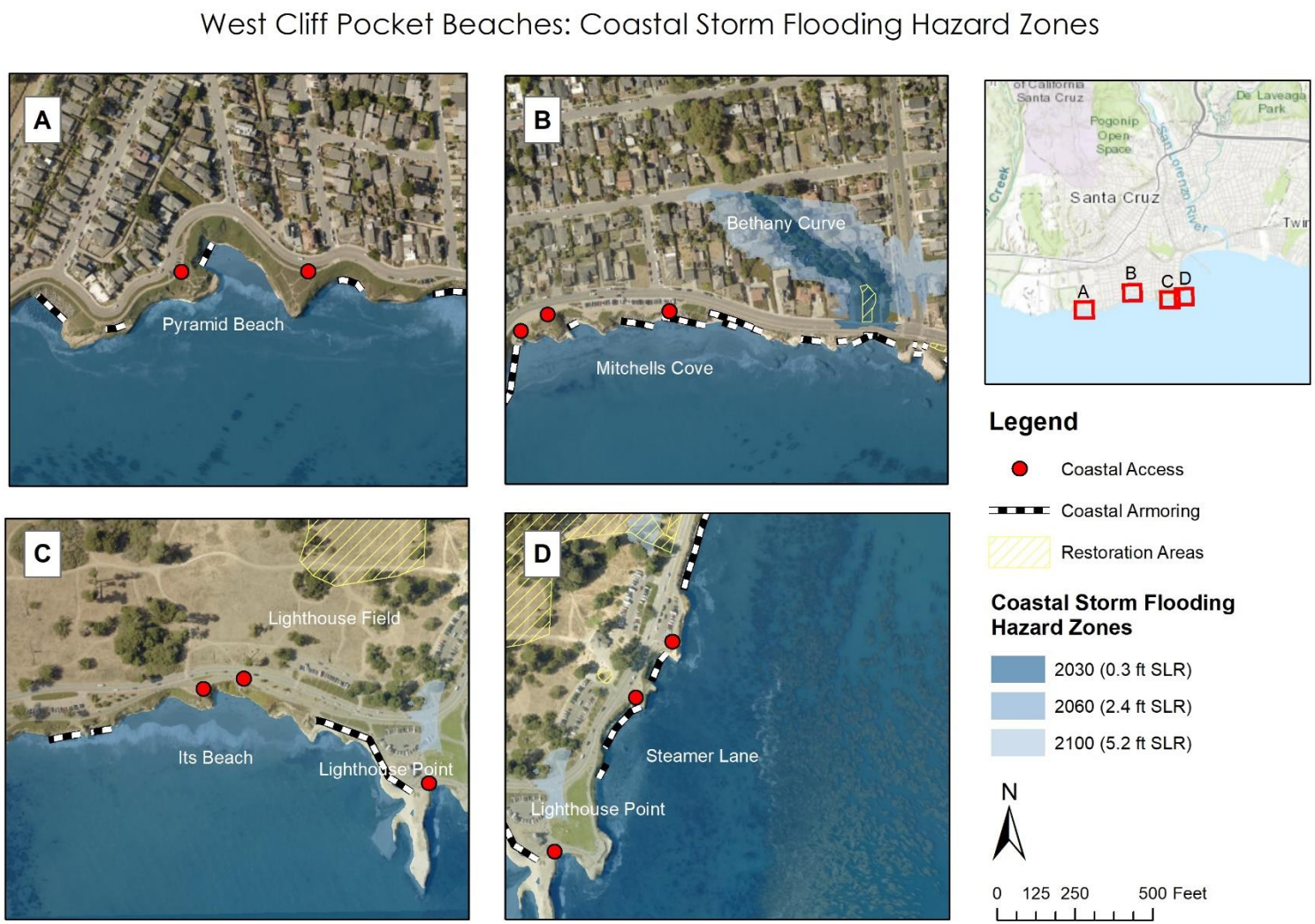


Figure 40. Coastal storm flooding hazard zones along West Cliff pocket beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

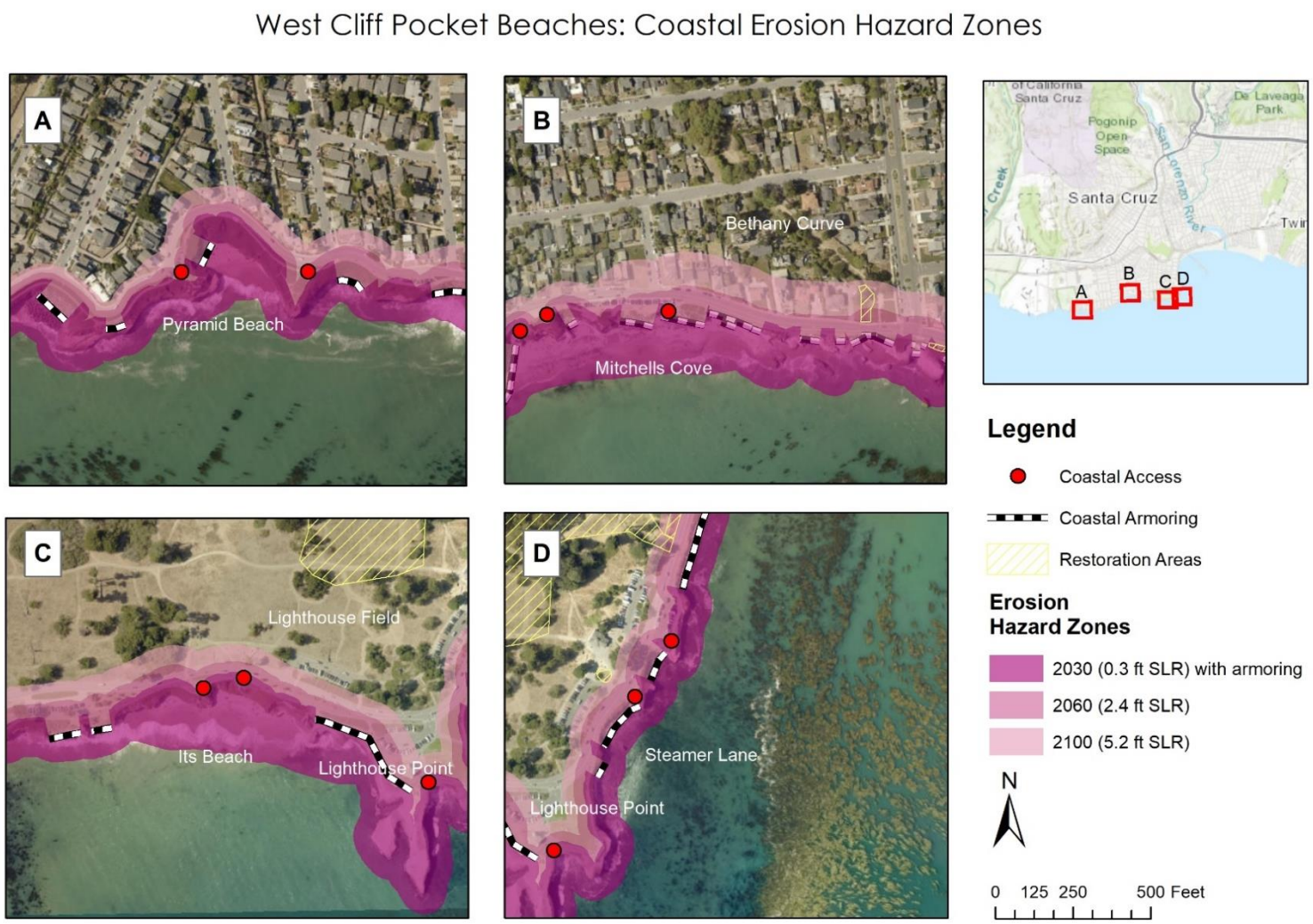


Figure 41. Coastal erosion hazard zones along select West Cliff pocket beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR). Existing armoring is accounted for (restricting erosion) through 2030 but assumed to fail to restrict erosion past that time horizon.

Main and Cowell Beaches Projected Coastal Hazards

The projected coastal hazard zones at Main and Cowell Beaches for rising tides, coastal storm flooding, and bluff erosion can be found in Figure 42, Figure 43, and Figure 44 below.

Projected Coastal Impacts

- Coastal Storm Flooding (CF): By 2030 all of the beach is projected to be inundated during large storm events.
- Rising Tides (RT): By 2030 the beach may be reduced by 5%, by 2060 it may be reduced by 30%-50%, and by 2100 most of beach is projected to be inundated during high tides.
- Bluff Erosion (ER): Erosion is projected to begin impacting the beach, coastal access ways, and amenities as early as 2030.

A summary of assets that are projected to be impacted by future coastal hazards is shown in Table 11.

Problem Statement

Storm flooding is projected to impact low lying areas including the Beach Flats community as higher waves overtop the coastal infrastructure on Beach Street. Wave impacts to adjacent buildings and flooding of low lying areas is anticipated to increase over time as sea level rises and storm intensity increases. Loss of beach infrastructure (volleyball courts, access ramps to boardwalks) is likely to become more frequent. Flooding when the river mouth is closed is an ongoing problem which leads to summer high ground water in the Beach Flats area, but is not the focus of this study.

Table 11. Assets projected to be impacted by coastal hazards at Main and Cowell Beaches.

Severity characterized as Low-short term impacts with minimal rebuild required, Moderate-some infrastructure replacement required, High- significant impact to infrastructure requiring significant replacement.

Asset	Hazard	Time Horizon	Severity
Access Ways	CF RT ER	2030 2100 2030	Low Moderate Moderate
Bathroom	CF ER	2030 2060	Low Moderate
Volleyball courts	CF RT ER	2030 2100 2030	Low Moderate Low
Wharf entry	CF RT ER	2030 2100 2060	Moderate Moderate Severe
Boardwalk	CF ER	2030 2060	Moderate Severe
Habitat (San Lorenzo River Mouth)	CF RT ER	2030 2030 2060	Low Moderate Low

Management and Resource Goals

Beach resource and management goals identified for Main and Cowell Beaches include:

- To the extent possible, work to maintain existing beach width but at a minimum, retain pre-harbor beach width (~220 ft) through 2100

- Ensure risks to residents and visitor serving businesses are considered when developing adaptation alternatives.
- Maintain diverse recreational opportunities (swimming, picnics, beach volleyball, surfing, kayaks, etc.) at Main and Cowells beaches for visitors of all socioeconomic levels.
- Retain easy access via multimodal transportation to the coast for use by residents and visitors of all socioeconomic levels to beaches, wharf and boardwalk.
- Maintain and, where feasible, improve flood protection infrastructure, e.g., pumps, levee and river mouth culvert, within Beach Flats and lower Ocean Street to safeguard residents, visitors, and assets.
- Retain safe access to the extent possible to the wharf and beaches through upgrades to access infrastructure by increasing their resiliency to winter storm events.
- Maintain structure of Santa Cruz Wharf as an important means of coastal access.
- Ensure river and beach management are coordinated.

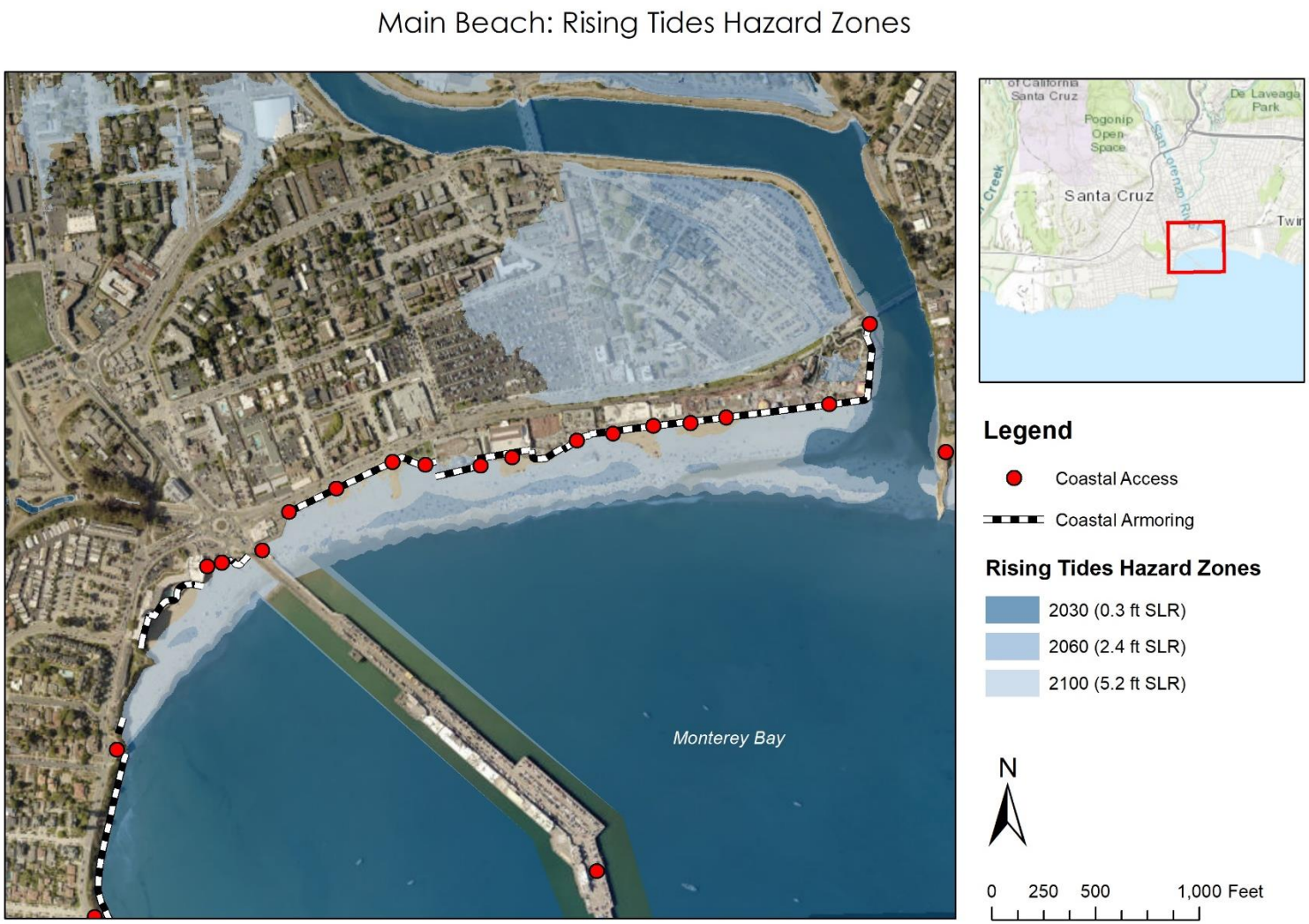


Figure 42. Rising Tides hazard zones at Main and Cowell Beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

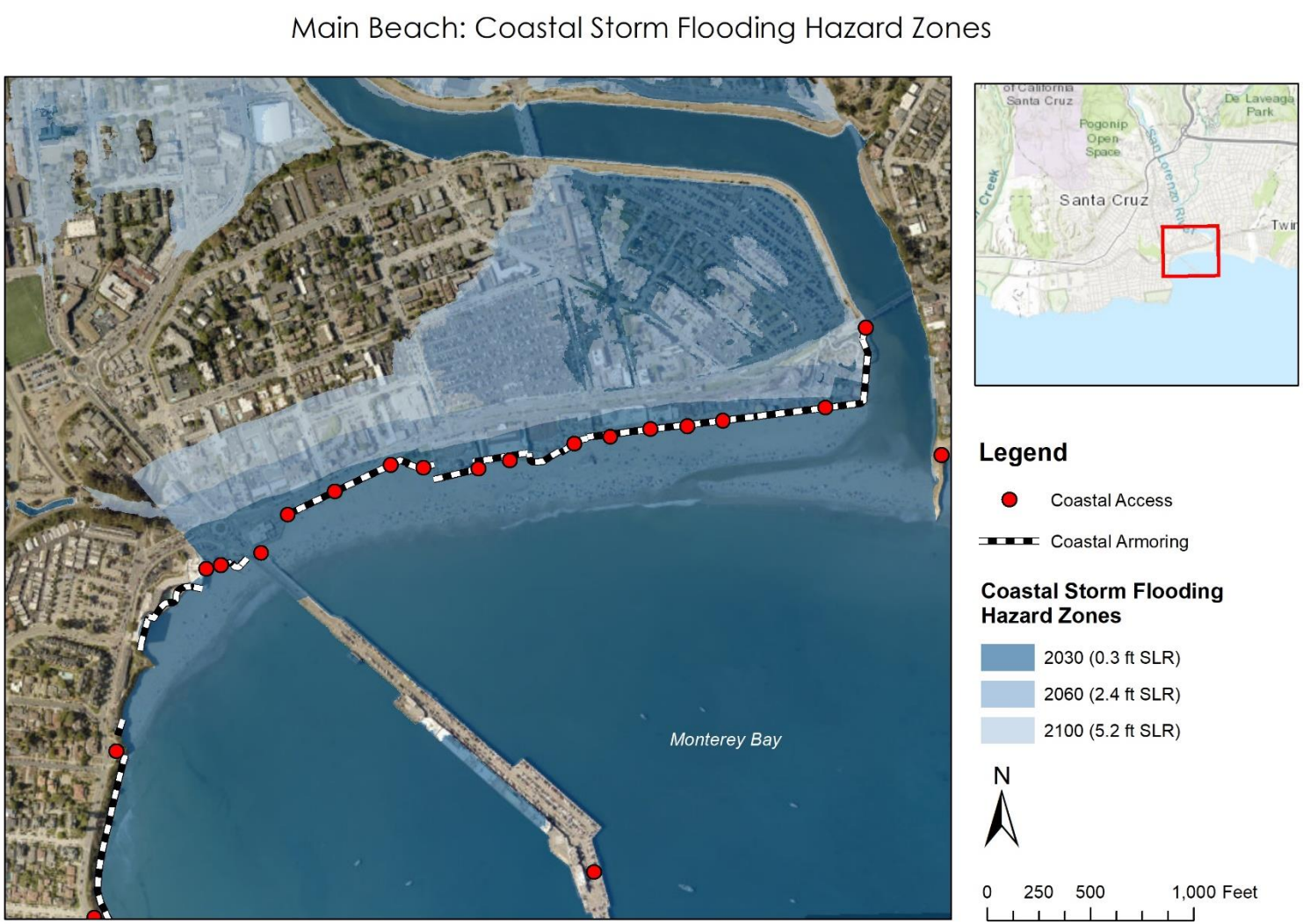


Figure 43. Coastal storm flooding hazard zones at Main and Cowell Beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

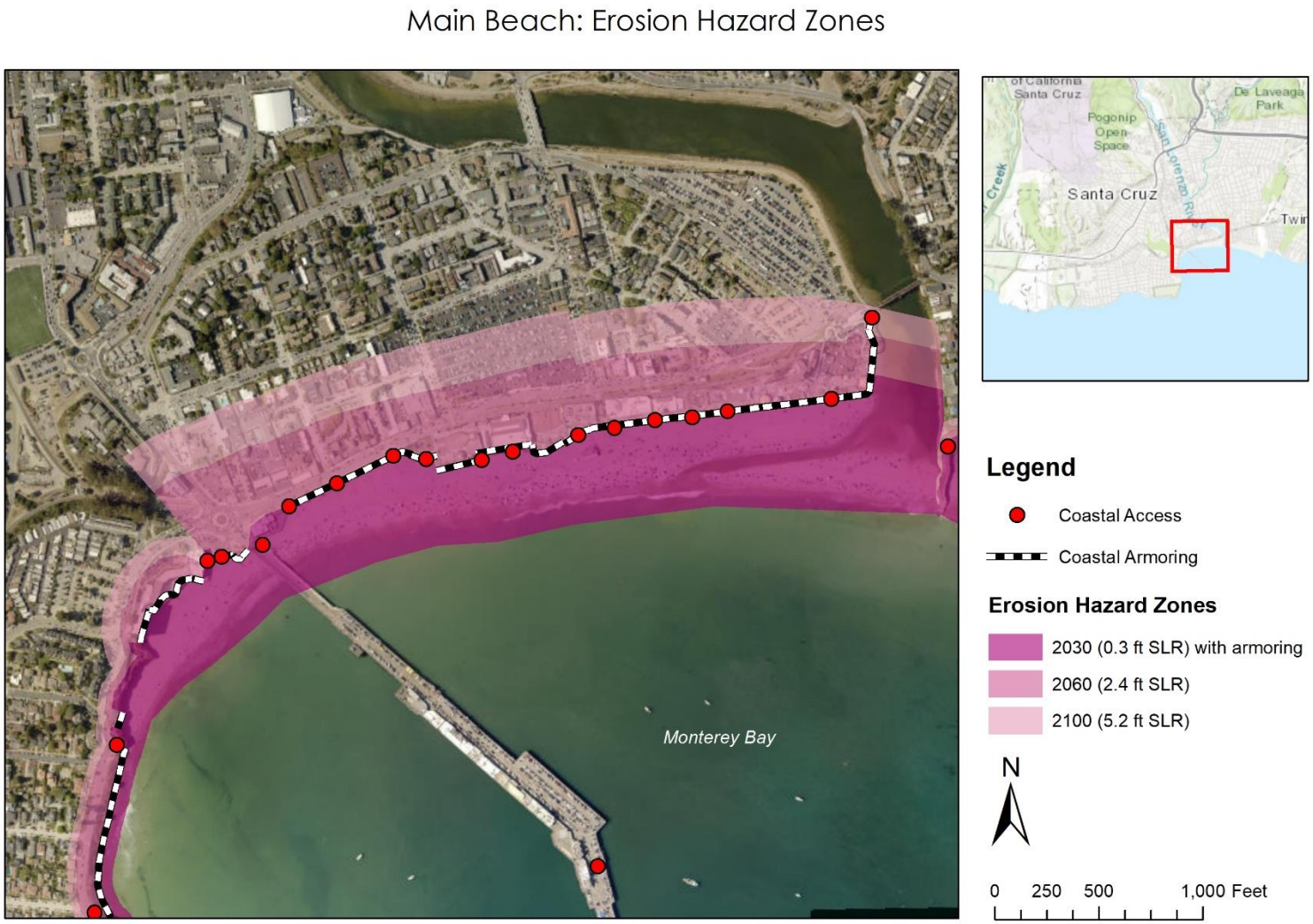


Figure 44. Coastal erosion hazard zones at Main and Cowell Beaches for time horizons 2030 (.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR). Existing armoring is accounted for (restricting erosion) through 2030 but assumed to fail to restrict erosion past that time horizon.

Seabright State Beach Projected Hazards

The projected hazard zones for rising tides, coastal storm flooding, and bluff erosion can be found in Figure 45, Figure 46, and Figure 47 below.

Projected Coastal Impacts

- Coastal Storm Flooding (CF): By 2030 all of beach may be inundated during large storm events.
- Rising Tides (RT): By 2030 the beach may be reduced by 10%, and by 2100 the beach may be reduced by 30-50%.
- Bluff Erosion (ER): Bluff erosion may impact coastal access ways and back beach dune habitat by 2030 and roadways and private homes by 2060. Aging storm drains may exacerbate bluff erosion during discharge events.

A summary of assets that are projected to be impacted by future coastal hazards is shown in Table 12.

Problem Statement

Seabright beach is the widest beach within the City of Santa Cruz because sand accumulates behind the Santa Cruz Harbor Jetty. Winter waves are projected to impact the bluff face leading to bluff erosion and potential loss of adjacent habitat, sidewalks, roadway, homes and the remaining portions of East Cliff Dr and sidewalk. Management decisions regarding how to retain certain levels of access will need to prioritize the protection of public and private property and coastal access (auto, bike, pedestrian and parking). New bluff protective structures may be needed to protect portions of East Cliff (Seabright) where no structures currently exist or alternative adaptations strategies that prioritize beach resources may require revisions to inland infrastructure alignment.

Table 12. Assets projected to be impacted by coastal hazards at Seabright Beach.

Severity characterized as Low-short term impacts with minimal rebuild required, Moderate-some infrastructure replacement required, High- significant impact to infrastructure requiring significant replacement.

Asset	Hazard	Time horizon	Severity
Access Ways	CF ER	2030 2030	Low Moderate
Bathroom	CF	2030	Low
Fire Pits	CF	2030	Low
Habitat	ER CF	2030 2030	Moderate Low
Volleyball	CF	2030	Low

Coastal Management & Resource Goals

Beach resource and management goals identified for Seabright State Beach include:

- To the extent possible, work to maintain existing beach width; but at a minimum, retain pre-harbor beach (150 ft) width through 2100.
- Maintain and enhance native back beach vegetation.
- Focus on living shoreline adaptations.

- Retain lateral coastal access along blufftop (California Coastal Trail segment) for multi modal transportation where beach sand can be considered as a secondary access.
- Retain or enhance beach amenities including restrooms and fire pits.
- Establish 2100 beach management goals and bluff erosion strategies.
- Work with the Port District on dredge management and jetty maintenance and ensure that coastal adaptation strategies and harbor adaptation strategies are integrated.
- Address storm drainage issues causing bluff erosion.

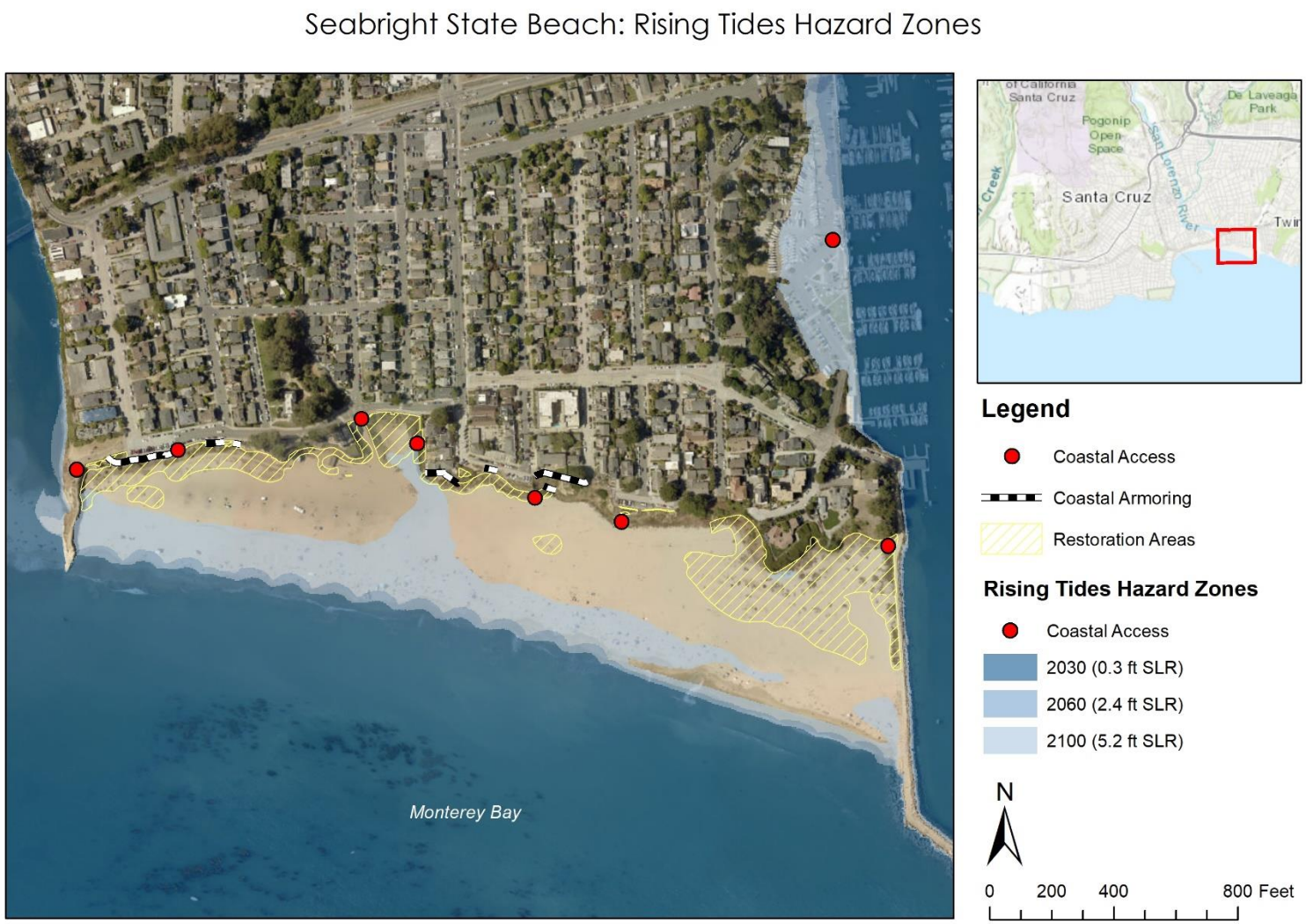


Figure 45. Rising tides hazard zones at Seabright Beach for time horizons 2030 (0.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

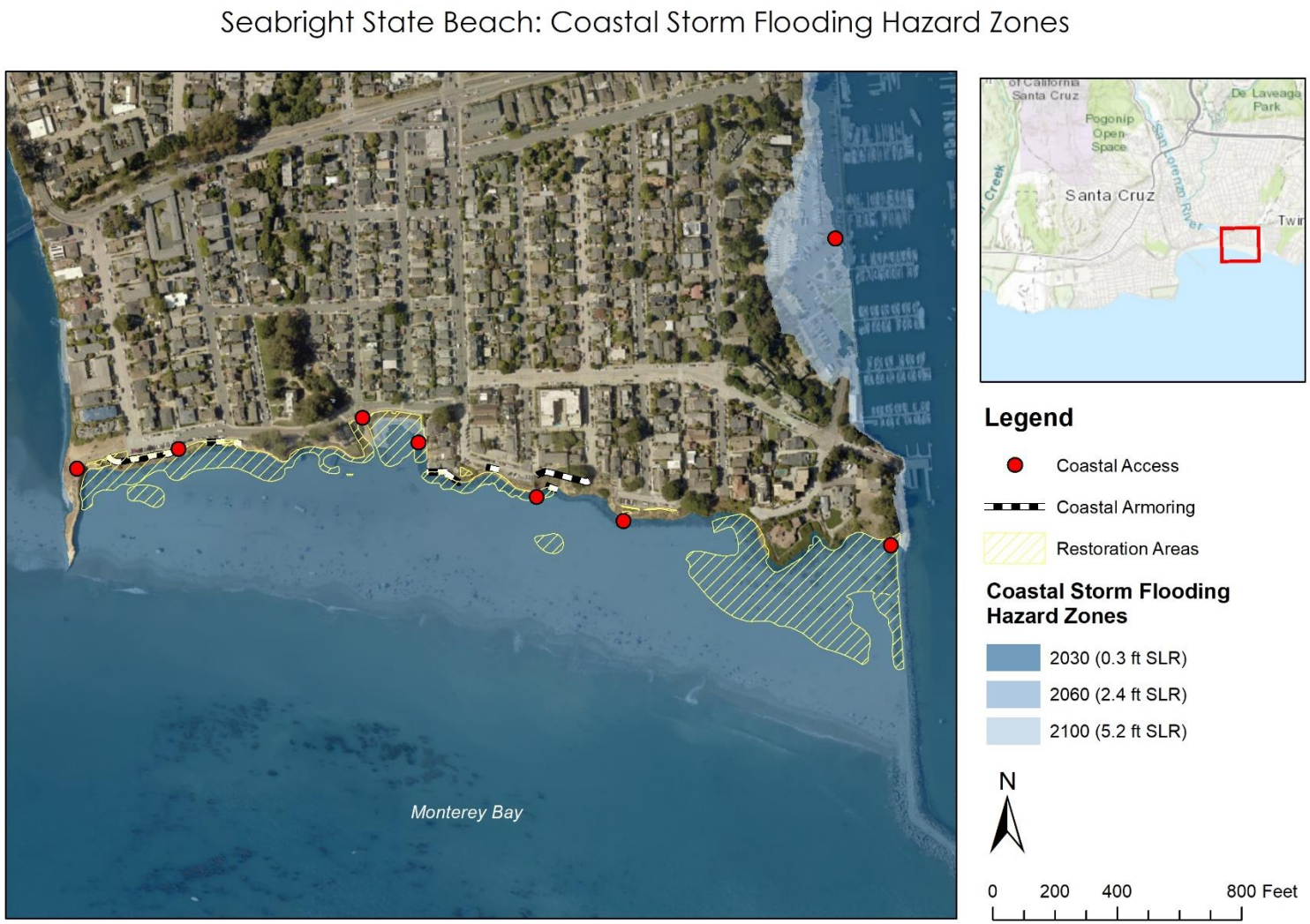


Figure 46. Coastal storm flooding hazard zones at Seabright Beach for time horizons 2030 (0.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR).

Seabright State Beach: Erosion Hazard Zones

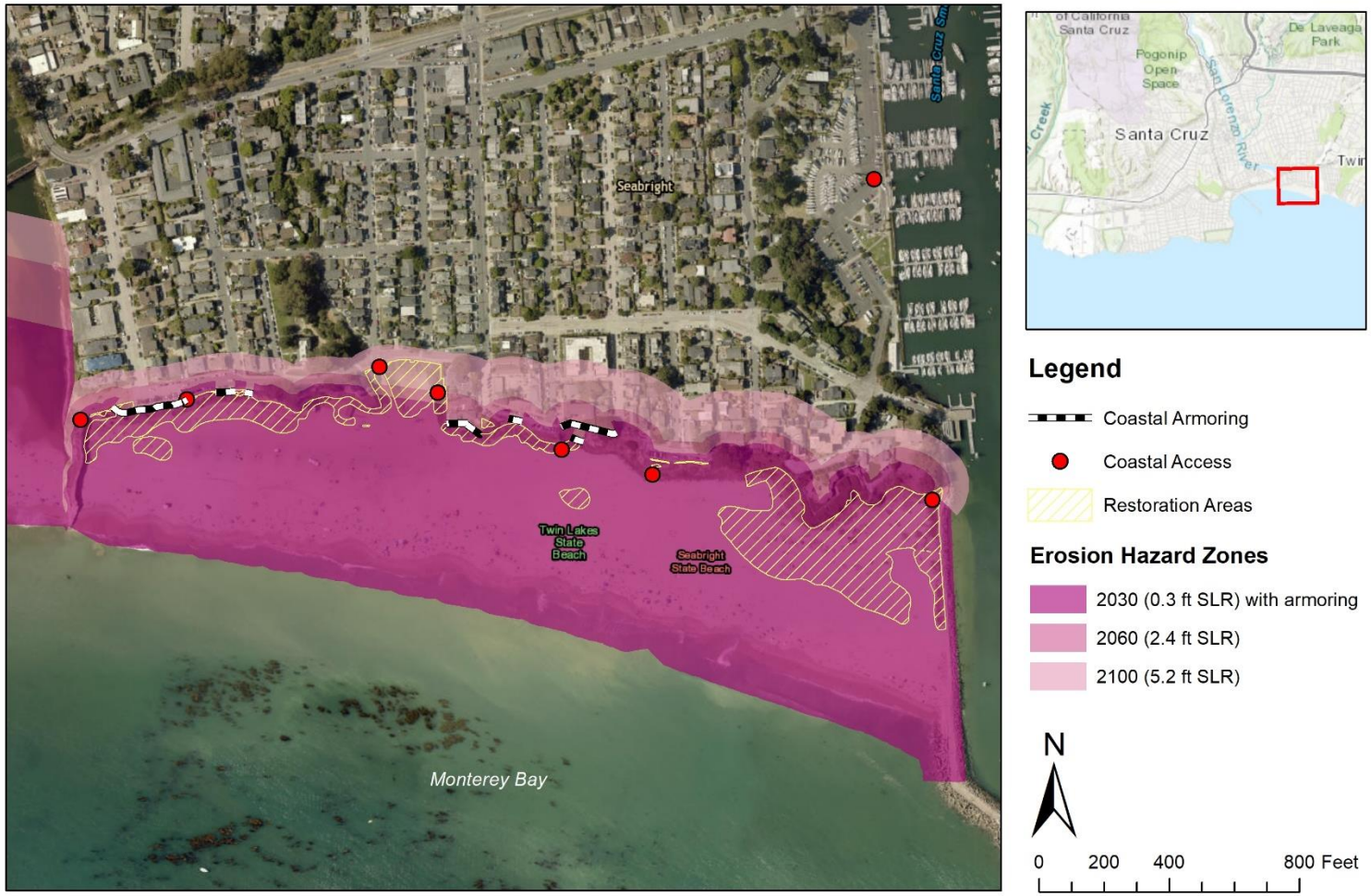


Figure 47. Coastal erosion hazard zones at Seabright Beach for time horizons 2030 (0.3 ft SLR), 2060 (2.4 ft SLR), and 2100 (5.2 ft SLR). Existing armoring is accounted for (restricting erosion) through 2030 but assumed to fail to restrict erosion past that time horizon.

4. Adaptation Alternatives

Categories of Adaptation Strategies

Adaptation strategies generally fall into three categories: accommodate, protect, and retreat. Each category of strategy defined below achieves different levels of benefits, consequences, certainty of hazard mitigation, and costs. Hybrid approaches employ strategies from multiple categories.

Accommodate

Accommodation strategies refer to those methods that lead to redesigning existing developments or new development to become more resilient to the projected hazard.

Protect

Protection strategies are those that use engineered structures or other measures to defend development (or other resources) in the current location.

Retreat (Realign)

Retreat strategies are those strategies that relocate or remove existing development within defined hazard areas and limit the construction of new development in vulnerable areas.

Green vs. Gray Approach

Strategies that fall in the protect and accommodate categories can range from a “green” to “gray” approach and include either “soft” or “hard” measures. A green, or soft, approach relies on both natural and manmade ecological systems, such as a vegetated dune. A gray, or hard approach, named because of the concrete commonly used, is artificial and constructed, like a sea wall or groin. Adaptation strategies can fall somewhere in between, such as a sand dune with an artificially constructed base.

Adaptation Strategy Alternatives

An overview is provided below of various adaptation strategies that are applicable to the beaches within the City of Santa Cruz.

Business as Usual (Protect as things fail)

The City has, since the 1980s, responded to periodic cliff erosion through the placement of and improvements to rock revetments and sea walls (Figure 48). As those structures become damaged by repeated wave impacts, new material is added to retain their effectiveness.

The City has completed a number of emergency and planned upgrades and repairs to coastal revetments, often using emergency permitting processes that later require follow up actions. Funding for these emergency activities are often allocated through budget amendments by the Public Works Department. See, for example, the West Cliff Drive revetment cost evaluation in the 2019 West Cliff Drive Existing Conditions Inventory and Future Vulnerability Assessment.

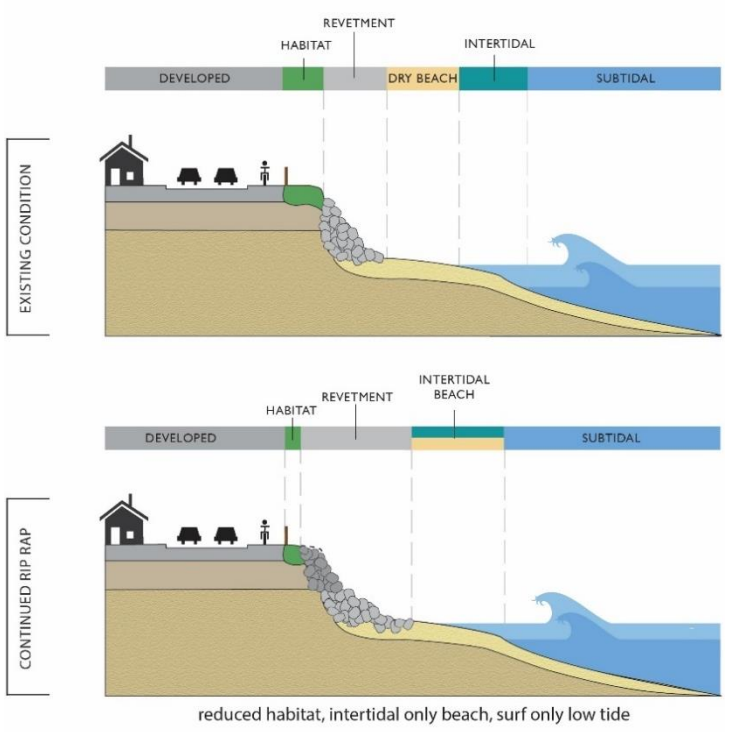


Figure 48. Depiction of Business as Usual: Placing additional riprap to respond to periodic failures or reduction in protection

As sea levels rise, these structures will likely need to be fortified more frequently to continue to provide the expected protections to inland resources. This Business as Usual strategy requires long-term emergency response funding, periodic renewal of complex permits, and will likely lead to the further loss of beach areas adjacent to these structures. The consequential failure of the revetment and cliff edge during winter storms is also likely to threaten inland infrastructure more frequently.

Cliff Armoring

City cliffs (i.e., the cliffs and softer upper portion bluffs along West Cliff Drive) have seen periodic erosion since development was first established. As early as 1948, cliff erosion led to the loss of sections of East Cliff and West Cliff Drives, leading to the relocation of West Cliff and the loss of portions of East Cliff in the Seabright area. As homes became vulnerable, armor was installed by property owners at several locations along East Cliff and later, when West Cliff Dr. and the pedestrian/bike lane became vulnerable, the City began to construct protections. Those protections were predominantly riprap, or stacked rock or concrete to prevent shoreline erosion. These structures may also be referred to as revetments (Figure 49).

Armoring also includes sea walls, which are vertical walls that commonly take up less horizontal area than riprap, but can be more costly. A sea wall armors the upper portion of the cliff at Lighthouse Field State (Its) Beach (Figure 50
). Soil nail walls are similar to sea walls, but consist of a grid structure anchored into the cliff that is covered in concrete. Pleasure Point on East Cliff Drive is armored with a soil nail wall (Figure 51).

Figure 49. Revetment along West Cliff

Figure 50. Bluff top seawall at Lighthouse Point

Figure 51. Soil nail wall with vertical beach/ocean access stair at Pleasure Point

Looking forward, new riprap, sea walls and other structures can be installed to reduce wave impacts to vulnerable portions of the cliff (Figure 52). This strategy can be implemented piecemeal over time or through the completion of a shoreline characterization and prioritization study that estimates future cliff failure potential.

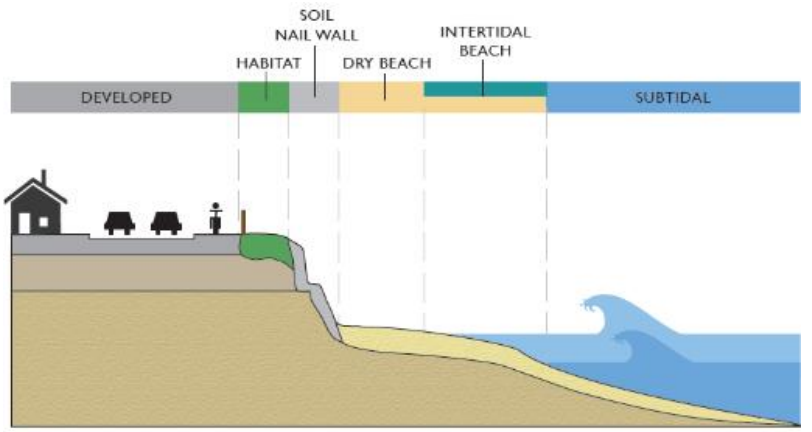


Figure 52. Depiction of sea level rise induced coastal cliff erosion halted through construction of a soil nail wall

The study would also identify structural replacements (sea walls) needed to make various portions of the coastline more resilient and achieve other coastal management goals, discussed later in this report. By planning for coastal impacts, upgrades to existing infrastructure (for maintenance or enhancement) can be completed prior to failure, limiting inland impacts associated with catastrophic failures, reducing construction costs and permitting challenges associated with emergency permits (See Business as Usual strategy).

Through completion of a coastline characterization study (currently underway for West Cliff Drive but outside the scope of this project focused on beaches) prior to an emergency situation, the City can develop more refined adaptation strategies that rely on a combination of green and gray strategies that address the hazards and resulting risks facing specific resources and infrastructure.

Sand Retention (Groins and Jetties)

Sand retention structures, such as groins, are used as a hard adaptation strategy where large rocks or concrete blocks are installed perpendicular to the shore in order to interrupt longshore drift and impede the flow of sediment along a shoreline (Figure 53). This causes nearshore sand and sediment to accrete on the updrift side of the structure until the capacity of the groin is reached. Groins function similarly to the natural geologic headlands that span the Santa Cruz coastline. Artificial groins are able to trap sand and create beaches where they previously did not exist or widen existing beaches.

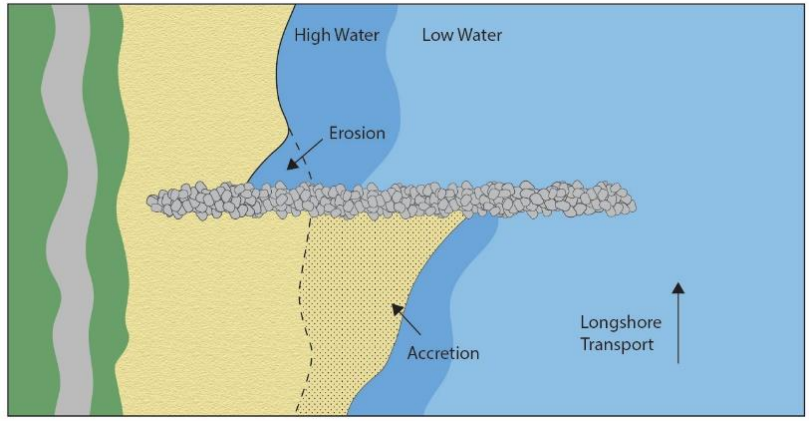


Figure 53. Depiction of groin along a beach

The most notable local example of sand retention is the Santa Cruz Harbor Jetty constructed in 1963 (Figure 54). The jetty has led to the trapping of a significant volume of sand at Seabright Beach which widened the beach and currently helps protect the Seabright neighborhood from erosion.

Figure 54. Santa Cruz harbor jetty. Photo Source: Coastal Records Project, Copyright © 2003-2019 Kenneth & Gabrielle Adelman - Adelman@Adelman.COM

The accretion of sand caused by groin installations can diminish the sediment supply to downcoast areas, leading to accelerated erosion. This may be mitigated by artificially nourishing the beaches after construction is complete. Groins are seen as a structural tool to increase the longevity of local beach nourishment projects.

Infrastructure Resiliency

There is a significant amount of coastal infrastructure located along the City beach front. Parking, roads, bike and pedestrian pathways, stairs, and overlooks provide visual and direct access to the coast. To ensure that critical access accommodations are maintained or enhanced, infrastructure and other structures can be modified, elevated, or rebuilt to increase resiliency to projected hazards (Figure 55). Structure enhancement strategies can be (and have been) integrated into operations and maintenance efforts by the City, State Parks and private property owners.

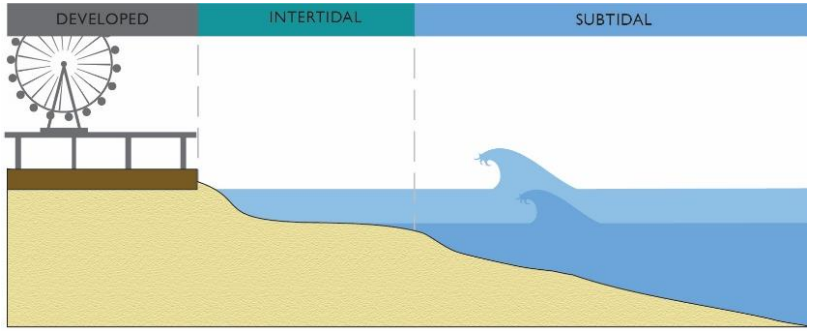


Figure 55. Depiction of structure raised on piers to accommodate for flooding during extreme high tides or storm events

The redesign of beach access infrastructure can help ensure levels of service are maintained, repetitive replacement costs are reduced and infrastructure upgrades are absorbed (as feasible) into ongoing operations and maintenance budgets.

Living Shorelines

The term 'living shorelines' encompasses many different techniques surrounding the use of coastal ecosystems for protection. The central approach incorporates natural habitats into shoreline stabilization designs. Applications of living shorelines range from the use of natural features, such as natural shoreline vegetation to stabilize and accrete sand, to hybrid approaches where natural assets are paired with additional hardened features such as groins. Living shoreline treatments applicable to Santa Cruz beaches are described below.

Dune Restoration, Construction, or Enhancement

More resilient back beach dune habitat can be established with or without vegetation that will hold and possibly accrete sand for years until high waves erode those areas. Dependent on the needed level of protective certainty, back beach dunes can be constructed to include a base layer of wood, rock or other material that will withstand wave impacts once the dune habitats have eroded (Figure 56).

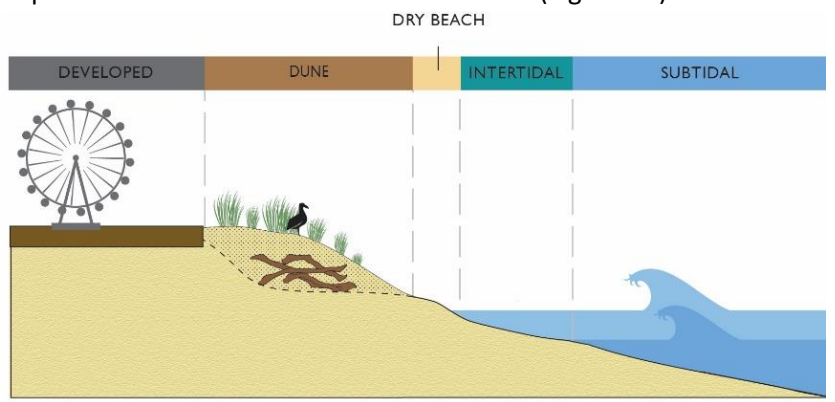


Figure 56. Depiction of living shoreline being used to protect inland infrastructure

These sacrificial dunes may have to be reestablished after winter storms have ended.

Living Cliff Faces

Areas of the cliffs that back Santa Cruz beaches range in condition and stability. In some areas where land has already been lost, the cliff face angle is gradual, and includes vegetation (both native plants and the non-native iceplant) and appears to be more resilient to further cliff failure. In some areas where cliff top infrastructure is vulnerable, armoring and sea walls with various levels of engineering sophistication have been constructed, some of which have left the cliff more vulnerable to future failure from wave impacts stormwater erosion during winter storms. Enhanced cliff face engineering, contouring and habitat revitalization may work in concert with other select managed retreat efforts to increase the resiliency of Santa Cruz cliffs (Figure 57).

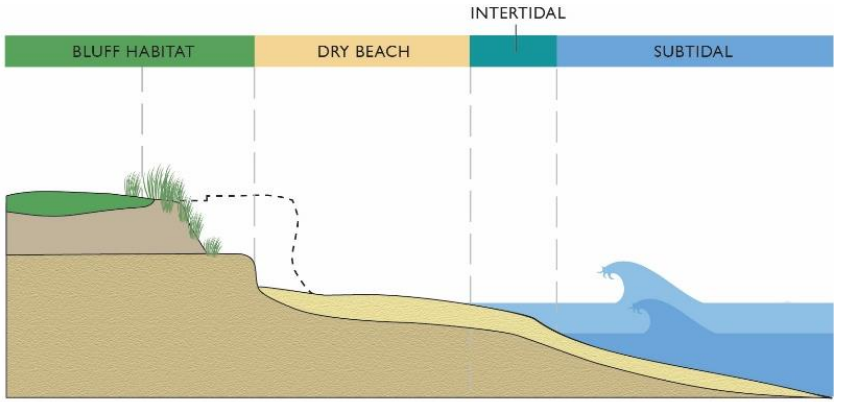


Figure 57. Depiction of cliff erosion mitigated by native plantings along cliff face and terrace

A number of informal access ways (i.e., narrow dirt paths) created by foot traffic and stormwater runoff leave the cliffs more vulnerable to erosion and could be upgraded or retired to increase cliff resiliency in concert with native revegetation.

Beach Contour Management

Managed sand placement on beaches (beach scraping) has been used locally in Santa Cruz at Main Beach and in Capitola as a temporary protection of back beach resources during winter storms (Figure 58). Sand can be piled in mounds (similar to that employed in Capitola) to act as a sacrificial barrier to waves. Such actions can be repeated between storm events if needed.

Figure 58. Beach contour management along Main Beach by the San Lorenzo River mouth

Beach Nourishment/Sand Management

Beach nourishment is the process of artificially placing sand (or other aggregates such as gravel) on or near a coastline in order to enlarge an existing beach or construct a new one (Figure 59). This intervention differs from beach contour management in that sediment is added from outside the system, normally from a 'borrow site', while beach contouring relies on the redistribution of existing sand.

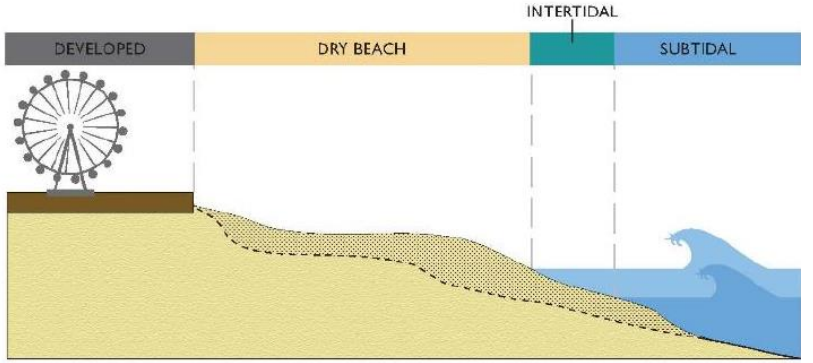


Figure 59. Depiction of beach nourishment

Beach nourishment is often undertaken as a strategy to combat coastal erosion and to augment the natural buffering action of beaches against storm surge. It is used to combat sea level rise that inundates beaches and exacerbates erosion and coastal storm flooding. Beach nourishment is often used with other adaptation strategies such as beach contouring, dune restoration, hard engineering (groins), and development set-backs.

There is a degree of uncertainty as to the long-term effectiveness of beach nourishment projects. In some cases, storms can quickly remove sediment. In order to be truly effective, nourishment projects need to be planned carefully to account for the limited temporal effectiveness of this strategy and the long-term hazards projected for coastal assets.

The inevitable transport of deposited sands from a beach nourishment project can be part of a less focused strategy to increase sand supply to a larger portion of the coast. Depositing sands in select areas to support littoral transport to down coast beaches can help minimize beach erosion and loss.

Storm Water Infrastructure Upgrades

Stormwater flows to the Santa Cruz coastline through a number of natural drainage ways and an extensive storm drain system. Much of this storm drain system is more than 70 years old and has deteriorated due to coastal salt spray, in some places, leading to local failures of the discharge (Figure 60). Bluff erosion has similarly damaged this infrastructure which allows stormwater to flow from pipes onto the bluff before discharge to the ocean. This situation compromises both water quality and coastal bluff stability.

Figure 60. A storm drain outfall along West Cliff in very poor condition

The city receives storm drain maintenance funding from a storm drain overlay fund that may need to be increased to address the added management challenge associated with upgrades to ensure coastal bluff stability.

Informal Trail Management

Informal trail networks exist along most sections of the Santa Cruz coastline (Figure 61). These informal trails provide access to some otherwise inaccessible beach and terrace locations, as well as secondary (or tertiary) access pathways that provide no added benefit. These pathways lead to erosion of the soft upper bluff sediments, often becoming drainage pathways that increase erosion. Investments in upgraded access infrastructure (sanctioned trails, boardwalks, stairs) to coastal access locations without alternative access should be prioritized, and efforts to restrict access along unnecessary or hazardous pathways (through fencing, signage or plantings) can help reduce bluff top failure not associated with wave impacts.

Figure 61. An informal trail down to a beach along West Cliff

Managed Retreat

Managed retreat implies the shifting of assets, activities and people away from coastal hazards. Activities can entail removal or relocation of existing structures in hazard prone coastal areas (Figure 62). The term "managed realignment" is also used, as well as "managed or planned relocation." Managed retreat policies can be used to regain public beach and beach access as private infrastructure becomes threatened. The term "managed" suggests that planning has been undertaken to address the logistical, financial, social and legal implications of this transfer of use.

Managed retreat plans and policies can complement aspects of other adaptation strategies. Retreat can therefore be conceptualized as a broad suite of adaptation options. There have been cases where coastal hazards including coastal flooding or storm damage have created the impetus for retreat from defined hazard areas (see the Surfers Point review case study in Appendix A).

Managed retreat options will differ depending on the type of infrastructure to be relocated and the owner of that property. For much of Santa Cruz, the coastline is managed by the City or State Parks. City owned properties along Seabright provide several key public access functions. Two-way traffic and a recreational trail exist for approximately half of East Cliff Drive within the Seabright area and for all of West Cliff Drive.

Because of the high density of development along the Santa Cruz coastline, managed retreat of private property – notably single family homes– is complex and costly. However, managed retreat efforts could lead to an increase in public access and recreation if such a transition could be done legally and was supported fiscally by the community.

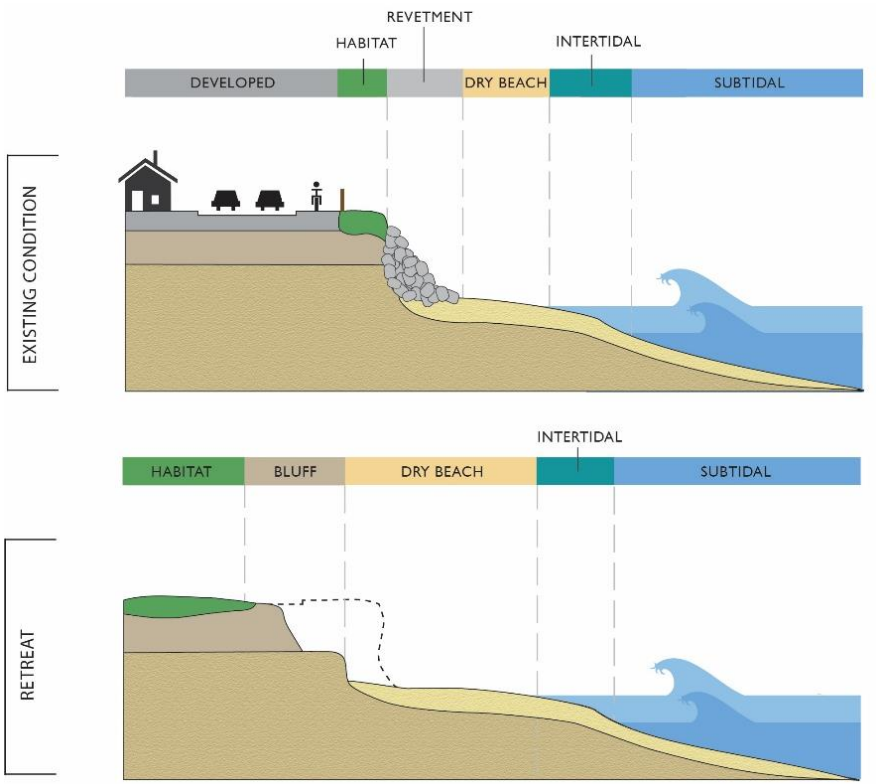


Figure 62. Depiction of managed retreat

5. Beach Specific Adaptation Strategies & Pathways

Adaptation Pathway Overview

An adaptation pathway provides a vision for managing climate risks through a sequence of adaptation strategies over time to avoid a threshold of potential impacts, each of which is initiated by a trigger, or a change in social, environmental, or hazard conditions. By defining a trigger as a condition to catalyze planning for future adaptation planning (e.g. beach width) rather than a time horizon (e.g. 2050), the adaptation pathway can manage the uncertainty of sea level rise, consider secondary consequences and change the adaptive management approach as actual coastal erosion impacts occur.

The benefit of developing adaptation pathways that plan for years or decades is the time allowed for extensive feedback on adaptation strategies. In contrast to mitigating emergency hazards as they occur under a business as usual approach, adaptation pathway planning allows the community an opportunity to express their preferred future for their coastline. Additionally, planners can identify funding needs, explore policies and programs needed to implement adaptation strategies, and design effective monitoring programs to identify triggers.

Engaging the community in the adaptation pathways process can foster a common vision, and an understanding of the tradeoffs and secondary consequences of short and long-term adaptation approaches. By integrating selected adaptation strategies into City policies, plans, and funding operations as triggers occur, the City is prepared to take action based on sound planning, addressing anticipated costs through establishing fiscal programs in advance to sponsor community resiliency.

This Beach Specific Adaptation Strategies and Pathways chapter aims to integrate previous information developed through this planning process and describe various adaptation strategies from which Santa Cruz can move forward over time to address projected impacts associated with coastal climate change. Based on community input, TAC guidance, and City priorities, short term and long term adaptation strategies for the coast and clifftop amenities and transportation corridor were identified. These strategies were then organized into a decision tree framework (Appendix C) in order to guide selection of individual adaptation pathways. Detailed information about adaptation strategy alternatives and alternative adaptation pathways is provided within Chapter 5 of this report.

Each pathway responds to projected hazards by implementing specific strategies (described within this document and reviewed in Appendix B, Adaptation Strategy Overview Matrix) over time. For each beach specific adaptation strategy, the following items are discussed:

- Plans or programs that could be used to implement the strategy
- Physical, environmental or policy triggers that can be used to initiate a change from one strategy to another (See Appendix

E, Triggers and Monitoring Strategy for more information about trigger types)

- Relative costs and funding strategies (See Appendix F, Funding Strategies for a full range of funding options)
- Benefits and consequence of the strategy
- Disproportionate impacts to under-represented user groups
- Mitigation measures to reduce consequence and disproportionate impacts

Furthermore, adaptation pathways are identified for each beach segment that define a logical progression from one strategy to the next over time as triggers are met. Each strategy listed within the pathway can be either phased incrementally or concurrently where appropriate. Up to three (or four for West Cliff) alternative adaptation pathways are described for each beach segment to provide the community with alternative approaches to adaptation.

The primary policy focus of each pathway is provided within the title, and incremental actions and costs of each pathway are described. Incremental and 2100 endpoint results of each pathway are drafted to describe the 2100 coastline condition each strategy achieves. While this process is not comparable to a classic cost benefit analysis, this approach does aim to generally describe the actions, costs, impacts and end product of each alternative adaptation pathway. This information may help encourage a discussion regarding which actions the community is willing to invest to maintain a set of coastal resources that meets the community vision for a resilient 2100 Santa Cruz coastline.

Monitoring, Triggers, and Thresholds

Triggers represent a point in time when action must be taken to address coastal hazard-related vulnerabilities before impacts reach a point of emergency. Triggers are measurable indicators that must be monitored to initiate planning, permitting, and/or the implementation process for adaptive measures. An appropriate trigger provides enough notice and lead time to plan for and implement an adaptation strategy before vulnerabilities become severe.

Triggers are an important component of the implementation of climate adaptation plans and pathways. Adaptation plans which utilize triggers supports a planning process which incorporates the inherent uncertainty (risk) surrounding the effects of climate change on coastal areas. These risks are often preceded by the crossing of 'tipping points' or thresholds. The use of triggers can help to identify when planning and permitting processes should be initiated and when adaptation action should be implemented.

Triggers must be monitored to inform adaptation decisions, and triggers should be reevaluated and updated as needed in the future to capture advances in sea level rise science and changing conditions. A monitoring program plays an important role in the implementation of adaptation pathways, in order to limit risks. This report recommends planning-level adaptation thresholds that can be drafted in to a monitoring program and codified within the city LCP update. The City will need to monitor and evaluate progress towards these thresholds to determine whether and when these thresholds are met and thus initiate action and expenditure of funds. Strategies may be implemented before a trigger threshold is met. See Appendix E for more information about triggers and monitoring.

Recommended Future Plans

Three supporting plans are identified within these strategies and pathways that the authors recommend developing or updating to describe the decision making process, the monitoring program, maintenance strategies, and the funding mechanisms needed to achieve each pathway. This report provides the foundation for those future plans; we present key partners as well as special districts and other regulatory and revenue generating strategies for each adaptation pathway. By drafting these city-wide plans, changes in coastal resources within beach sub-areas can be managed systematically and holistically, thereby mitigating loss to coastal access and resources at some beaches through increases in amenities at other beaches. Plans to support coordinated coastal adaptation include:

Resilient Beaches Management Plan

The Resilient Beaches Management Plan is envisioned to be an update and expansion of the City's existing Beach Management Plan (most recently updated 2019), which is updated every 5 years and is approved by the Coastal Commission. The Resilient Beaches Management Plan will outline how city beaches will be managed in the face of sea levels rise and should include: 1) a sand management/beach nourishment implementation strategy, 2) a living shoreline management plan, and 3) a beach monitoring program to identify when thresholds are met that trigger the transition from one adaptation strategy to the next (see chapter 5 and Appendix E for more information about triggers and monitoring).

Coastal Armoring Management Plan

In coordination with the West Cliff Drive Adaptation and Management Plan, the Coastal Armoring Management Plan should describe a process for ongoing maintenance of existing structures, as well as identify areas to be prioritized for upgrades to existing armoring. Upgrades should include structure designs that protect inland structures while enhancing beach and terrace access and coastal viewing opportunities. The plan should:

1. Describe actions to mitigate coastal impacts of structures.
2. Establish monitoring criteria to determine when these structures need additional repair or can no longer provide intended functions, and thus, trigger short term repair and/or longer term alternative actions.
3. Outline priority areas for armoring restrictions and describe strategies that support incremental sacrificial loss of public infrastructure while maintaining public safety.
4. Identify managed retreat policies and programs that prioritize preservation of certain public infrastructure.
5. Identify strategies for the removal of infrastructure determined to be unsafe.
6. Identify funding mechanisms that ensure all phases of the coastal armoring plan are implemented.

Beach Flats Redevelopment Plan

The Beach Flats Redevelopment plan would describe future development goals, zoning modifications and restrictions, strategies to manage land use changes, and fiscal and regulatory incentives through tax credits and transfer of development programs to encourage managed retreat. The plan must recognize established community goals for this area including providing affordable housing and vital resources for a unique portion of the Santa Cruz community. The plan would establish monitoring and infrastructure maintenance strategies to track incremental impacts to existing buildings and populations, ensure stormwater upgrades are implemented as needed and other protective structures are maintained, and discuss equitable economic strategies to support this transition. Integration of this redevelopment plan with the San Lorenzo Urban River Plan (2003), the San Lorenzo Lagoon Interim Management Plan (2015), other pertinent Management/Area plans, and the Resilient Beaches Management plan is needed.

Natural Bridges State Beach Adaptation Strategy Options & Pathway Alternatives

Natural Bridges Adaptation Strategy Options

Living Shoreline

Implementation Programs: Support State Parks efforts to expand their living shoreline restoration effort to support increased wave resiliency of the backshore habitat. Include Natural Bridges restoration actions within the Resilient Beaches Management Plan.

Triggers to Initiate Strategy: Table 13 provides examples of monitoring parameters and trigger criteria that could be used to trigger the construction of a living shoreline at Natural Bridges State Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 13. Example monitoring parameters and trigger criteria to be used for constructing a living shoreline at Natural Bridges State Beach.

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Beach width during winter king tides of 100 feet or less for 3 years in a row. Or Average annual late summer (September) dry beach of 200 feet or less for more than 3 years in a row.

Costs and Funding Strategy: Support State Parks efforts to expand revegetated dunes program. Investigate establishing a City/State Parks living shoreline program for all appropriate city beaches. Costs are low when compared to other armoring resilience measures; a 2005 dune restoration plan for the Marina dunes was budgeted at ~$8,500 per acre of habitat (Monterey Peninsula Regional Parks District, 2005). However, vegetated dunes require ongoing maintenance funding to maximize habitat and wave resiliency. Some of this maintenance (planting, etc.) could be completed with an organized volunteer force. Due to the interest in "nature based solutions" for sea level rise, a living shoreline project would be an ideal candidate for grant funding and partnerships with state or non-governmental organization (NGO) sources of funding (e.g. Coastal Conservancy).

Benefits:

- Enhances beach habitat and coastal views.
- Can be designed to allow for lateral access.
- No anticipated impacts on unique user groups with planning (e.g., beach wheelchair accessible path through dune).
- Relatively inexpensive

Consequences:

- Loss of recreational beach area.
- Regular maintenance required; expected effective lifespan of living shoreline is less than armoring.

Implications to unique user groups: Potential impacts to unique user groups who value open beach area for recreation. May benefit user groups who valued natural habitat areas.

Mitigation Actions: Lateral access along the beach will be reduced through transition of some recreational areas to habitat. Designing lateral trails through the living shoreline can reduce this consequence and/or benefit visitor experiences.

Managed Retreat of State Parks Infrastructure

Implementation Programs: Support implementation/expansion of managed retreat and infrastructure relocation efforts described within the Natural Bridges State Beach Plan (located within the 1992 LCP), which describes strategies to prioritize preservation of certain public infrastructure such as restrooms, parking, access roads, etc. A Plan update should identify and resolve decisions regarding protection or sacrifice of parking and vehicle access infrastructure (specifically access and parking off of West Cliff Dr.). The Plan should also support the removal of infrastructure determined to be unsafe and redesign those areas to support alternate public access and coastal viewing opportunities. Maintaining beach width and low impact visitor access into the park should be a priority (i.e., moving access road and guiding foot traffic through designated entrances). Decisions regarding realignment of parking and vehicle access locations will be informed by the West Cliff Drive Adaptation and Management Plan, currently in development.

Triggers to Initiate Strategy: Table 14 provides examples of monitoring parameters and trigger criteria that could be used to trigger the transition to managed retreat of State Park infrastructure at Natural Bridges State Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 14. Example monitoring parameters and trigger criteria to be used for managed retreat of State Park infrastructure at Natural Bridges State Beach.

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Beach erodes (mean high tide line) to within 100 feet of restroom
Repairs Frequency	Access road or clifftop parking lot from West Cliff needs to be repaired twice within a 5 year period.
Cost exceedance	Repair or replacement costs exceed 10% of cost to relocate access road to Delaware Ave.
Loss of public use and access	Occurrence of days public facilities/ infrastructure/ access is closed due to flooding or erosion is more than 10 days/year for 3 years.
Flood impacts to park infrastructure and frequency	Storm waves flood restroom, ADA parking in visitor center lot, or access road from West Cliff, more than 5 times/year or 1x a year for 3 consecutive years
Blufftop offset (West Cliff access and parking on point)	Any erosion damages to state park parking lot.

Costs and Funding Strategy: Support State Parks efforts to seek funding to implement actions to relocate infrastructure out of hazard areas. Moving infrastructure has variable costs, depending on the scope and complexity of the projects. Examples range from relocating benches, to realignment of vehicular access. Retreat actions could be funded differently depending on the infrastructure impacted. Funding from a statewide funding program to build resiliency of State Parks may support these adaptation actions (e.g. vehicle license fee for parks). The City should support broader State Parks and other statewide actions to fund these efforts. (See Appendix F, Funding Strategies).

Benefits:

- Relocating infrastructure before cliff erosion or flooding occurs will eliminate need for costly emergency repairs.
- Planning retreat ahead of cliff erosion will allow City to prioritize and maintain select infrastructure (including identifying different means for auto access and parking and developing alternative access opportunities).
- Allowing for backshore retreat can maintain beach width.

Consequences:

- Possible loss of services (e.g., eliminating auto access from West Cliff Dr., or loss of parking due to managed retreat).

Implications to Unique User Groups: The loss of services (roadway and parking) may impact user groups who rely on ADA amenities, and cliff top infrastructure.

Mitigation Actions: By prioritizing the retention of cliff top public infrastructure (walkways and bike paths), the loss of public access and viewing opportunities will be minimized. If the West Cliff Drive parking lot is decommissioned, parking could be reconfigured on-site, or Swanton Blvd and Delaware Ave.

Natural Bridges State Beach Adaptation Pathway

Pathway Description

This adaptation pathway focuses on expanding living shoreline efforts and ultimately managed retreat/realignment of services as sea levels rise (Figure 63 and Figure 64). Since this area is within the jurisdiction of State Parks, use of armoring to protect infrastructure is restricted due to State Park policies. The Natural Bridges pathway aligns with many aspects of the Natural Bridges State Beach Plan (1992) and supports coordination with adaptation strategies for City beaches and West Cliff Drive.

Key Goals Supported by this Pathway:

- Maintain or increase beach area for public recreation.
- Work with State Parks on managed retreat plan that meets beach width goals, considers unique aquatic habitat (e.g., tidepools, lagoon etc.), and supports habitat restoration objectives.
- Investigate alternative ways to access Natural Bridges State Beach to avoid erosion and flood hazard zones and maintain multimodal access.
- Focus on living shoreline adaptations.

Incremental Change in Beach Resources & 2100 End Point

By supporting natural retreat processes as outlined in the Natural Bridges Management Plan, State Parks will support the incremental relocation of visitor serving amenities and coastal access opportunities while supporting the continued migration of the beach and lagoon inland. This natural process will likely lead to the continued presence of a valuable beach area and the likely future return of new Natural Bridges geologic structures. This strategy will ensure that the City of Santa Cruz continues to have beach access and recreational opportunities on the west end of town.

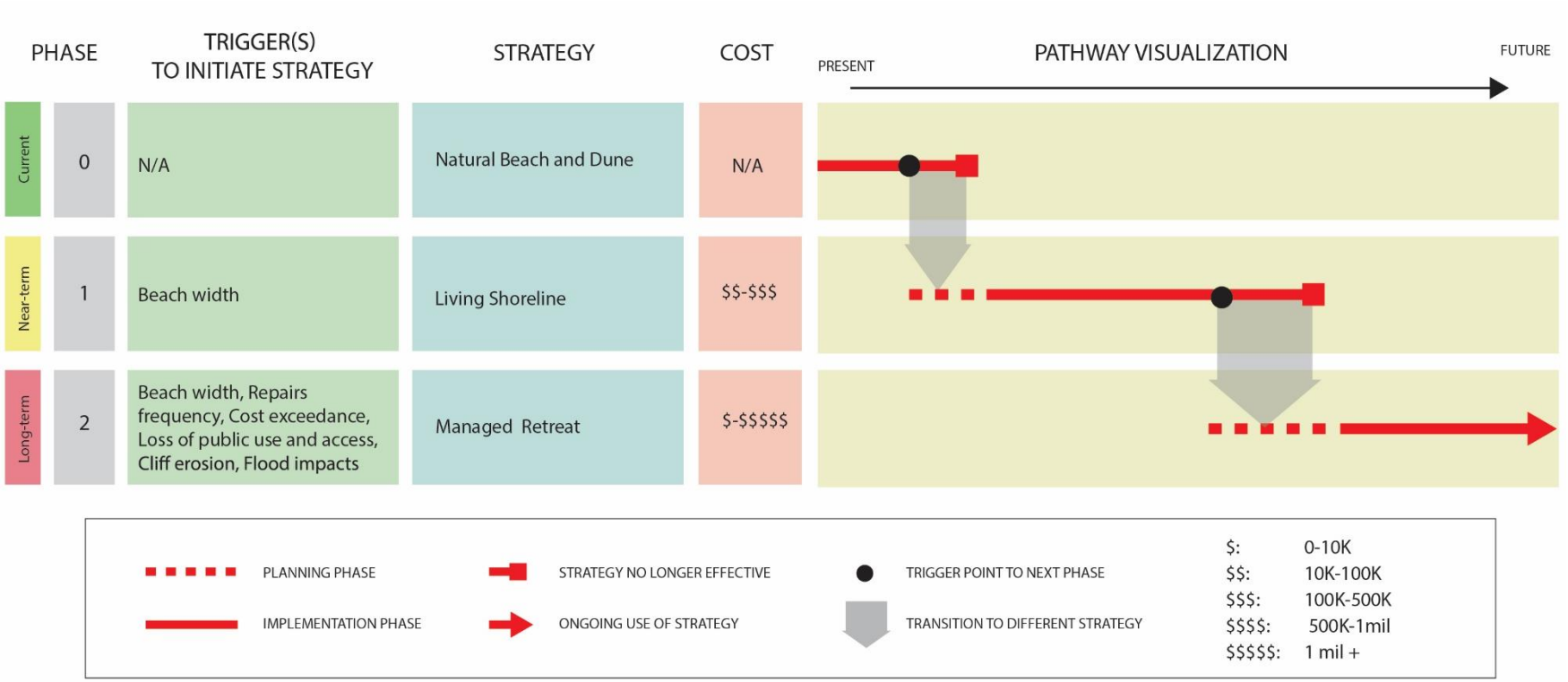


Figure 63. Natural Bridges State Beach adaptation pathway

Figure 64. Map showing potential locations to implement strategies within the Natural Bridges State Beach adaptation pathway

Adaptation Impacts to Under-represented Groups

By implementing the Managed Retreat Adaptation Pathway and implementing measures to upgrade specific services, overall level of service for unique user groups is estimated to increase by 2100 (Table 15). Methods used to calculate these benefits are described in Appendix D. Future job opportunities remain low leading to a low estimated level of unique service for low income residents.

Measures to support community equity and access opportunities for all include:

- Provide fire pits and evening access
- Upgrade/integrate coastal trail with park access
- Maintain ADA parking

Relative costs to implement the Natural Bridges Managed Retreat Pathway (5$) and add the amenities and measures needed to ensure equitable access (4$) are relatively low and provide a high quality level of service to most groups compared with other beach segments.

Table 15. Estimated change in level of service at Natural Bridges State Beach resulting from each adaptation pathway for each stakeholder group compared with current level of service. Relative costs (combine number of $) for implementation and for additional infrastructure needed to achive this level of service.

Under-Represented Group	Current	Managed Retreat
Elderly	92%	100%
Youth	86%	71%
People with Disabilities	92%	100%
Low Income residents	50%	50%
Tribal	100%	100%
Homeless	50%	83%
LGBTQ+	100%	100%
Fishers	100%	100%
Costs # $	1	5
Mitigations # $	0	4
Total $	**1**	**9**

West Cliff Pocket Beaches Adaptation Strategy Options & Pathway Alternatives

West Cliff Pocket Beaches Adaptation Strategy Options

Sand Management/Beach Nourishment

Implementation Programs: Draft Resilient Beaches Management Plan that evaluates and outlines a Sand Management/Beach Nourishment implementation strategy that deposits sand on selected West Cliff beaches (e.g. Pyramid Beach) to support local beach expansion and increase sand supply for the West Cliff littoral zone. This effort should also be coordinated with the Regional Sediment Management Plan and the Coastal Sediment Management Workgroup. By using a multi-beach sand management strategy, sand carried away from one location could be deposited on other city beaches before being carried further downcoast. Beach nourishment can be coordinated with living shoreline program and river mouth management efforts along other segments of the city coastline.

Triggers to Initiate Strategy: Table 16 provides example monitoring parameters and trigger criteria that could be used to trigger the transition to beach nourishment/sand management along West Cliff pocket beaches and cliffs. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 16. Example monitoring parameters and trigger criteria to be used for a beach nourishment/sand management program along West Cliff pocket beaches.

Monitoring Parameter	Trigger Criteria/Threshold
Beach width (Pyramid Beach)	Average annual late summer (September) dry beach width is less than 25ft fronting (seaward of) the revetment for more than 3 years in a row.
Beach width (Its Beach and Mitchell's Cove)	Average annual late summer dry beach area at mean high tide is less than 25ft for Mitchell's and 50ft for Its beach fronting (seaward of) the revetment for more than 3 years in a row.

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that equitably allocates costs among City of Santa Cruz and property owners who benefit from existing armoring that has led to a reduction in beach area and protection of the path and infrastructure. Beach nourishment may also be funded as mitigation banking for armoring occurring in other parts of the city. A recent (2018b) California Coastal Commission staff report quotes the cost of transporting and depositing sand at $50 per cubic yard, but this is dependent on availability of source sand. This would be a regular ongoing cost and will need to be evaluated with in comparison to other strategies.

Benefits:

- Reduces wave impacts to back shore cliffs and/or armoring.
- Enhances recreational beach area.
- Improved public access and recreational opportunities.

Consequences:

- The sand management program relies on routine beach nourishment efforts and may compromise sand supply along other segments of the coastline.

Implications to unique user groups: No anticipated impacts on any unique user groups. May benefit user groups who value recreational beach opportunities.

Mitigation Actions: Acquire sand from off shore or remote locations to minimize changes in down coast sand supply. Prioritize bluff top recreational access and direct ocean access to compensate for any loss of beach area that occurs in non-prioritized areas.

Example Activities:

- Implement beach nourishment of Pyramid Beach to retain pocket beach and support littoral sand transport east to other West Cliff zones
- Implement Beach nourishment of Mitchell's Cove to mitigate beach loss due to riprap

Upgrade Stormwater Infrastructure & Manage Informal Trails

Implementation Programs: Draft Cliff Top Maintenance Plan or include within the Coastal Armoring Management Plan a section that outlines stormwater and dirt path access upgrades needed to reduce or eliminate cliff erosion and failure caused by erosive foot traffic and poorly managed or failing storm drain infrastructure. Revegetation of eroded areas with native plants can be included in the plan.

Triggers to Initiate Strategy: Table 17 provides example monitoring parameters and trigger criteria that could be used to trigger the upgrade of stormwater infrastructure and management of informal trails along West Cliff pocket beaches and cliffs. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 17. Example monitoring parameters and trigger criteria to be used for upgrading storm water infrastructure along West Cliff pocket beaches and cliffs.

Monitoring Parameter	Example Trigger Criteria/Threshold
Storm drain caused cliff erosion	Annual survey of condition of storm water infrastructure shows failed or damaged storm water pipes or outfalls contributing to erosion
Erosion due to informal access trails	Annual survey of informal access trails shows trails contributing to erosion

Costs and Funding Strategy: Include expanded funding for coastal storm drain infrastructure upgrades that address cliff failure and erosion, storm water quality, and other infrastructure damage. Costs can be shared with larger Santa Cruz community as part of funding an enhanced citywide storm water management program.

Benefits:

- Reduces storm water impacts to back shore cliffs and/or armoring.
- Improved public access/safety and recreational opportunities and reduce erosion on cliff tops.
- Improved cliff top habitat areas

Consequences:

- Additional community costs to improve the storm drain system
- Potential loss of informal vertical or lateral access

Implications to Unique User Groups: No anticipated impacts on any unique user groups. May benefit user groups who value safe access ways, natural habitat areas and clean water.

Mitigation Actions: Implement Citywide Storm Water program. Include/implement reduction strategies to minimize coastal discharge through LCP policies and directives.

Example Activities:

- Use storm water infrastructure inventory to prioritize infrastructure upgrades focused on Zones 1 & 2.
- Upgrade storm water infrastructure to reduce water quality impacts to entire zone, especially Michell's and Its beach where public use is highest.

Maintain or Repair Revetment

Implementation Programs: This action "holds the line" and invests in securing the shoreline in place. Draft a Coastal Armoring Management Plan that outlines armoring upgrades and replacement strategies to protect public and private buildings and infrastructure along West Cliff. Policies and programs to be included within the Coastal Armoring Management Plan should describe how to upgrade existing, and design new structures to enhance beach and terrace access and coastal viewing opportunities, and how to provide mitigation for unavoidable impacts. Repairs to revetment can be done in coordination with removal of rip rap at other locations and therefore repurpose locally unnecessary rock. The plan should establish indicators to determine when these upgraded structures no longer provide intended functions and thus, trigger long term alternative actions. The forthcoming West Cliff Drive Adaptation and Management Plan may fulfill this need, and will include a more detailed analysis than the one presented here.

Triggers to Initiate Strategy: Table 18 provides examples of monitoring parameters and trigger criteria that could be used to trigger the repair or maintenance of a revetment along West Cliff pocket beaches. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that allocates costs among City of Santa Cruz, West Cliff residents and visitors who benefit from shoreline armoring. Include in the Coastal Armoring Management Plan funding strategies to support structural integrity monitoring and repair/upgrade/removal costs. One financing option is a Community Facilities District for the properties near the coast, where revenue is used for resilience measures, in addition to a tax on visitors, such as an increased transient occupancy tax. The cost of revetment repairs is variable between years. In 2017 the City estimated cost to repair revetment was $398,807 (City of Santa Cruz, 2018b), while in 2018 the estimated cost was substantially less (City of Santa Cruz, 2019). See the forthcoming West Cliff Drive Adaptation and Management Plan for a more detailed cost benefit analysis for revetment.

Table 18. Example monitoring parameters and trigger criteria to be used for maintaining/repairing a revetment along West Cliff pocket beaches.

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width (Mitchell's Beach and Its Beach)	Average annual late summer dry beach area at mean high tide is less than 25 ft2 for Mitchell's and 50 ft for Its beach fronting (seaward of) the revetment for more than 3 years in a row.
Integrity of Armoring	Revetment showing signs of failure (rock that has detached from the revetment or moved seaward of the permitted footprint, a drop in the back shore elevation of the revetment, exposure of the underlying fabric layer, etc.)
Repairs frequency	The Rec Trail and/or beach access has to be repaired more than twice per year over a five-year period.

Benefits:

- Maintain cliff top area with high level of protective certainty, maintain cliff top benches and trails.
- Protects private and public property (roads, Rec Trail, public parking, coastal access, houses, utilities etc.).
- Longer protective lifespan than living shorelines.
- This strategy can protect coastal structures (stairs) that provide access to the water and beaches.

Consequences:

- This strategy may lead to additional visual impacts from larger structures.
- Potential beach access restrictions due to footprint of structure.
- Loss of sandy beach area as shoreline erodes towards revetment (coastal squeeze).
- Potential mitigation fees and permitting requirements associated with loss of beach area due to footprint.
- May impact wave patterns, and therefore offshore surfing and other important recreational opportunities.
- Riprap compromising pest management issues.

Implications to unique user groups: May impacts unique user groups who value coastal views, beaches, and surfing.

Mitigation Actions: Implementation of beach nourishment programs can minimize the loss of beach area.

Example Activities:

- Upgrade revetment near Woodrow Ave

Replace Revetment with, or Construct New Soil Nail Wall or other Hard Structure (Cave Fill or Artificial Bedrock Platform)

Implementation Programs: This action "holds the line" and invests in new (or repurposed) infrastructure to maintain the shoreline in place. Selective removal of revetment (for reuse elsewhere) that hinders access, reduces beach area and lateral access and reduces coastal views can be investigated. This strategy can include a number of options:

- Soll nail wall: A soil nail wall or vertical seawall would remove riprap and increase the usable recreational beach by reducing the foot print of the protective structure on the beach and

ecology while maintaining vertical access and enhancing lateral access (Zones 1 to 4).

- Artificial bedrock platform: Removing or repurposing the existing revetment to construct an artificial bedrock platform, which would allow for enhanced shore protection over a 30-50 year timeframe while promoting lateral access along the existing artificial bedrock platform. This method has been applied in Pebble Beach and can integrate aesthetic, vertical access, and habitat elements into the design (Zone 1).
- Cave fill: Deposit new material or repurpose existing revetment to construct cave fill and entrance cap which would reduce future risk of cave roof failure and resulting loss of coastal infrastructure. This method can be prioritized among the numerous caves based on 1) likelihood of failure, 2) clifftop resources at risk, 3) impacts to lateral access (pedestrian, bike, auto), 4) risk to utilities or private infrastructure.

Draft a Coastal Armoring Management Plan that outlines armoring upgrades and replacement strategies to protect public and private buildings and infrastructure along West Cliff. Policies and programs to be included within the Coastal Armoring Management Plan should describe how to upgrade existing, and design new structures to enhance beach and terrace access and coastal viewing opportunities, and how to provide mitigation for unavoidable impacts. The plan should establish indicators to determine when these upgraded structures no longer provide intended functions and thus, trigger long term alternative actions. Refer to the forthcoming West Cliff Drive Adaptation and Management Plan for a more detailed analysis and feasibility of armoring options on West Cliff Dr.

Triggers: Table 19 provides examples of monitoring parameters and trigger criteria that could be used to trigger replacing a revetment with a soil nail wall or other armoring structure along West Cliff. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 19. Example monitoring parameters and trigger criteria to be used for replacing a revetment with a soil nail wall along West Cliff pocket beaches.

Monitoring Parameter	Example Trigger Criteria/Threshold
Cliff erosion/Blufftop offset	Distance between blufftop edge and Rec Trail is less than 10 feet
Repairs frequency	The Rec Trail and/or beach access sustains significant damage twice within a five-year period.
Cost exceedance	Repair costs from sea level rise related impact exceed $500,000 (2020 value).
Cave Ceiling thickness (erosion concern areas)	Cave ceiling thickness is less than 4 ft at narrowest point

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that, similar to the revetment funding strategies, allocates costs among City of Santa Cruz, West Cliff residents and visitors who benefit from shoreline armoring. Include funding strategies in the Coastal Armoring Management Plan to support structural integrity monitoring and repair/upgrade/removal costs. One option would be a Community Facilities District for the properties near the coast, where revenue is used for resilience measures. Another option is a tax on visitors, such as an increased transient occupancy tax. Soil nail walls can be the most expensive of armoring options; the East Cliff soil nail wall, along with trail improvements extending from

Pleasure Point Park to 36th Avenue, was reported to cost $3.1 million (Hoppin, 2011).

Benefits:

- Maintain cliff top area with high level of protective certainty, probably higher than with rip rap
- Maintain cliff top benches and trails.
- Protects private and public property (roads, Rec Trail, public parking, coastal access, houses, etc.).
- Longer protective lifespan than living shorelines.
- This strategy can lead to an enhancement in cliff face infrastructure that provides access to the water and beaches.
- Structure has a smaller footprint than revetment (i.e. rip rap) increasing the amount of available beach space.

Consequences

- This strategy may lead to continued visual impacts of structures, although less than rip rap
- Potential beach access restrictions
- Loss of sandy beach area as shoreline erodes towards armoring (coastal squeeze).
- Potential mitigation fees and permitting requirements associated with loss of beach area due to footprint of structure.
- Significantly higher cost than revetments (rip rap).
- May impact wave patterns, and therefore offshore surfing and other important recreational opportunities.

Implications to unique user groups: May benefit user groups who value access to the water (fishing from beach), and ADA cliff top infrastructure. May impact those who prefer to fish from mid-level terraces along cliffs.

Mitigation Actions: Soil nail wall upgrades can include design elements that enhance public use of roadway, public bike and pedestrian pathways, and access points to the beach and terrace. Implementation of beach nourishment programs in conjunction with construction of hard armoring can minimize the loss of beach area.

Construct Sand Retention Structure/Groin

Implementation Programs: This action invests in new infrastructure to retain sand within priority beach areas. Selective placement of groins in coordination with a beach nourishment or sand management program, can increase beach area and lateral access and reduces coastal cliff erosion within these beach areas.

Triggers: Table 20 provides examples of monitoring parameters and trigger criteria that could be used to trigger the transition to constructing a groin at a West Cliff pocket beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 20. Example monitoring parameters and trigger criteria to be used for constructing a groin along West Cliff pocket beaches

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width (Mitchell's Cove)	Average annual late summer (September) dry beach width is less than 25 feet fronting (seaward of) the revetment for more than 3 years in a row.
Loss of public use and access	Occurrence of days beach/access is closed due to coastal flooding is more than 10 days/year for 3 years

Costs and Funding Strategy: Groin cost will vary based on the dimensions of the structure. The projected cost of a single groin for a recent southern California proposal was approximately $2 million (Diehl, 2019). See the forthcoming West Cliff Drive Adaptation and Management Plan for a more detailed cost-benefit analysis. Groins could be financed with a special district, as with other armoring measures, but it may be also appropriate to associate their costs with nourishment funding strategies due to the sand they accumulate.

Benefits:

- Leads to the additional collection of sand at Mitchell's Cove.
- Lateral access along the beach and recreational areas on the beach will be enhanced due to an increase in sand accumulation.
- Long expected life of project.

Consequences:

- Initial loss of beach footprint depending on footprint of jetty.
- May reduce sand supply to eastern beaches.
- May impact wave patterns, and therefore offshore surfing and other important recreational opportunities.

Implications to unique user groups: No anticipated impacts on any unique user groups. May benefit user groups who value natural habitat areas and beach recreation.

Mitigation Actions: Beach nourishment can be implanted in conjunction with the groin strategy to offset impacts to down coast sand supply.

Example Activities:

- Construct a groin at Mitchell's Cove to help slow sediment transport, impound sand, and help to create more usable recreational beach.

Remove Armoring & Managed Retreat

Implementation Programs: Draft a Coastal Armoring Management Plan that outlines armoring restrictions and future removal strategies. Managed retreat policies and programs to be included within the Coastal Armoring Management Plan should describe equitable strategies to transition property at risk to other land uses that reduce these risks (See Appendix G for Strategies and Tools). These strategies could include special districts to fund this transition, and legal procedures and policies to incrementally implement redevelopment or retreat programs. Support the removal of infrastructure determined to be unsafe and redesign those areas to support public cliff top and beach access opportunities needed to retain, restore, or enhance existing 2020 amenities and level of service (see April 2020 Social Vulnerability Need and Risk Assessment).

Triggers: Table 21 provides examples of monitoring parameters and trigger criteria to be used to remove armoring and allow managed retreat along West Cliff pocket beaches. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 21. Example monitoring parameters and trigger criteria to be used for removing armoring and allowing managed retreat along West Cliff pocket beaches

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width (Mitchell's Cove and Its Beach)	Average annual late summer (September) dry beach width is less than 25 feet fronting (seaward of) the revetment for more than 3 years in a row.
Cliff erosion/Blufftop offset	Distance between clifftop edge and Rec Trail is less than 5 feet. Distance between clifftop edge and Lighthouse is less than 40 feet
Repairs frequency	The Rec Trail and/or beach access has to be repaired more than twice over a five-year period
Cave ceiling thickness	Cave ceiling thickness is less than 4 ft at narrowest point
Cost exceedance	Repair costs from sea level rise related impact exceed $500,000 (2020 value).
Loss of public use and access (Its Beach lateral access)	Lateral access along beach west of riprap is blocked during mean sea level.

Costs and Funding Strategy: Strategies could include a tax and other financial incentives (See Appendix F, Funding Strategies) that support private redevelopment investments. Integrate public infrastructure upgrades/realignment costs in existing or future special tax district. Managed retreat can be costly; the City of Pacifica, with funding from the California Coastal Conservancy, purchased two homes and the surrounding acreage for $2.2 million to restore a dune and wetland habitat in 2002 (NOAA, 2015). Acreage amounts would be smaller in Santa Cruz, but costs may still be high. Municipal acquisition of lands at risk helps retain public access along cliff tops and enables greater options for adaptation within those areas (see Appendix G for other strategies and tool for managed retreat).

Benefits:

- Supports the retention of public lands (i.e. Michell's Cove and pocket beaches).
- Relies on redevelopment plan to maintain public access along West Cliff.

Consequences:

- Potential loss of infrastructure could occur.
- Potential loss of visitor serving infrastructure including West Cliff Drive could occur.
- Potential loss of public and private property within sea level rise and coastal erosion impact zones.
- High cost of private property and the potential need to protect the new interface.

Implications to Unique User Groups: The potential loss of services (roadway and parking) may impact user groups who rely on ADA amenities, and cliff top infrastructure.

Mitigation Actions: By prioritizing the retention of public infrastructure (walkways and bike paths), a loss of public access will be

minimized. Strategic realignment of roadway and recreation trail within existing 5' roadway right of way can support public use with limited private impacts. As cliff tops erode inland, a gradual change in land use is needed. Public acquisition of these vulnerable properties and existing buildings and infrastructure can limit private risk by allowing the continued use of existing land uses through leasing back of lands for current use while safe to do so. When hazards are too great the municipally owned infrastructure can be converted to open space.

Example Activities:

- Remove revetment on Its Beach that is restricting lateral beach access.
- Remove revetment on Mitchell's Cove beach that has reduced beach area and use.

West Cliff Pocket Beaches Adaptation Pathways

Pathway Description

No single adaptation strategy will address the projected hazards or support the priority management goals for West Cliff beaches. By identifying priority beach and coastal management objectives for beaches in each zone, the four adaptation pathways aim to support a strategic adaptation plan that maintains access and use of priority beaches, protects lateral access and recreational opportunities, retains all vehicular access to visitors, residents, and services, and invests in managed retreat where such strategies will prioritize investments of limited funds to best achieve the City's coastal goals (Figure 65 through Figure 72). These pathways are intended to work in unison with the West Cliff Drive Adaptation and Management Plan.

These adaptation pathways focus on a combination of approaches to initially retain coastal and visitor serving infrastructure in their current locations, where retreat would lead to a reduction in resources. In areas where inland migration of infrastructure is feasible, management of beach and cliff top access and recreation are prioritized over protection in place strategies. If lateral access and beach area are lost within priority beach areas, beach nourishment can be implemented to regain beach area. If impacts compromise the ongoing use of recreational infrastructure the strategy will focus on redesign of infrastructure to be resilient to projected hazards or relocated out of hazard areas. As projected hazards become more severe, a removal of low priority infrastructure within its current location can be implemented (i.e. reduction in coastal parking and two way roadway) and alternate locations for those services can be identified (managed retreat of auto use). Preservation of remaining beaches, visitor serving amenities and coastal access are a priority.

Key Goals Supported by these Pathways:

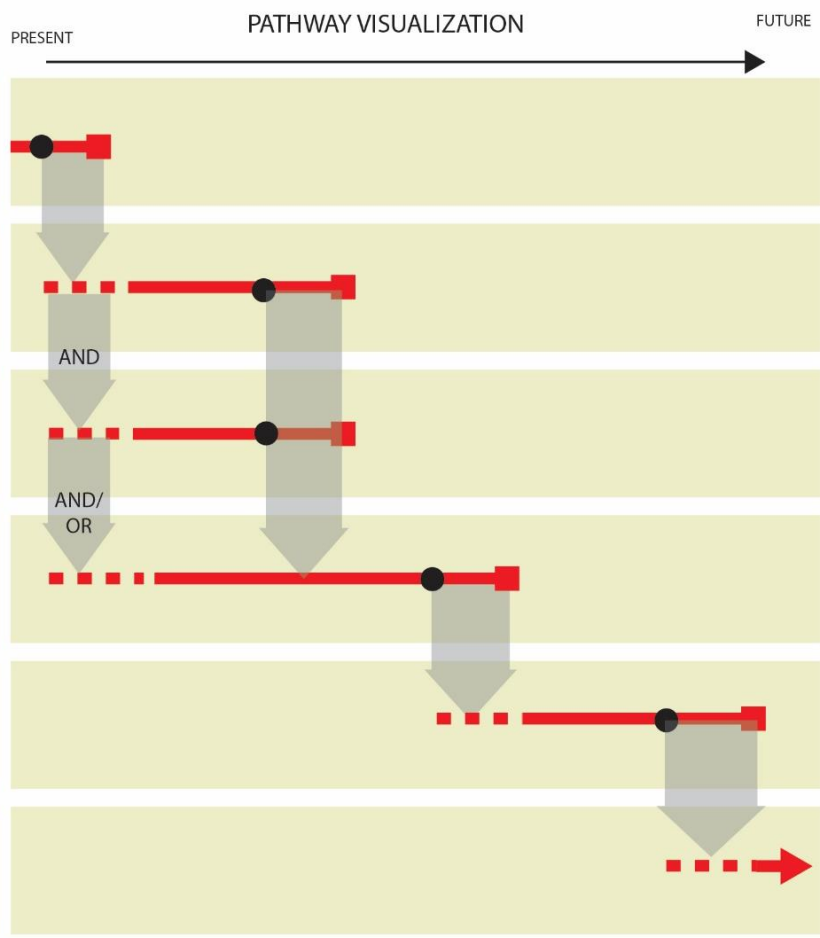
- To the extent possible, retain access to some pocket beaches including Lighthouse and Mitchell's Cove through 2100.
- Manage public safety (on beach and bluff) with respect to bluff failure and access ways.
- Retain level of multi modal beach access adjacent to priority pocket beaches.
- Identify options for continued access along the coast even where beaches are lost (through blufftop trails, parks, etc. and/or access features along seawalls).

Incremental Change in Beach Resources & 2100 End Point

Reclamation of lost pocket beaches is unlikely but preservation of key pocket beaches including Pyramid Beach, Mitchell's Cove, and Its Beach may be feasible through the transition of rip-rap to vertical sea walls (to reduce the footprint of the coastal armoring structure and reclaim beach), beach nourishment and sand management efforts, and removal of rip-rap to support natural coastal erosion processes at Its beach. The integration of lateral access along terraces within seawall upgrades can improve coastal viewing, access, and recreational and fishing opportunities in places where pocket beach reclamation is unlikely. Allowing natural coastal erosion processes at Its beach and Lighthouse Point can benefit natural coastline processes and be integrated with other bluff top visitor serving upgrades.

Adaptation Pathway West Cliff Zone 1 (Pyramid Beach)

	PHASE	TRIGGER(S) TO INITIATE STRATEGY	STRATEGY	COST
Current	0	N/A	Revetment	N/A
Near-Term	1a	Storm drain caused cliff erosion, Erosion due to unsanctioned access trails	Upgrade storm water infrastructure & manage informal access trails	$$-$$$
Near-Term	1b	Integrity of structure, Repairs frequency	Maintain/repair existing revetment	$$$-$$$
Near-Term	1c	Beach width	Sand management & Beach nourishment	$$$$-$$$$$
Mid-Term	2	Cliff erosion, Repairs frequency, Cost exceedance, Cave ceiling thickness	Upgrade structure to soil nail wall, or other hard structure, and cave fill	$$$$$
Long-Term	3	Cliff erosion, Repairs frequency, Cost exceedance	Remove armoring/ Managed retreat	$$$$$



PLANNING PHASE
IMPLEMENTATION PHASE
STRATEGY NO LONGER EFFECTIVE
ONGOING USE OF STRATEGY
TRIGGER POINT TO NEXT PHASE
TRANSITION TO DIFFERENT STRATEGY

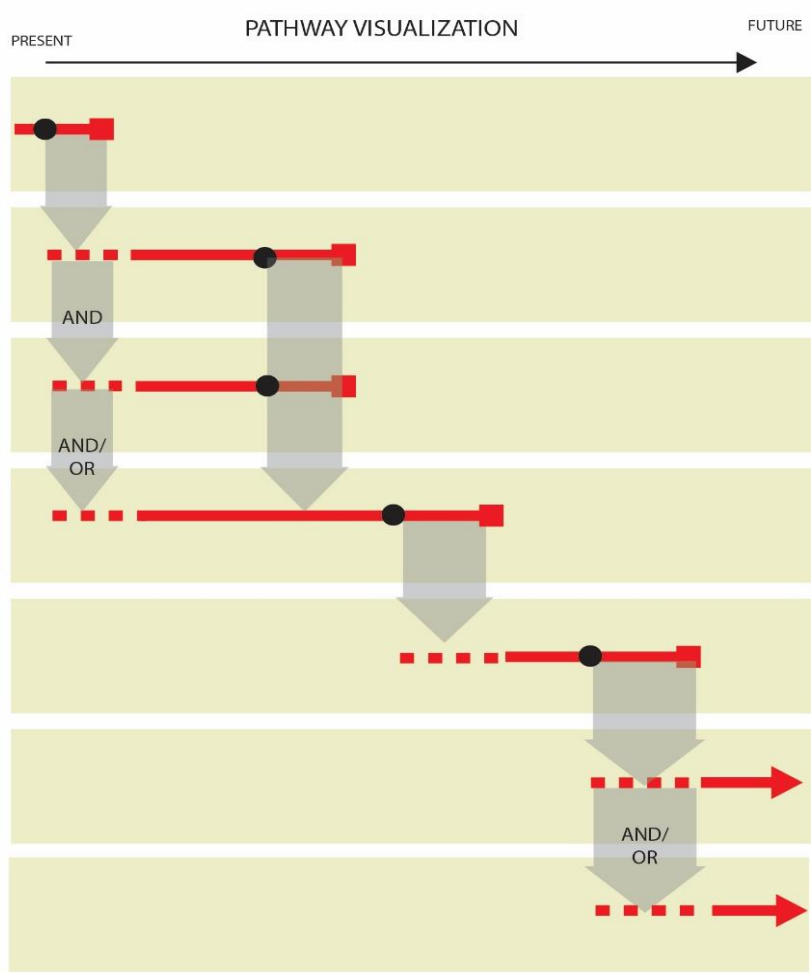
$:	0-10K
$$:	10K-100K
$$$:	100K-500K
$$$$:	500K-1mil
$$$$$:	1 mil +

Figure 65. West Cliff Drive Zone 1 (Pyramid Beach) adaptation pathway

Figure 66. Map showing potential locations to implement strategies within the West Cliff Drive Zone 1 (Pyramid Beach) adaptation pathway

Adaptation Pathway West Cliff Zone 2 (Mitchell's Cove)

	PHASE	TRIGGER(S) TO INITIATE STRATEGY	STRATEGY	COST
Current	0	N/A	Revetment	N/A
Near Term	1a	Storm drain caused cliff erosion, Erosion due to unsanctioned access trails	Upgrade storm water infrastructure & manage informal access trails	$$-$$$
Near Term	1b	Integrity of structure, Repairs frequency	Maintain/repair existing revetment	$$$-$$$$
Near Term	1c	Beach width	Sand management (from Zone 1/Pyramid Beach)	$$$-$$$$$
Mid-Term	2	Cliff erosion, Repairs frequency, Cost exceedance, Cave ceiling thickness	Upgrade revetment to soil nail wall or sea wall	$$$$$
Long-Term	3a	Beach width, Loss of public use and access	Construct sand retention structure/Groin	$$$$$
Long-Term	3b	Beach width, Cliff erosion, Repairs frequency, Cost exceedane	Remove armoring/ Managed Retreat	$$$$$



PLANNING PHASE
IMPLEMENTATION PHASE
STRATEGY NO LONGER EFFECTIVE
ONGOING USE OF STRATEGY
TRIGGER POINT TO NEXT PHASE
TRANSITION TO DIFFERENT STRATEGY

$:	0-10K
$$:	10K-100K
$$$:	100K-500K
$$$$:	500K-1mil
$$$$$:	1 mil +

Figure 67. West Cliff Drive Zone 2 (Mitchell's Cove) adaptation pathway

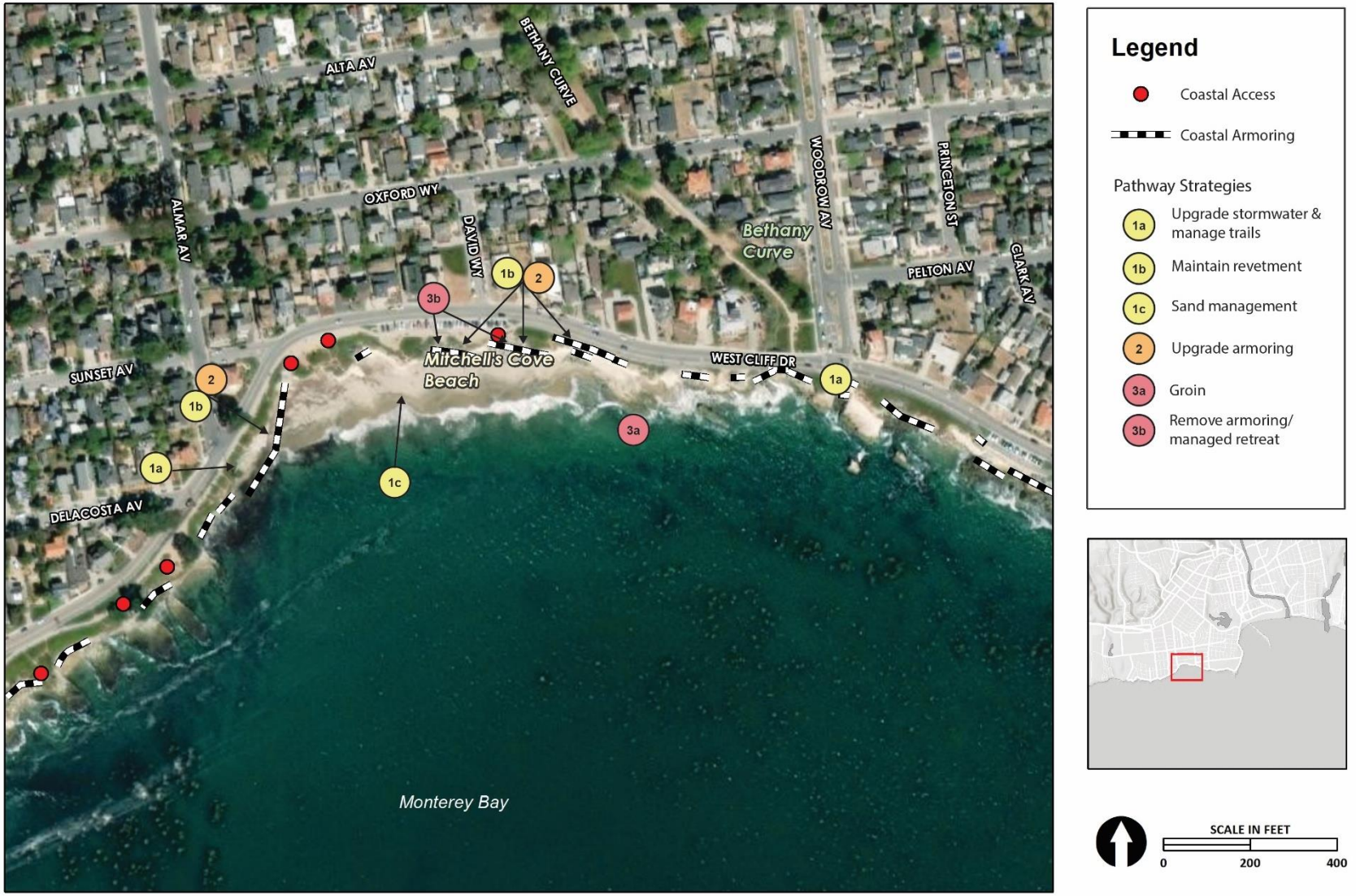
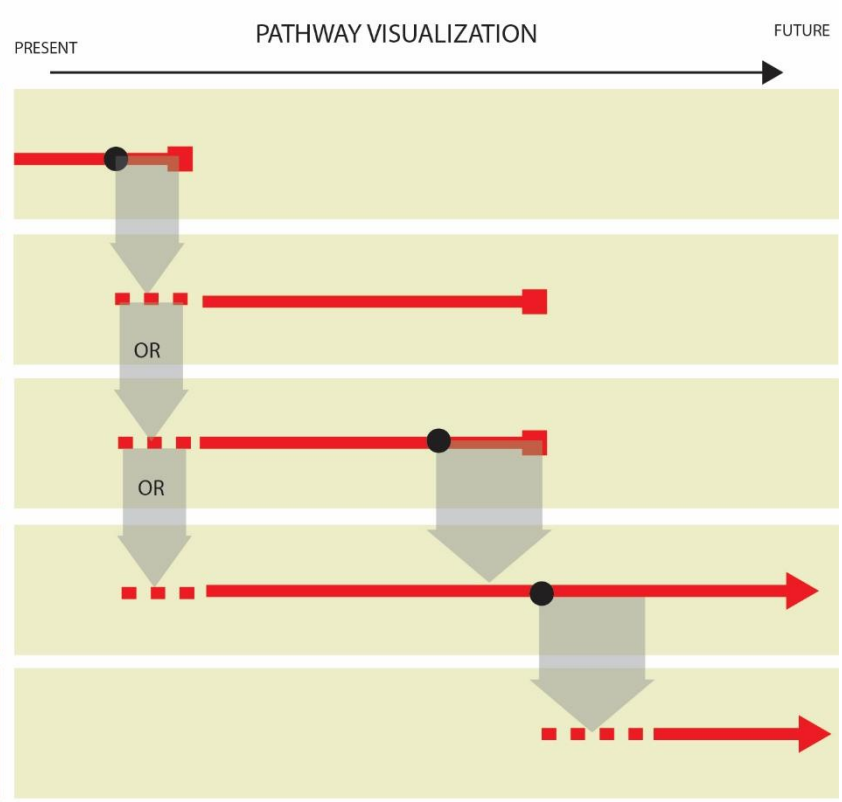


Figure 68. Map showing potential locations to implement strategies within the West Cliff Drive Zone 2 (Mitchell's Cove) adaptation pathway

Adaptation Pathway West Cliff Zone 3 (Its Beach & Lighthouse Point)

	PHASE	TRIGGER(S) TO INITIATE STRATEGY	STRATEGY	COST
Current	0	N/A	Revetment & upper bluff sea wall	N/A
Near-Term	1a	Beach width	Sand management (from Zone 1/Pyramid Beach)	$$$-$$$$$
Near-Term	1b	Cave ceiling thickness	Cave fill (Lighthouse Point Cave)	$$$-$$$$
Near-Term	1c	Cliff erosion, Beach width, Loss of public use and access, Cave ceiling thickness, Repairs frequency, Cost exceedance	Remove armoring/ Managed retreat (Its Beach and Lighthouse)	$$$$
Long-Term	2	Cliff erosion, Repairs frequency, Cave ceiling thickness, Cost exceedance	Upgrade revetment to soil nail wall (east of Lighthouse Point)	$$$$$



PLANNING PHASE
IMPLEMENTATION PHASE
STRATEGY NO LONGER EFFECTIVE
ONGOING USE OF STRATEGY
TRIGGER POINT TO NEXT PHASE
TRANSITION TO DIFFERENT STRATEGY

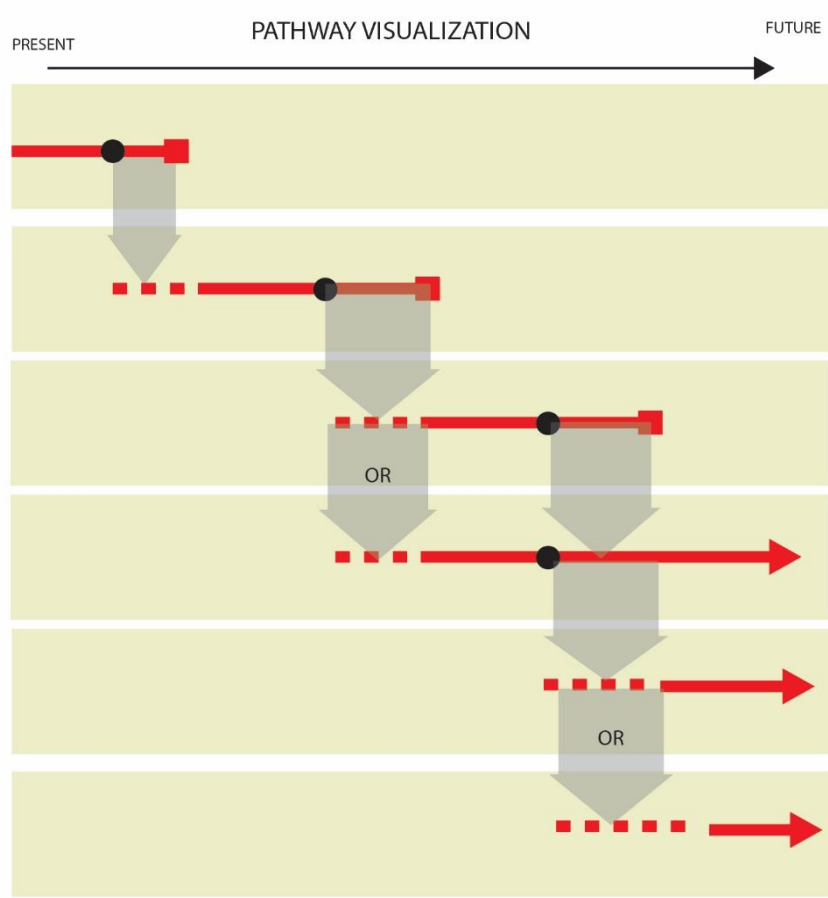
$:	0-10K
$$:	10K-100K
$$$:	100K-500K
$$$$:	500K-1mil
$$$$$:	1 mil +

Figure 69. West Cliff Drive Zone 3 (Its Beach and Lighthouse Point) adaptation pathway

Figure 70. Map showing potential locations to implement strategies within the West Cliff Drive Zone 3 (Its Beach and Lighthouse Point) adaptation pathway

Adaptation Pathway West Cliff Zone 4 (Pelton Ave to Bay Ave)

	PHASE	TRIGGER(S) TO INITIATE STRATEGY	STRATEGY	COST
Current	0	N/A	Revetments	N/A
Near-Term	1	Beach width	Sand management (from Zone 1/Pyramid Beach)	$$$-$$$$$
Mid-Term	2a	Cave ceiling thickness	Cave fill	$$$-$$$$
	2b	Repairs frequency, Cost exceedance, Cliff erosion, Cave ceiling thickness	Managed Retreat (Erosion concern areas)	$$$$$
Long-Term	3a	Repairs frequency, Cost exceedance, Cliff erosion, Cave ceiling thickness,	Upgrade existing armoring to soil nail wall and cave fill	$$$$$
	3b	Repairs frequency, Cost exceedance, Cliff erosion, Cave ceiling thickness	Remove armoring/ Managed retreat	$$$$$



PLANNING PHASE
IMPLEMENTATION PHASE
STRATEGY NO LONGER EFFECTIVE
ONGOING USE OF STRATEGY
TRIGGER POINT TO NEXT PHASE
TRANSITION TO DIFFERENT STRATEGY

$:	0-10K
$$:	10K-100K
$$$:	100K-500K
$$$$:	500K-1mil
$$$$$:	1 mil +

Figure 71. West Cliff Drive Zone 4 (Bay Ave to Pelton Ave) adaptation pathway

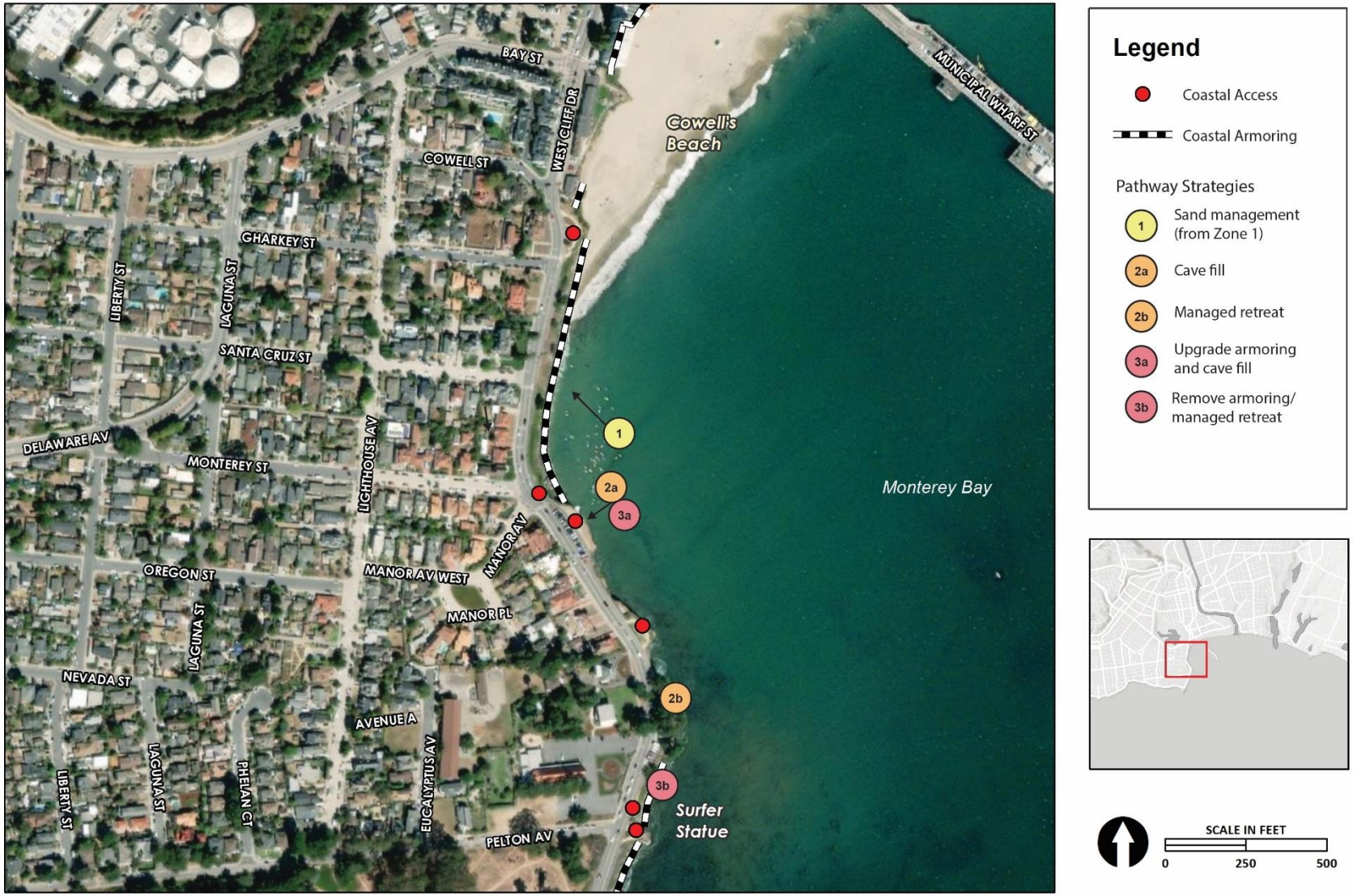


Figure 72. Map showing potential locations to implement strategies within the West Cliff Drive Zone 4 (Bay Ave to Pelton Ave) adaptation pathway

Adaptation Impacts to Under-represented Groups

Implementing the Armor Maintenance, Sea Wall Upgrade and Managed Retreat Adaptation Pathways will affect the overall level of service for unique user groups by 2100 (Table 22).

In most cases, if design elements and upgrades are included within the adaptation pathway (described below) then the level of service can be increased above current levels. Relative costs to implement each pathway and the additional relative costs to include needed mitigation actions are presented the table. Estimated costs to maintain current infrastructure is also noted.

Upgrading existing revetment to sea walls (with included design elements/mitigations) is shown to increase the level of service within each zone for most user groups. Costs associated with this are often high, as is supporting a manage retreat policy. In many cases the needed mitigations to address loss in the level of access are similarly high to the adaptation strategies within this portion of the City coastline. Level of service provided along West Cliff zones 1 and 4 remain low, regardless of the adaptation strategy selected, for these user groups.

Adopting and implementing the managed retreat actions at Its beach are estimated to lead to the greatest increase in the level of service for all under-represented user groups.

Measures to support community equity and access opportunities for all while adapting to sea level rise include:

- Install/maintain/ upgrade stairs
- include cliff top fishing spots
- expand ADA parking
- Remove rock impeding water access
- upgrade stormwater and surface drainage infrastructure
- replace lookouts as they fail
- maintain coast trail
- replace benches
- provide gender neutral/late night bathroom
- Integrate grassland/wetland restoration
- Remove riprap and enhance stairs
- Enhance overlooks
- upgrade trail

Relative costs to implement the upgrade armoring and remove armoring strategies for each zone are high as are the costs to upgrade the amenities needed to ensure equitable access. The greatest increase in level of service for all groups is provided by implementing pathways and mitigation actions identified for (West Cliff Drive Zone 3) Lighthouse Point and Its Beach.

Table 22. Current and future level of service for interviewed under-represented stakeholder groups for adaptation pathways of each West Cliff zone. Relative costs are estimated by summing $ for each action.

WCD Zone 1	Under-represented Group	Current	Upgrade Armoring	Remove Armoring
	Elderly	50%	58%	50%
	Youth	43%	64%	43%
	People with Disabilities	33%	42%	33%
	Low Income residents	0%	25%	0%
	Tribal	0%	75%	0%
	Homeless	0%	17%	0%
	LGBTQ+	0%	0%	0%
	Fishers	40%	80%	40%
	Costs # $	8	10	10
	Mitigations # $		11	6
	Total $	**8**	**21**	**16**

WCD Zone 3	Under-represented Group	Current	Upgrade Armoring	Remove Armoring
	Elderly	92%	92%	92%
	Youth	100%	100%	100%
	People with Disabilities	67%	67%	67%
	Low Income residents	75%	100%	100%
	Tribal	75%	100%	100%
	Homeless	50%	50%	67%
	LGBTQ+	50%	50%	100%
	Fishers	90%	100%	100%
	Costs # $	4	9	6
	Mitigations # $		7	15
	Total $	**4**	**16**	**21**

WCD Zone 2	Under-represented Group	Current	Upgrade Armoring	Remove armoring
	Elderly	58%	100%	92%
	Youth	57%	79%	79%
	People with Disabilities	33%	67%	67%
	Low Income residents	0%	25%	25%
	Tribal	50%	75%	75%
	Homeless	0%	50%	50%
	LGBTQ+	0%	100%	100%
	Fishers	60%	80%	80%
	Costs # $	7	9	9
	Mitigations # $		13	16
	Total $	**7**	**22**	**25**

WCD Zone 4	Under-represented Group	Current	Upgrade Armoring	Remove Armoring
	Elderly	58%	100%	58%
	Youth	71%	83%	71%
	People with Disabilities	42%	71%	42%
	Low Income residents	25%	25%	25%
	Tribal	25%	33%	25%
	Homeless	17%	25%	17%
	LGBTQ+	0%	0%	0%
	Fishers	50%	63%	50%
	Costs # $	4	6	6
	Mitigations # $		9	13
	Total $	**4**	**15**	**19**

Main & Cowell Beaches Adaptation Strategy Options & Pathway Alternatives

Main & Cowell Beaches Adaptation Strategy Options

Living Shoreline with Cobble

Implementation Programs: Draft a Resilient Beaches Management Plan that evaluates and outlines a Beach Nourishment/Living Shoreline implementation strategy that supports increased wave resiliency of Main and Cowell Beach back shore. Integrate hard structures within the dunes, where appropriate, to increase protective capacity of living dune habitats. Efforts should be integrated with ongoing beach grooming and river mouth management.

Triggers to Initiate Strategy: Table 23 provides examples of monitoring parameters and trigger criteria to be used for constructing a living shoreline at Main Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that equitably allocates costs among City of Santa Cruz, visitors, and commercial/other who would benefit from construction of protective infrastructure. Costs to expand revegetated dunes are low but will require ongoing maintenance funding to maximize habitat and wave resiliency. Costs to add cobble or other harder structures within the dunes will be more expensive and require restoration of dunes but will be significantly less expensive than revetment or sea wall construction. Due to the interest in "nature-based solutions" for sea level rise, a living shoreline project would be an ideal candidate for grant funding and partnerships with state or NGO sources of funding (e.g. California Coastal Conservancy). Dune construction maintenance could also be funded by a visitor tax (i.e., transient occupancy tax), parking fees, or mitigation associated with armoring other parts of the City's coastline.

Table 23. Example monitoring parameters and trigger criteria to be used for constructing a living shoreline at Main Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Beach width during winter king tides is 100 feet or less for 3 years in a row
Wave overtopping and repairs frequency	Wave overtopping 3 days/year that causes store front damage or flood damage to Beach Flats neighborhood

Benefits:

- Dunes with structural components could have increased functional life.
- Enhances beach habitat and coastal views.
- Can be designed to allow for lateral access.
- No anticipated impacts on unique user groups if amenities are added (e.g. include beach wheelchair accessible path through dune).

Consequences:

- Some loss of recreational beach area
- Expected effective lifespan of living shoreline is less than armoring structure.

Implications to Unique User Groups: No anticipated impacts on any unique user groups. May benefit user groups who valued beach habitat areas.

Mitigation Actions: Lateral access along the beach could be reduced through transition of some recreational areas to habitat. Lateral trails through the living shoreline can enhance access. Paths through the dunes could be angled to the east to reduce winter wave run up "funneling".

Beach Nourishment

Implementation Programs: Draft a Resilient Beaches Management Plan that evaluates and outlines a Beach Nourishment strategy that supports increased resiliency to wave impacts of Main and Cowell Beach back shore and helps to maintain recreational beach area. Beach nourishment can be coordinated with a living shoreline program and river mouth management efforts. This effort should also be coordinated with the Regional Sediment Management Plan and the Coastal Sediment Management Workgroup.

Triggers to Initiate Strategy: Table 24 provides examples of monitoring parameters and trigger criteria that could be used to trigger a beach nourishment strategy at Cowell Beach and Main Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 24. Example monitoring parameters and trigger criteria to be used for beach nourishment at Cowell Beach and Main Beach

Monitoring Parameter	Trigger Criteria/Threshold
Beach width	Average annual late summer (Sept) beach width is less than the pre-harbor beach width (220 ft) for more than 3 years OR Beach width during winter king tides of 100 ft or less for 3 years in a row
Wave overtopping and repairs frequency	Wave overtopping 3 days/year that causes store front damage or flood damage to Beach Flats neighborhood

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that equitably allocates costs among City of Santa Cruz, private property owners, and possibly beach visitors who will benefit from an increase in beach area. Beach nourishment programs have received federal funding. Costs can be shared with the larger Santa Cruz community as part of a citywide sand management program. There is also potential to financially partner with jurisdictions downcoast that receive sediment from City beaches (e.g. the County). Because the beaches are a large draw for tourists, it may be appropriate to raise funds for beach nourishment through an increased tax targeted towards tourists, such as a transient occupancy tax or admissions tax. Beach nourishment may also be funded from armoring mitigation fees occurring in other parts of the city. A recent (2018b) California Coastal Commission staff report quotes the cost of transporting and depositing sand at $50 per cubic yard, but this is dependent on availability of source sand.

Benefits:

- Reduce wave-overtopping and flood damage to backshore infrastructure.
- Helps maintain beach width.
- Can be designed to enhance habitat restoration, public access and recreational opportunities.
- Could be incorporated into large sand management plan with West Cliff Drive beaches.

Consequences:

- Temporary loss of beach use.
- The expected life of a beach nourishment project is short and would need to be repeated.
- Possible change in wave patterns, and therefore may impact offshore surfing and other important recreational opportunities.

Implications to Unique User Groups: No anticipated impacts on any unique user groups. May benefit user groups who value wide beach areas.

Mitigation Actions: Beach contouring can be implemented to limit impacts to beach use and access to waves.

Raise Curb/Support Wall

Implementation Programs: This action "holds the line" and buys time to implement other adaptation measures. Draft Coastal Armoring Management Plan that outlines armoring upgrade and replacement strategies to protect buildings and infrastructure along Beach Street. Policies and programs to be included within the Coastal Armoring Management Plan should describe how to design those structures to protect or enhance lateral public access and coastal viewing opportunities (see April 2020 Social Vulnerability Needs and Risk Assessment). The plan should establish indicators to determine when these upgraded structures no longer provide intended functions and thus, trigger other long term alternative actions.

Triggers to Initiate Strategy: Table 25 provides example of monitoring parameters and trigger criteria to be used for raising the curb wall along Beach Street. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 25. Example monitoring parameters and trigger criteria to be used for raising the curb wall along Beach Street

Monitoring Parameter	Example Trigger Criteria/Threshold
Wave overtopping	Wave overtopping 3 days/year that causes store front damage or flood damage to Beach Flats neighborhood

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that equitably allocates costs among City of Santa Cruz, visitors, and others would benefit from protective infrastructure. Include in the Coastal Armoring Management Plan funding strategies to support structural integrity monitoring and repair/upgrade/removal costs. Some cities utilize a business improvement district for infrastructure upgrades, and resilience measures would qualify as such upgrades. Revenue from businesses may also come from a business license tax or other special tax. Curb wall costs vary depending on the height and thickness of the wall.

Benefits:

- Could be designed to protect coastal roads, public access and visitor serving/recreational opportunities and the businesses along the Main & Cowell beaches waterfront
- Could protect public and private property in the Beach Flats area from wave induced flooding

Consequences:

- Possible visual impacts of structures
- Potential beach access restrictions
- Loss of sandy beach area as shoreline erodes towards revetment (coastal squeeze)
- High Cost

Implications to Unique User Groups: No anticipated impacts on any unique user groups with proper coastal access planning.

Mitigation Actions: Curb wall upgrades can include design elements that enhance public use of roadway, public bike and pedestrian pathways and access points to the beach. Implementation of beach nourishment programs can minimize the loss of beach area.

Accommodate/Increase Resiliency of Infrastructure

Implementation Programs: Augment the South of Laurel/Beaches Area Plan with an equitable Beach Flats Redevelopment Plan that, among other objectives, describes how residential, commercial and visitor serving infrastructure can be upgraded/redeveloped to increase resilience to projected wave impacts and periodic flooding. Define planning and zoning changes to support the investment in resilient infrastructure. Include an analysis of future flooding to ensure stormwater infrastructure remains able to manage projected flood waters.

Triggers to Initiate Strategy: Table 26 provides examples of monitoring parameters and trigger criteria that could be used to trigger increasing infrastructure resiliency at Main and Cowell Beaches. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 26. Example monitoring parameters and trigger criteria to be used for increasing infrastructure resiliency at Main and Cowell Beaches and Beach Street businesses

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Average annual late summer (Sept) beach width is less than the pre-harbor beach width (220 ft) for more than 3 years OR Beach width during winter king tides of 100 ft or less for 3 years in a row
Wave overtopping	Waves overtop curb wall and requires closure of Beach Street more than 3 times/year.
Repairs Frequency	Infrastructure has to be repaired due to sea level rise related impacts more than twice over a five-year period.

Costs and Funding Strategy: Improving the resilience of structures can be costly. For example, elevating a structure out of a flood zone can cost more than $75 per square foot (Cardenas, 2018). Federal assistance may be available if upgrades occur in response to a natural disaster; however, waiting to increase resilience capacity until after a

natural disaster is an undesirable course of action. FEMA does offer some pre-disaster mitigation funding. Generally, federal sources of funding are more accessible when efforts are managed by the City rather than on an individual basis. See Appendix F for additional options.

The City could also evaluate increasing its stormwater overlay fund and other related revenues. Stormwater funding can be used to maintain and upgrade City stormwater infrastructure, including a possible increase of pump capacity in the Beach Flats area. The City could also establish tax incentives for private redevelopment investments (See Appendix F, Funding Strategies). Larger projects that promote housing opportunities and other community services, for which grant funding is more available, could include resilience measures. Tax incentives could entice private investments in resilient infrastructure.

Benefits:

- Maintains visitor serving businesses and city infrastructure.
- Opportunity to enhance recreational opportunities and support local economy.
- Possible decrease in insurance premiums with more resilient structures.

Consequences:

- Expected life of redesigned buildings and infrastructure would be dependent on future rates of sea level rise
- Costs to upgrade public and private property in high flood risk areas would be dependent on future rates of sea level rise.
- Gentrification of beach flats may occur if redevelopment does not provide affordable housing.
- If properties are upgraded but road remains inaccessible during frequent flooding, resilience of area is effectively diminished

Implications to unique user groups: May lead to access/ADA challenges if infrastructure is raised or otherwise reinforced. Improvements to high flood risk areas may not be economically feasible for property owners, or may lead to increased housing costs that limit the affordability to the existing community.

Mitigation Actions: City could change building codes/zoning regulations so that improvements made in areas at high risk for flooding include some resilience measures. Housing initiatives could include resilience measures and require affordable housing. The City could design of a green workforce training program to provide jobs needed to assist in the implementation of the construction of infrastructure elements within the Redevelopment Plan.

Managed Retreat

Implementation Programs: Draft a Coastal Armoring Management Plan that outlines managed retreat strategies. Managed retreat policies and programs to be included within the Coastal Armoring Management Plan should describe equitable strategies to transition at risk properties to lower risk land uses (See Appendix D for Strategies and Tools). Support the removal of infrastructure determined to be unsafe and redesign those areas to support public beach access opportunities needed to retain, restore, or enhance existing 2020 amenities and level of service (see April 2020 Social Vulnerability Needs and Risk Assessment). Draft Coastal Armoring Management Plan that outlines armoring restrictions and derelict infrastructure

removal strategies, use of special districts to fund this transition, and legal procedures and policies to incrementally implement redevelopment/retreat program. Identify planning and tax incentives to support relocation of infrastructure.

Triggers: Table 27 provides example of monitoring parameters and trigger criteria that could be used to managed retreat strategies at Main and Cowell Beaches. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Identify tax and other financial incentives (See Appendix F, Funding Strategies) that support private redevelopment investments. Integrate public infrastructure upgrades/realignment costs in existing or future special tax district, or other revenue sources such as visitor parking fees. Managed retreat can be costly; the City of Pacifica, with funding from the California Coastal Conservancy, purchased two homes and the surrounding acreage for $2.2 million to restore a dune and wetland habitat in 2002 (NOAA, 2015). Acreage amounts would be smaller in Santa Cruz, but costs will still be high. Eventually equitable relocation of residents in hazardous areas will be required, and the needs of renters and owners considered. Zoning requirements could be changed to allow for higher density residences to be built in partnership with equitable housing initiatives in less hazardous areas (CA Coastal Commission, 2018a; ULI, 2018). See Appendix G for strategies and tools for managed retreat.

Benefits:

- Supports the retention of public trust lands (i.e. Main and Cowell beaches).
- Relies on redevelopment planning to transition properties deemed at risk of loss away from hazards.
- Establishes a strategy from which public and private development can proceed in unison.
- Supports Boardwalk redevelopment on adjacent inland properties.

Table 27. Example monitoring parameters and trigger criteria to be used for phased managed retreat Main and Cowell Beaches

Monitoring Parameter	Trigger Criteria/Threshold
Beach width	Average annual late summer (Sept) beach width is comparable to pre-harbor beach width (220 ft) for more than 5 years OR Beach width during winter king tides of 50 ft or less for 3 years in a row
Repairs Frequency	Public infrastructure has to be repaired more than three times over a five-year period.
Loss of use and access	Occurrence of days public facilities/infrastructure is closed due to storm wave flooding is more than 10 days/year for 3 years.
Cost exceedance	Repair costs from sea level rise related impact exceed $500,000 (2020 value).

Consequences:

- Loss of infrastructure would occur.
- Loss of visitor serving infrastructure would occur.
- Loss of jobs and tax revenue are possible.
- May disproportionately impact socially vulnerable populations

Implications to unique user groups: The loss of services (roadway and parking) may impact user groups who rely on ADA amenities, and beach front public infrastructure. Loss of jobs and housing may impact local workforce and Beach Flats community.

Mitigation Actions: By prioritizing the retention of public infrastructure (walkways, bike paths, roadway, etc.), a loss of public access will be minimized. Redevelopment planning that supports a mix of residential and commercial infrastructure will more equitably share redevelopment burden and coastal benefits.

Main & Cowell Adaptation Pathways

Pathway 1: Accommodate then Retreat

Pathway Description

This adaptation pathway focuses initially on retaining beach area and beach habitat through sand retention and living shoreline restoration programs (Figure 73 and Figure 74). As projected hazards become more severe, a transition toward increasing the resiliency of existing infrastructure in its current location will be implemented, until wave and flooding impacts become too frequent and severe to continue current land uses. Once impacts compromise these structures the strategy will transition to the managed retreat of vulnerable infrastructure.

Key Goals Supported by this Pathway:

- Focus on living shoreline adaptations
- Work to maintain existing beach width but at a minimum, retain pre-harbor beach width (~220 ft) through 2100
- Ensure risks to residents and visitor serving businesses are considered when developing adaptation alternatives
- Maintain diverse recreational opportunities (swimming, picnics, beach volleyball, surfing, kayaks, etc.) at Main and Cowell beaches for visitors of all socioeconomic levels
- Retain easy access via multimodal transportation to the coast for use by residents and visitors of all socioeconomic levels to beaches, wharf and boardwalk
- Maintain and, where feasible, improve flood protection infrastructure, e.g., pumps, levee and river mouth culvert, within Beach Flats and lower Ocean Street to safeguard residents, visitors, and assets

Incremental Change in Beach Resources & 2100 End Point

Short and midterm strategies focus on maintaining coastal uses within this core area of the Santa Cruz beach tourist economy. Beach nourishment and living shorelines to address periodic winter storm hazards while maintaining summer recreational opportunities. Over time these pathways transition to either increasing the resiliency of infrastructure to projected hazards or moving infrastructure out of harm's way. The City would need to determine which infrastructure is redesigned and which is moved to determine how the community prioritizes wide beach areas over other coastal infrastructure. A Beach Flats Redevelopment plan would need to be developed to set the priorities regarding how to equitably redevelop this area to be resilient to flooding while maintaining the unique residential and business community makeup of this area. Retaining business opportunities along the back beach benefits the local economy and maintains recreational opportunities.

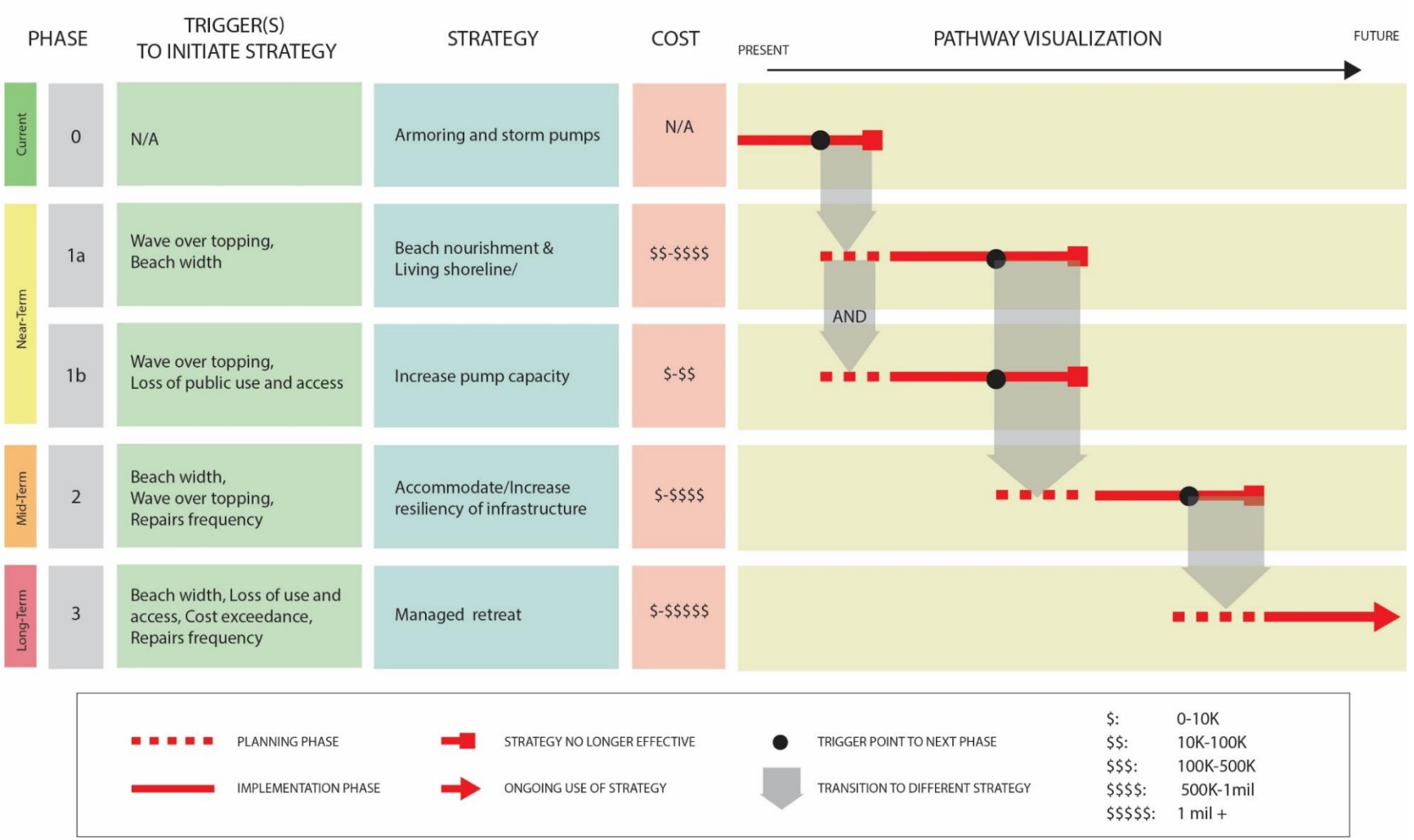


Figure 73. Main and Cowell Beaches adaptation pathway with a focus on accommodating and then retreating.

Figure 74. Map showing potential locations to implement strategies within the Main and Cowell Beaches adaptation pathway with a focus on accommodating and then retreating

Pathway 2: Protect and then Accommodate or Retreat

Pathway Description

This adaptation pathway focuses initially on retaining beach area and beach habitat through sand retention and living shoreline restoration programs (Figure 75 and Figure 76). When wave overtopping of the back shore infrastructure becomes problematic, protective structures (curb wall and increased pumping) would need to be constructed. As projected hazards become more severe, a transition toward increasing the resiliency of existing infrastructure in its current location could be implemented, until wave and flooding impacts become to frequent and severe too continue current land uses. If impacts compromise the ongoing use of these structures the strategy would focus on moving infrastructure away from hazards. This strategy supports living shorelines and beach nourishment to help limit beach loss and wave/flooding impacts. Preservation of public beach area and coastal recreation and access should be managed equitably.

Key Goals Supported by this Pathway

- Work to maintain existing beach width but at a minimum, retain pre-harbor beach width (~220 ft) through 2100
- Ensure risks to residents and visitor serving businesses are considered when developing adaptation alternatives
- Maintain diverse recreational opportunities (picnics, beach volleyball, surfing, kayaks, etc.) at Main and Cowell beaches for visitors of all socioeconomic levels
- Maintain and, where feasible, improve flood protection infrastructure, e.g., pumps, levee and river mouth culvert, within Beach Flats and lower Ocean Street to safeguard residents, visitors, and infrastructure assets
- Retain safe access to the extent possible to the wharf and beaches through upgrades to access infrastructure by increasing their resiliency to winter storm events

Incremental Change in Beach Resources & 2100 End Point

Short and midterm strategies focus on maintaining coastal uses within this core area of the Santa Cruz beach tourist economy. Beach nourishment and curb wall construction aims to address periodic winter storm hazards while maintaining summer recreational opportunities. Loss of beach area due to coastal squeeze will likely occur. Over time these pathways transition to increasing the resiliency of infrastructure to projected hazards. Cost or safety considerations would determine the necessity to move infrastructure out of harm's way and how to prioritize wide beach areas over protection of other coastal infrastructure. A Beach Flats Redevelopment Plan is recommended that would focus on how to equitably redevelop this area to be resilient to flooding while maintaining the unique community opportunities this area provides. Retaining business opportunities along the back beach benefits the local economy and recreational opportunities for many.

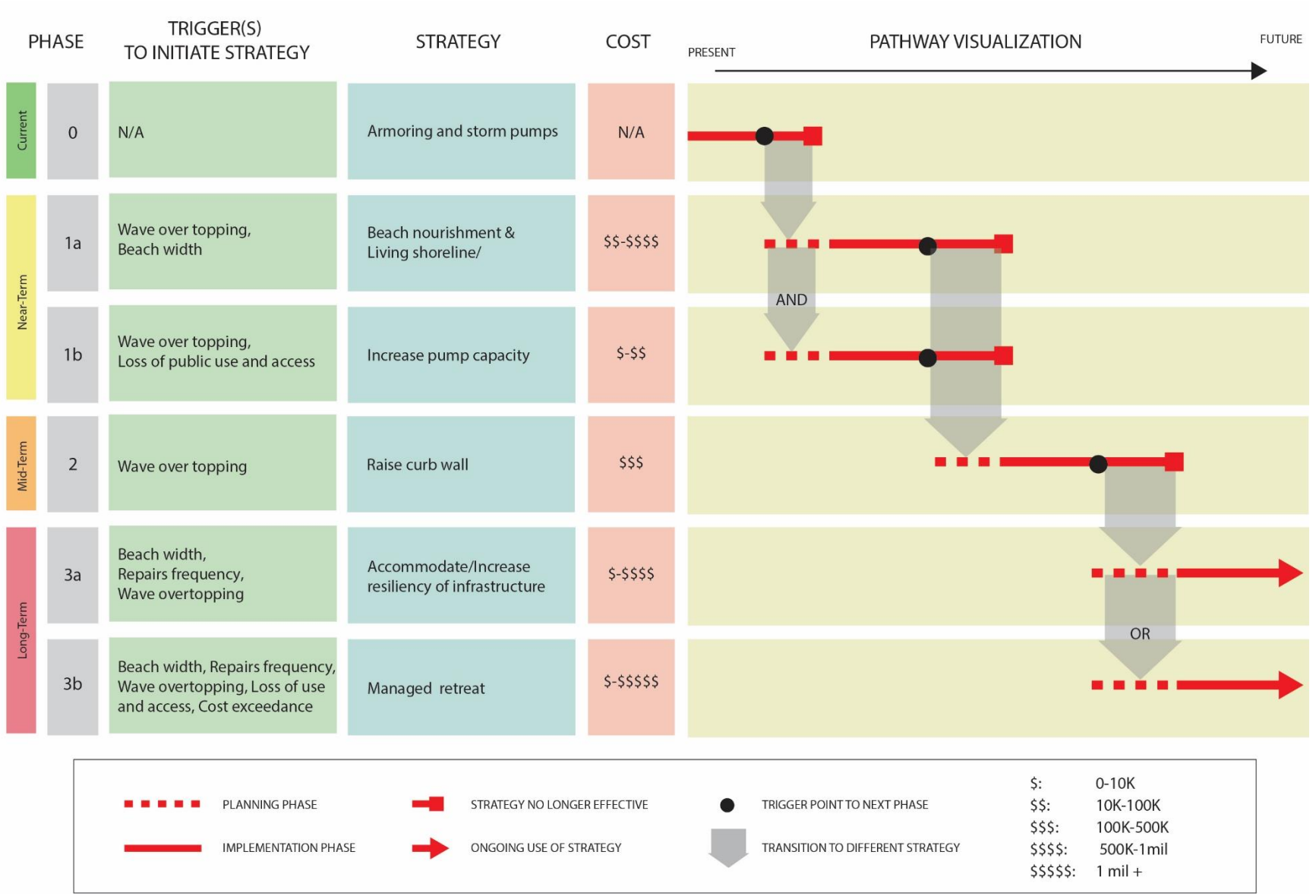


Figure 75. Main and Cowell Beaches adaptation pathway with a focus on protecting and then either accommodating or retreating.

Figure 76. Map showing potential locations to implement strategies within the Main and Cowell Beaches adaptation pathway with a focus on protecting and then either accommodating or retreating

Adaptation Impacts to Under-represented Groups

In most cases, if design elements and upgrades are included within the adaptation pathway (described below) then the level of service can be retained near current levels and in some cases improved. Relative costs to implement each pathway and the additional relative costs to include needed mitigation actions are presented the table. Estimated costs to maintain current infrastructure is also noted.

Upgrading existing sea walls and increase resiliency of infrastructure is shown to increase the level of service within each zone for most user groups. Costs associated with accommodation are often high, as is supporting a manage retreat policy. In many cases the needed mitigations to address loss in the level of access are similarly high to the adaptation strategies within this portion of the City coastline. Level of service provided at Cowells and Main remain high, regardless of the adaptation strategy selected, for these user groups.

Adopting and implementing the managed retreat actions are estimated to lead to an increase in the level of service for most under-represented user groups. Table 28 provides an estimate of the relative change in level of service for each stakeholder group. Methods used to calculate these values are provided in Appendix D.

Measures to support community equity and access opportunities for all while adapting to sea level rise include:

- Include resilient access amenities
- Ensure that resilient infrastructure does not greatly compromise coastal views
- Ensure lateral access is resilient to impacts
- Ensure benches are maintained and resilient
- Maintain/enhance ADA parking
- Ensure beach width and lateral access are maintained
- Ensure access with water equipment
- Upgrade stormwater infrastructure
- Integrate with river management plan
- Accommodate access along entire beach a part of retreat program
- Ensure coastal trail is maintained along entire beach
- Integrate river management with Main Street adaptation
- Relocate bathrooms

Table 28. Estimated change in level of service at Main and Cowell Beaches resulting from each adaptation pathway for each stakeholder group compared with current level of service. Relative costs (combine number of $) for implementation and for additional infrastructure needed to achive this level of service.

Under-represented Group	Current	Accommodate	Retreat
Elderly	94%	83%	58%
Youth	93%	71%	86%
People with Disabilities	86%	83%	58%
Low Income residents	83%	100%	100%
Tribal	83%	75%	75%
Homeless	44%	50%	67%
LGBTQ+	100%	100%	100%
Fishers	83%	90%	80%
Costs # $	2	12	14
Mitigations # $		15	11
Total $	**2**	**27**	**25**

Seabright State Beach Adaptation Strategy Options & Pathway Alternatives

Seabright State Beach Adaptation Strategy Options

Dune Construction/Living Shoreline with Cobble

Implementation Programs: Draft a Resilient Beaches Management Plan that evaluates and outlines a Beach Nourishment/Living Shoreline implementation strategy that supports increased wave resiliency of Seabright backshore habitat. This plan can build on the living shoreline efforts already completed at Seabright Beach. In the future, hard materials, such as cobble, can be integrated within the dunes to increase protective capacity of living dune habitats.

Triggers to Initiate Strategy: Table 29 provides examples of monitoring parameters and trigger criteria that could be used to initiate the construction a living shoreline at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that equitably allocates implementation and maintenance costs among City of Santa Cruz, State Parks, and property owners who would benefit from protective infrastructure. Costs to expand revegetated dunes are low when compared to other armoring resilience measures; a 2005 dune restoration plan for the Marina dunes was budgeted at ~$8,500 per acre of habitat (Monterey Peninsula Regional Parks District, 2005). However, vegetated dunes require ongoing maintenance funding to maximize habitat and wave resiliency. Some of this maintenance (planting, etc.) could be completed with an organized volunteer force in collaboration with the City, contractors, academic partners, and stakeholder groups. Costs to add cobble or other harder materials within the dunes will be more expensive and require some replanting of dunes, but will still be significantly less than revetment or seawall construction. Due to the interest in "nature based solutions" for sea level rise, a living shoreline project would be an ideal candidate for grant funding and partnerships with state or NGO sources of funding.

Table 29. Example monitoring parameters and trigger criteria to be used for constructing a living shoreline at Seabright State Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Beach width during winter king tides of 200 ft or less for 3 years in a row.
Erosion of existing dune	Existing dune is reduced in height by storm waves (>50%).

Benefits:

- Dune with structural components have increased functional life
- Enhances beach habitat and coastal views
- Can be designed to allow for lateral access
- Opportunity to improve community engagement on coastal resilience efforts.

Consequences:

- Loss of recreational beach area
- Expected effective lifespan of living shoreline is less than armoring

- Cobble or wood components of dune may be dislodged during winter storms and move downcoast or to harbor dredge area

Implications to unique user groups: No anticipated impacts on any unique user groups. May benefit user groups who value natural habitat areas.

Mitigation Actions: Lateral access along the beach will be reduced through transition of some recreational areas to habitat. Designing lateral trails through the living shoreline can reduce this consequence and/or benefit visitor experiences.

Upgrade Stormwater Infrastructure and Manage Informal Access Trails

Implementation programs: Draft a Coastal Armoring Management Plan or Stormwater Plan that outlines stormwater and dirt path access upgrades needed to reduce or eliminate cliff erosion and failure caused by erosive foot traffic and poorly managed or failing storm drain infrastructure.

Triggers to Initiate Strategy: Table 30 provides examples of monitoring parameters and trigger criteria that could be used to trigger upgrading stormwater infrastructure and managing access trails at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 30. Example monitoring parameters and trigger criteria to be used for upgrading storm water infrastructure and managing informal trails at Seabright State Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Storm drain caused cliff erosion	Annual survey of condition of storm water infrastructure shows failed or damaged storm water pipes or outfalls contributing to erosion
Erosion due to informal access trails	Annual survey of informal access trails shows trails contributing to erosion

Costs and Funding Strategy: Include expanded funding for coastal storm drain infrastructure upgrades that address cliff failure and erosion. Costs can be shared with larger Santa Cruz community as part of the citywide storm water management program. If utilities are being impacted by cliff erosion, revenue may be generated by a rate increase.

Benefits:

- Reduces storm water impacts to back shore cliffs and/or armoring.
- Improved public access and recreational opportunities and reduce erosion on cliff tops.

Consequences:

- Additional community costs to improve the storm drain system
- Potential loss of informal vertical or lateral access

Implications to Unique User Groups: No anticipated impacts on any unique user groups. May benefit user groups who value safe access ways, natural habitat areas and clean water.

Mitigation Actions: Include inland storm water reduction strategies to minimize coastal discharge.

Example Activities:

- Use 2019 storm water infrastructure inventory to prioritize infrastructure upgrades focused on Zones 1 & 2.
- Upgrade storm water infrastructure to reduce water quality impacts to Seabright Beach.

Raise Jetty with Living Shoreline

Implementation Programs: Draft a Resilient Beaches Management Plan that supports future efforts by the Port District to increase harbor resiliency to wave impacts. This can include raising jetty infrastructure in coordination with Seabright Beach accretion and living shoreline expansion efforts. In combination, these strategies support increased wave resiliency of Seabright backshore habitat and increased recreational beach area during summer months.

Triggers to Initiate Strategy: Table 31 provides examples of monitoring parameters and trigger criteria that could be used to trigger the raising the Harbor jetty at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Support Port District efforts to acquire state and federal grant funds to implement jetty upgrades and identify matching funding that equitably allocates costs among City of Santa Cruz, State Parks, harbor users, and private property owners who will benefit from protective infrastructure. Raising the jetty will support the resiliency of the Santa Cruz Harbor, but will be costly. As an example, 250 feet of the Mission Bay Channel jetty was repaired in San Diego for $2.3 million in 2010 (Gentile, 2010).

Table 31. Example monitoring parameters and trigger criteria to be used for raising the Harbor jetty at Seabright Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Average annual late summer beach width is comparable to the summer time pre-harbor beach width (~150 ft) for more than 3 years OR Beach width during winter king tides of 100 ft or less for 3 years in a row.
Erosion of existing dune	Existing dune is reduced in height by storm waves (>50%).
Loss of public use and access	Occurrence of days beach/access is closed due to coastal flooding is more than 10 days/year for 3 years

Benefits:

- Lead to the additional collection of sand on Seabright Beach and potentially mitigate loss of any recreational beach area associated with living shoreline actions.
- Lateral access along the beach and recreational areas on the beach would be enhanced due to an increase in sand accumulation.
- Long expected life of project.

- Continue to provide recreational access (Walton Lighthouse path).
- Maintain safe entry to Santa Cruz Harbor.

Consequences:

- Initial loss of beach footprint depending on footprint of jetty.
- May reduce sand supply to eastern beaches (Twin Lakes Beach/ Blacks Beach, etc.) which may result in down coast loss of coastal resources.
- May impact wave patterns, and therefore offshore surfing and other important recreational opportunities.

Implications to unique user groups: No anticipated impacts on any unique user groups. May benefit user groups who value natural habitat areas and beach recreation.

Mitigation Actions: Beach nourishment can be included within the jetty enhancement project to offset impacts to down coast sand supply.

Upgrade Existing Armoring to, or Construct New Soil Nail Wall

Implementation Programs: Collaboratively funded sea wall construction protects cliff top property and infrastructure from flood and erosion risks. Draft a Coastal Armoring Management Plan that identifies areas that will be prioritized for armoring. The City's Coastal Armoring Management Plan, in collaboration with affected property owners and the public, should determine how armoring can be completed in a manner that is most effective to protect coastal property and infrastructure in response to anticipated sea level rise and erosion impacts.

Triggers to Initiate Strategy: Table 32 provides examples of monitoring parameters and trigger criteria that could be used for constructing a new seawall or soil nail wall at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 32. Example monitoring parameters and trigger criteria to be used for constructing a new seawall or soil nail wall at Seabright Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Average annual late summer beach width is comparable to the summer time pre-harbor beach width (~150 ft) for more than 3 years OR Beach width during winter king tides of 100 ft or less for 3 years in a row.
Cliff erosion/Blufftop offset	Average distance between bluff edge and bluff top assets is less than 20 feet
Integrity of Armoring (Existing structures)	Structure showing signs of failure (slope of overall structure has flattened since construction, fugitive rock has detached from revetment or moved seaward of permitted footprint, a drop in the back shore elevation of the revetment, exposure of the underlying fabric layer, concrete shrinkage, debonding, or fractures of structure).
Cost exceedance (existing structure)	Repair costs from sea level rise related impact exceed $500,000 (2020 value).

Costs and Funding Strategy: Include a funding strategy (See Appendix F, Funding Strategies) that allocates costs among City of Santa Cruz and property owners who would benefit from protective infrastructure. The City's planning process should include analysis of whether City funds would be required or used to implement coastal armoring in this area. Funding options include establishing a Community Facilities District that includes properties along the City coast who contribute to a fund to construct and maintain new armoring. Alternatively, the City could facilitate collaboration among property owners to collectively fund seawalls that directly benefit their properties. Policies and programs to be included within the Coastal Armoring Management Plan should describe armoring restrictions and equitable strategies to address properties at risk along cliff tops. The Plan should document how to fairly support the upgrade of any existing infrastructure determined to be unsafe, and to redesign those structures to protect or enhance lateral public access and coastal viewing opportunities needed to retain or enhance existing 2020 amenities. Include in the Coastal Armoring Management Plan preferred funding strategies to support structural integrity monitoring and repair costs, and considers removal costs. Seawalls are one of the most expensive resilience options; the East Cliff soil nail wall (similar to a seawall) and trail improvement was reported to cost $3.1 million (Hoppin, 2011).

Benefits:

- Maintain cliff top area with high level of protective certainty.
- Maintain cliff top benches and trails.
- Protects existing property (roads, public parking, coastal access, houses, etc.)
- Longer protective lifespan than living shorelines.

Consequences

- This strategy may lead to additional visual impacts of coastal armoring structures.
- Potential beach access restrictions.
- Loss of sandy beach area as shoreline erodes towards revetment (coastal squeeze).
- Potential mitigation fees or permitting requirements associated with loss of beach area due to footprint.
- May impact wave patterns, and therefore offshore surfing and other important recreational opportunities.
- Potential high cost to property owners

Implications to unique user groups: Potential impacts to user groups who value fire pits and beach recreation camps and activities due to loss of recreational area.

Mitigation Actions: Implementation of beach nourishment programs can minimize the loss of beach area. Soil nail wall structures can be designed to improve coastal access.

Phased Retreat of Public Infrastructure

Implementation Programs: Draft a Coastal Armoring Management Plan that outlines armoring restrictions and describes incremental sacrificial loss strategies to maintain safety, while allowing for the loss of public infrastructure. Managed retreat policies and programs should describe strategies to prioritize preservation of certain public infrastructure. Decisions regarding prioritization of parking or two way traffic must be made, and later, the need for roadway access along the cliffs at the expense of existing land uses would need to be assessed. The plan will support the removal of infrastructure determined to be

unsafe and redesign those areas to support lateral public access and coastal viewing opportunities. Public road retreat should account for public safety and private right of way requirements.

Triggers to Initiate Strategy: Table 33 provides examples of monitoring parameters and trigger criteria that could be used for phased managed retreat of public infrastructure and property at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Costs and Funding Strategy: Include a funding strategy (See Appendix G, Funding Strategies) that equitably allocates property acquisition and demolition costs among City of Santa Cruz, any Seabright special districts, and private property owners. Draft a Coastal Armoring Management Plan that outlines armoring restrictions and derelict infrastructure removal strategies, use of special districts to fund this transition, and legal procedures and policies (See Appendix G) to incrementally implement retreat program. Moving infrastructure (benches, public restrooms, access trails, roadway, stormwater infrastructure, etc.) has variable costs, depending on the scope and complexity of the projects. Examples range from relocating benches, to a complete relocation of storm drains or sewer components. Retreat actions could be funded differently depending on the infrastructure impacted. For example, a relocation of utilities may be funded through rate increases or grant funding opportunities.

Table 33. Example monitoring parameters and trigger criteria to be used for phased managed retreat of public infrastructure and property at Seabright Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Average annual late summer (Sept) beach width is comparable to the summer time pre-harbor beach width (~150 ft) for more than 5 years OR Beach width during winter king tides of 50 ft or less for 5 years in a row.
Cliff erosion/Blufftop offset	Average distance between bluff edge and bluff top assets is less than 10 feet
Repairs Frequency	Lateral coastal access along blufftop for multi modal transportation needs to be repaired more than 3 times in 5 years
Cost exceedance	Repair costs from sea level rise related impact exceed $500,000 (2020 value).
Loss of public use and access	Occurrence of days public facilities /infrastructure/access is closed due to coastal flooding or erosion is more than 10 days/year for 3 years

Consequences:

- There may be a loss of services (e.g., moving from a two way to one way road, or loss of parking lots) associated with managed retreat
- There may be loss of access for private property owners associated with coastal erosion.

Implications to Unique User Groups: The loss of services (roadway and parking) may impact user groups who rely on ADA amenities, and cliff top infrastructure.

Mitigation Actions: By prioritizing the retention of cliff top public infrastructure (walkways and bike paths), the loss of public access and viewing opportunities will be minimized.

Phased Retreat of Private Property

Implementation Programs: Draft a Coastal Armoring Management Plan that outlines armoring restrictions and derelict structure removal strategies, use of special districts to fund this transition, and legal procedures and policies to incrementally implement a retreat program. Managed retreat policies and programs to be included within the Coastal Armoring Management Plan should describe equitable strategies to address properties at risk along cliff tops (see Appendix G for more strategies and tools). The plan should support the removal of infrastructure/structures determined to be unsafe and redesign those areas to support lateral public access and coastal viewing opportunities needed to retain or enhance existing 2020 amenities (see April 2020 Social Vulnerability Need and Risk Assessment).

Triggers to Initiate Strategy: Table 34 provides examples of monitoring parameters and trigger criteria that could be used for replacing or upgrading armor at Seabright Beach. Further evaluation is needed before numeric thresholds are adopted and will need to be one focus of the LCP update process.

Table 34. Example monitoring parameters and trigger criteria to be used for phased managed retreat of private property at Seabright Beach

Monitoring Parameter	Example Trigger Criteria/Threshold
Beach width	Average annual late summer (Sept) beach width is comparable to the summer time pre-harbor beach width (~150 ft) for more than 5 years
Cliff erosion/Blufftop offset	Average distance between bluff edge and bluff top assets is less than 10 feet
Repairs Frequency	Lateral coastal access along blufftop for multi modal transportation needs to be repaired more than 3 times in 5 years
Cost exceedance	Repair costs from sea level rise related impact exceed $500,000 (2020 value).
Loss of public use and access	Occurrence of days public facilities /infrastructure/access is closed due to coastal flooding or erosion is more than 10 days/year for 3 years

Costs and Funding Strategy: Include a funding strategy (see Appendix F, Funding Strategies) that equitably allocates property acquisition and demolition costs among City of Santa Cruz and private property owners. Buyouts of properties before a natural hazard is imminent is less common than post-disaster programs (e.g., properties purchased in flood zones following hurricanes), and the City should follow the implementation of funding strategies for managed retreat in the coming decades. Local, state, and federal government groups will need to consider possible buyout options, and decide how to value properties. Land acquisition for restoration to natural habitat has grant funding potential, as seen with the City of Pacifica, which received funding from the California Coastal Conservancy to purchase two

homes and the surrounding acreage for $2.2 million to restore a dune and wetland habitat in 2002 (NOAA, 2015).

Benefits:

- Retention of public trust lands; relies on establishment of a public acquisition program to transition properties deemed at high risk of loss

Consequences:

- Loss of infrastructure (e.g., parking lots) could occur.
- Loss of visitor serving infrastructure, possibly including portions of East Cliff Dr., could occur.
- Potential loss of property associated with coastal erosion.

Implications to unique user groups: The loss of services (roadway and parking) may impact user groups who rely on ADA amenities, and cliff top infrastructure.

Mitigation Actions: By prioritizing the retention of cliff top public infrastructure (walkways and bike paths), a loss of public access and viewing opportunities can be minimized. Disproportionate impacts to unique user groups can be mitigated through using public infrastructure upgrades.

Seabright State Beach Adaptation Pathways

Pathway 1: Moratorium on New Armoring

Pathway Description

This adaptation pathway focuses on retaining recreational beach area and beach habitat through living shoreline restoration and sand retention programs (Figure 77 and Figure 78). By partnering with the Santa Cruz Port District to raise the harbor jetty, additional sand accretion can limit beach loss and bluff erosion without needing to construct new seawalls. Once lateral access and beach area are compromised and bluff erosion again becomes a problem, bluff top retreat of private and public infrastructure will be implemented. Preservation of public lateral bluff top access is a priority.

Key Goals Supported by this Pathway

- Focus on living shoreline adaptations and
- Maintain and enhance native back beach vegetation
- Work with the Port District on dredge management and jetty maintenance and ensure that coastal adaptation strategies and harbor adaptation strategies are integrated
- Retain lateral access along blufftop for multi modal transportation where beach can be a secondary access.

Incremental Change in Beach Resources & 2100 End Point

This strategy focuses on the retention of beach area, access to the beach and blufftop and the use of living shorelines to build natural habitat areas of the beach and cliffs. Midpoint loss of beach area (2060) will be addressed through enhancing sand accretion through enhancement of the harbor. 2100 endpoints include a resilient harbor, maintenance of beach area, back beach habitat and public access along the cliff.

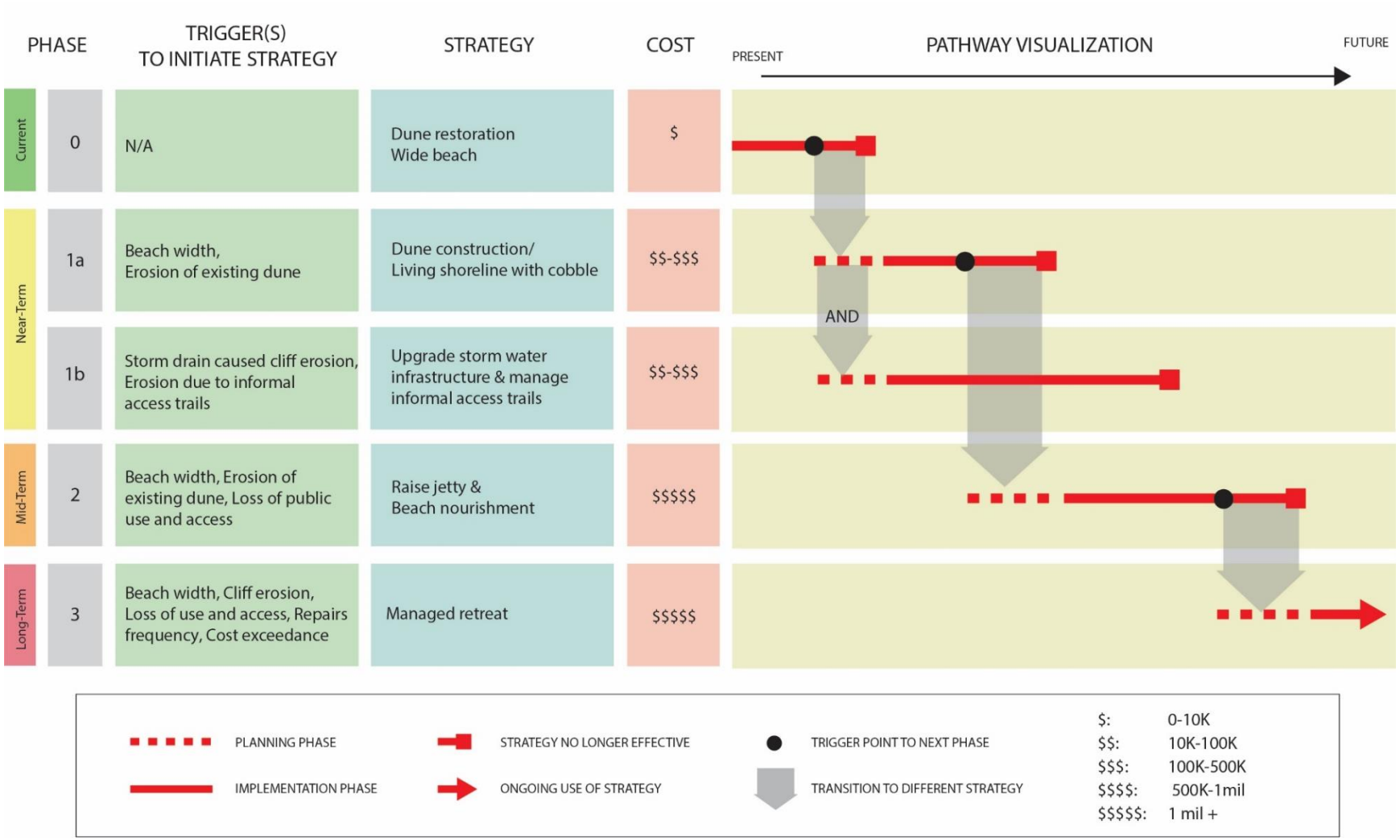


Figure 77. Seabright adaptation pathway: moratorium on new armoring

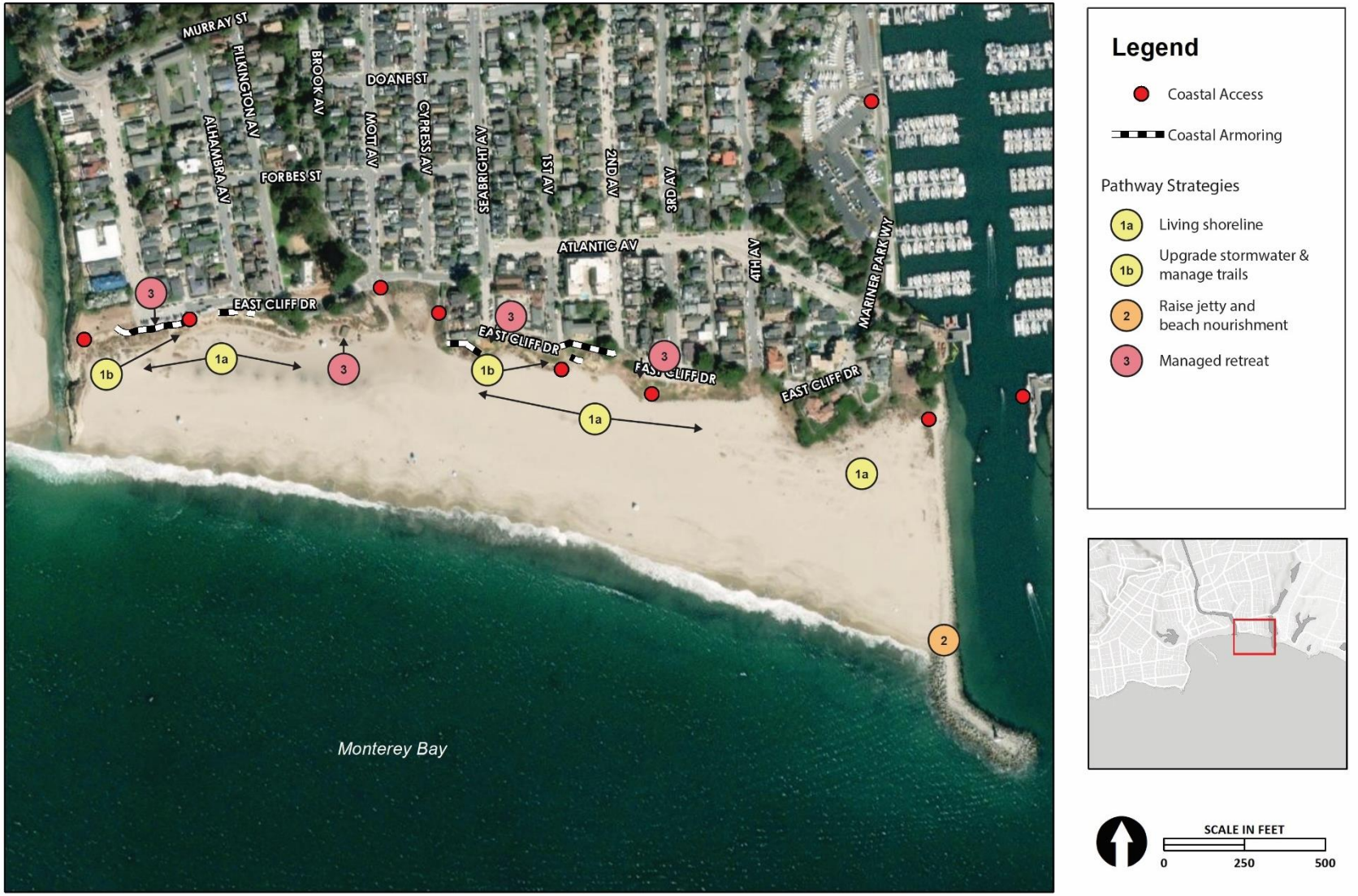


Figure 78. Map showing potential locations to implement strategies within the Seabright adaptation pathway: moratorium on new armoring

Pathway 2: Protect in Place

Pathway Description

This adaptation pathway focuses on protecting back shore and cliff top infrastructure through a combination of green and grey strategies (Figure 79 and Figure 80). Short term protections will rely on sand retention and living shoreline restoration programs and then progress to increased armoring of the back shore, once green infrastructure/soft adaptation fails to provide sufficient protective certainty. By partnering with the Port District to raise the jetty, additional sand accretion will be encouraged to help limit beach loss associated with coastal squeeze from building new seawalls. Once lateral access and beach area are compromised and bluff erosion again becomes a problem, a combination of beach nourishment and sea wall structural upgrades will be implemented. Longer-term decisions whether to sacrifice beach area and access in favor of continued upgrades to seawalls, or the abandonment of armoring once beach resources are reduced significantly, will need to be made.

Key Goals Supported by this Pathway

- Focus on living shoreline adaptations
- Establish 2100 beach management goals and bluff erosion strategies
- Retain or enhance beach amenities including restrooms and fire pits; Work with the Port District on dredge management and jetty maintenance and ensure that coastal adaptation strategies and harbor adaptation strategies are integrated.

Incremental Change in Beach Resources & 2100 End Point

This strategy focuses on the combined use of grey and green protective structures that initially focus on living shorelines, and then transition to seawall construction to maintain cliff top infrastructure in their current location. Midpoint protection of cliff top infrastructure will focus on construction of new seawalls, and loss of beach area will be addressed through enhancing sand accretion through enhancement of the harbor. 2100 endpoints include a resilient harbor, maintenance of public access along the cliff. Loss of beach area and lateral access may be compromised due to coastal squeeze.

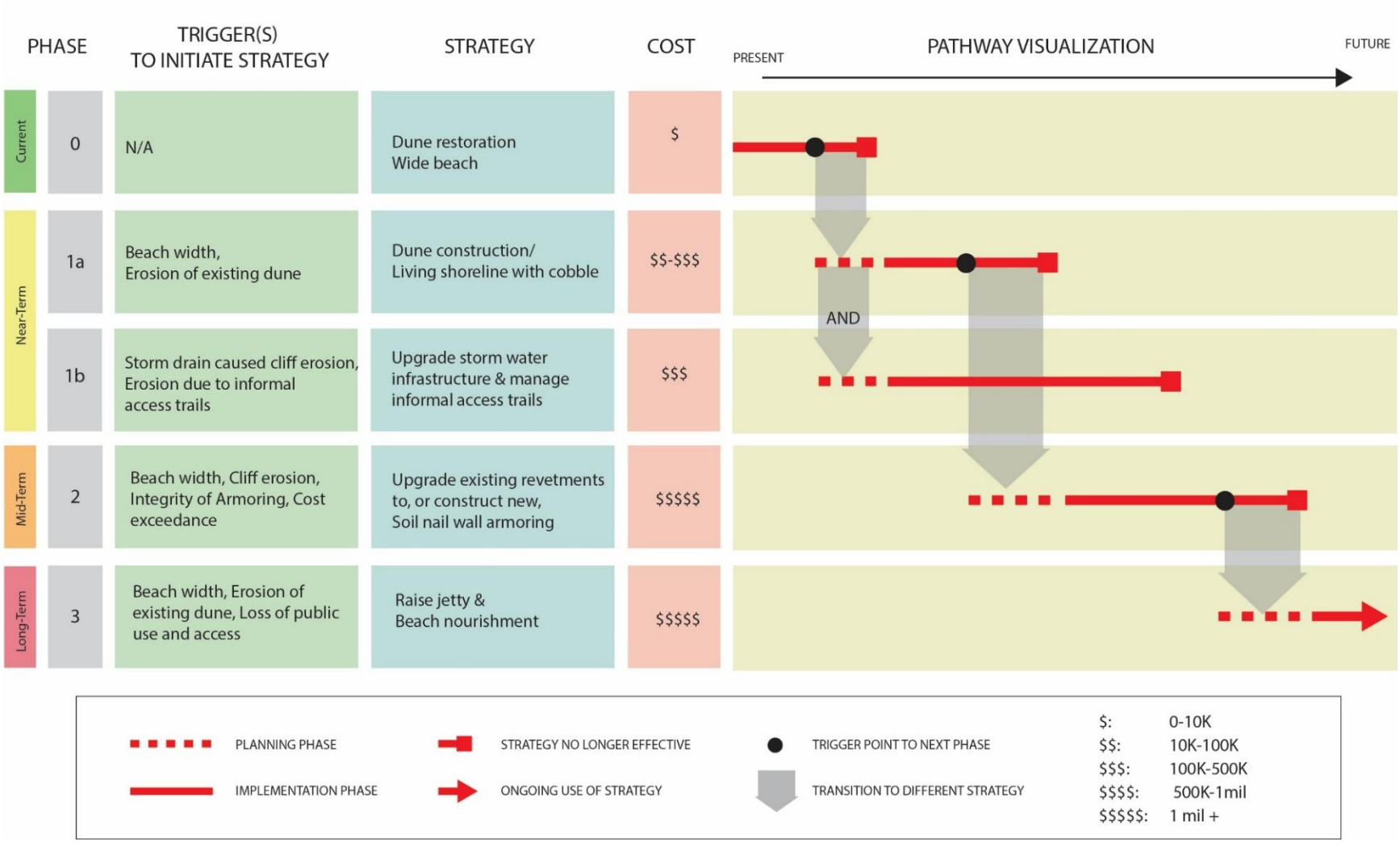


Figure 79. Seabright adaptation pathway: protect in place.

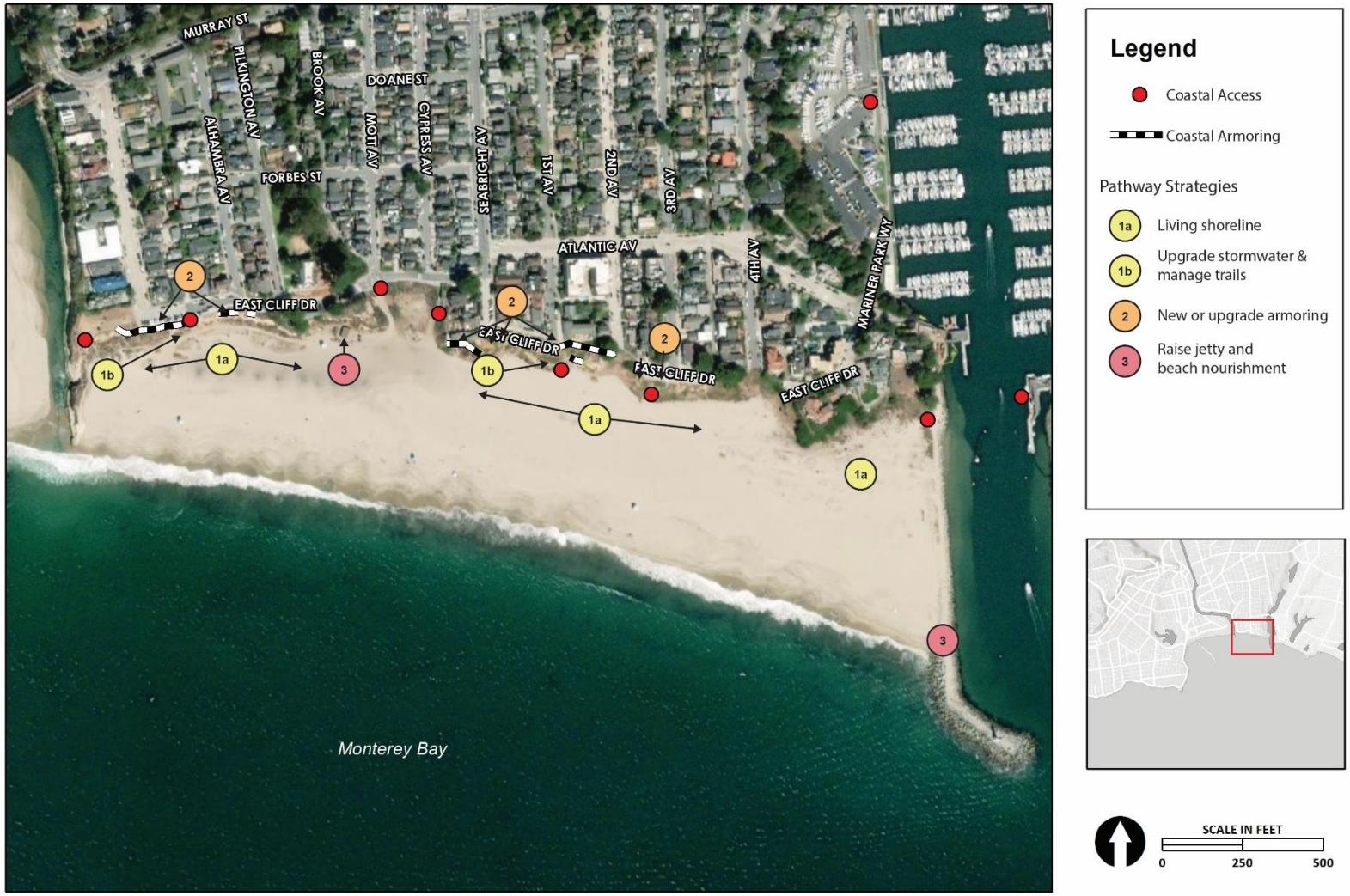


Figure 80. Map showing potential locations to implement strategies within the Seabright adaptation pathway: protect in place.

Pathway 3: Incremental Retreat of Public Property

Pathway Description

This adaptation pathway focuses on retaining beach area and beach habitat through living shoreline restoration programs (Figure 81 and Figure 82). Once lateral access and beach area are compromised and bluff erosion becomes a problem, bluff top retreat of public infrastructure will be implemented. Preservation of public lateral bluff top access is a priority.

Key Goals Supported by this Pathway

- Focus on living shoreline adaptations
- Maintain and enhance native back beach vegetation
- Work with the Port District on dredge management and jetty maintenance and ensure that coastal adaptation strategies and harbor adaptation strategies are integrated
- Retain lateral coastal access along blufftop for multi modal transportation where beach sand can be considered as a secondary access.

Incremental Change in Beach Resources & 2100 End Point

This strategy focuses on the retention of beach area, access to the beach and blufftop and the use of living shorelines to build natural habitat areas of the beach and cliffs. Midpoint loss of bluff top infrastructure will be addressed through prioritization of lateral access to pedestrians and bikes. 2100 endpoints include either A) the retention of beach area, a restrictions on construction of new and elimination of derelict coastal armoring, reduction in auto access, potential loss of some land uses and the retention of public access along the cliff; or B) Construction of new armoring to protect lateral cliff top access and existing land uses to the detriment of other public access and beach resource goals.

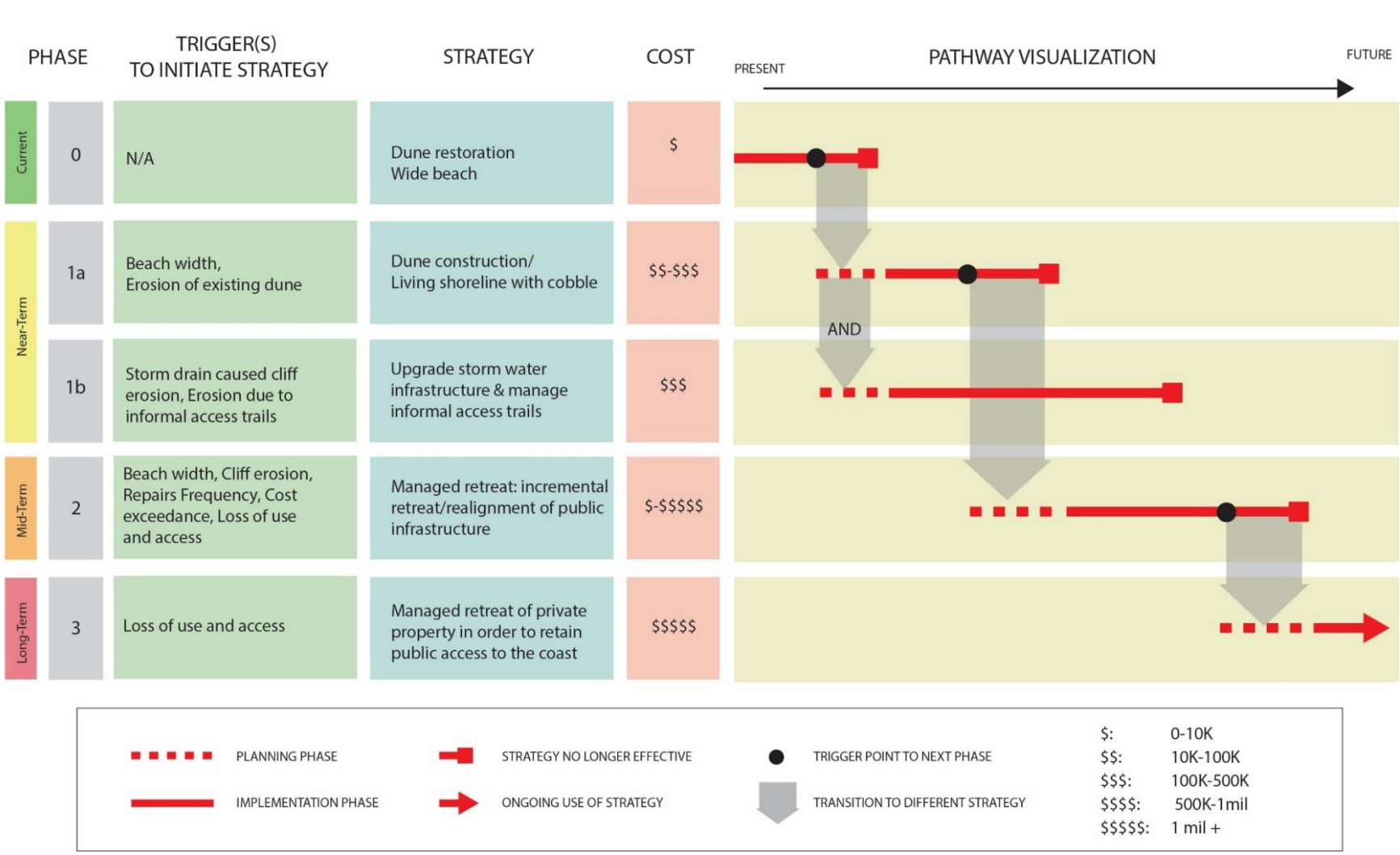


Figure 81. Seabright adaptation pathway: Incremental retreat

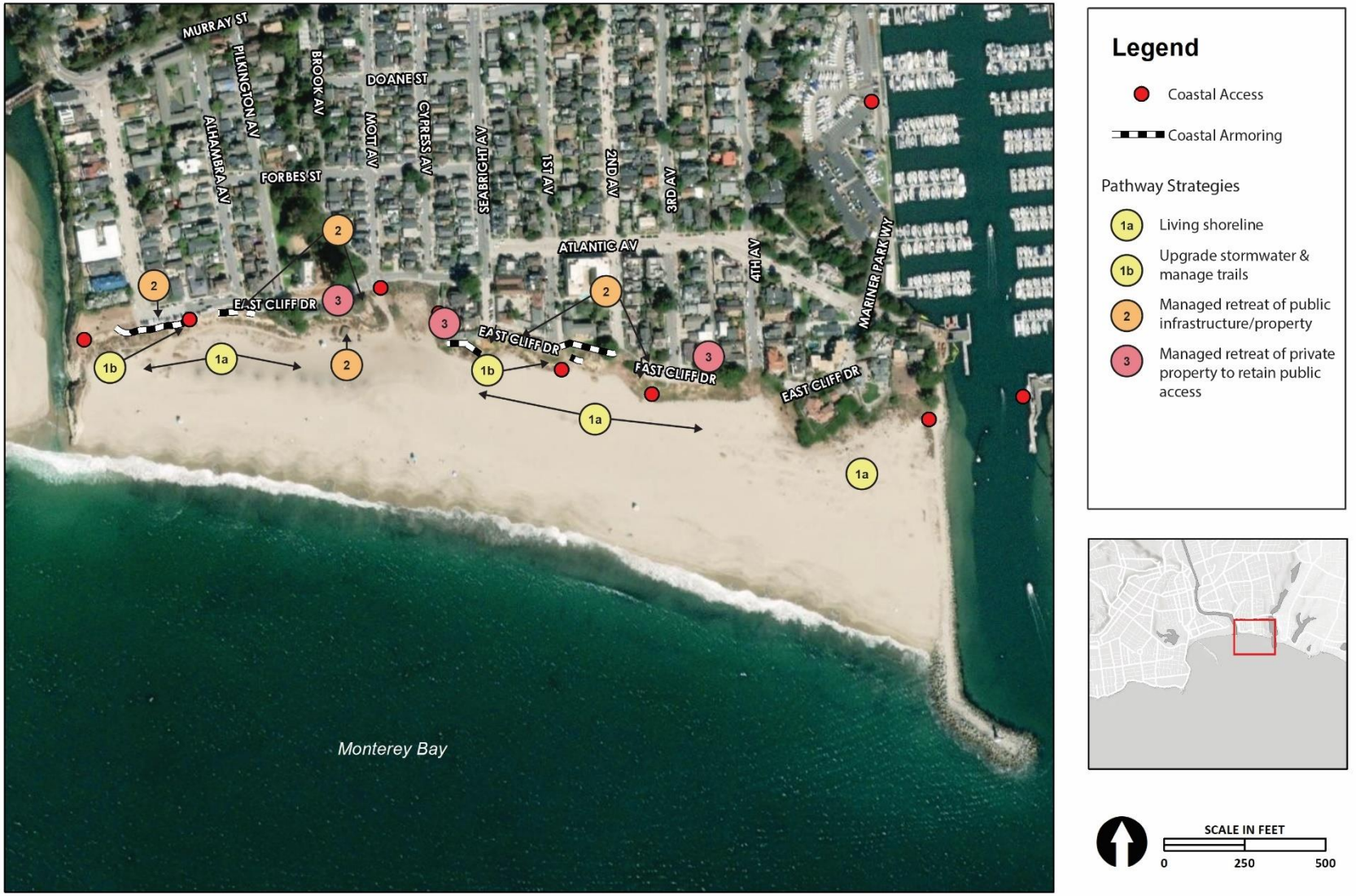


Figure 82. Map showing potential locations to implement strategies within the Seabright adaptation pathway: Incremental retreat.

Adaptation Impacts to Under-represented Groups

In most cases, if design elements and upgrades are included within the adaptation pathway (described below) then the level of service to most under-represented user groups can be improved at Seabright Beach. Relative costs to implement each pathway and the additional relative costs to include needed mitigation actions are presented in the table. Estimated costs to maintain current infrastructure is also noted.

Costs associated with upgrading armor are often high, as is supporting a manage retreat policy. In many cases the needed mitigations to address loss in the level of access are similarly high to the adaptation strategy costs themselves. integration of below listed measures will ensure the level of service provided at both the east and west sections of Seabright Beach will remain high, regardless of the adaptation strategy selected, for these user groups.

Adopting and implementing the managed retreat actions (moratorium on armoring) are estimated to lead to a similar level of service as constructing new sea walls for all under-represented user groups.

Measures to support community equity and access opportunities for all while adapting to sea level rise include:

- Enhanced access amenities at main entrances
- Construct stairs near west end of East Cliff Dr.
- Relocated walkway along entire bluff install/upgrade curb cuts and ADA parking upgrade
- Relocate restroom's, maintain gender neutral
- Replace benches in prime viewing locations along clifftop
- Maintain/expand ADA parking near high use areas
- Upgrade stormwater infrastructure where needed
- Install curb cuts, maintain benches and safety rails
- Replace benches in prime viewing locations along clifftop
- Maintain/expand ADA parking near high use areas
- Maintain living shoreline where feasible and does not compromise access

Table 35 Estimated change in level of service resulting from each adaptation pathway for each stakeholder group compared with current level of service. Relative costs (combine number of $) for implementation and for additional infrastructure needed to achieve this level of service.

Under-represented Group	Current	Moratorium on Armoring	Protect
Elderly	71%	100%	92%
Youth	86%	93%	64%
People with Disabilities	46%	83%	83%
Low Income residents	50%	50%	75%
Tribal	88%	100%	75%
Homeless	50%	83%	50%
LGBTQ+	50%	100%	100%
Fishers	85%	100%	70%
Costs # $	2	14	19
Mitigations # $		22	19
Total $	**2**	**36**	**38**

6. Conclusion

The Santa Cruz beaches and coastline face significant risks from projected rates of sea level rise. By establishing a predetermined adaptation strategy for all of the Santa Cruz coastline, we as a community will be able to better ensure that the future coastline resembles our community's priorities. This report describes a number of alternative adaptation approaches (pathways) that focus on different priorities and adaptation strategies. All pathways recognize the importance to retain access to beaches and the ocean and the need to protect lateral access along our beaches and cliff top.

Ways to achieve these priority actions range from gray to green and describe pathways that include multiple decision points that can be made using the data collected within the recommended monitoring programs (Appendix E). Some pathways support continued protection of cliff top infrastructure while allowing incremental loss of beaches through sea level rise induced coastal squeeze. Other pathways focus on retention of natural beach and cliff erosion processes to maintain beach area while allowing a certain level of incremental cliff loss.

Each pathway also describes resulting loss of infrastructure and coastal resources. In many cases management programs can help recover these resources (access ways and clifftop benches & parking) in other locations or through management actions (beach nourishment). By selecting a variety of pathways for different portions of the coastline, we will be able to retain coastal access, recreational opportunities, cliff top access and environmental benefits while prioritizing the protection of critical infrastructure and buildings needed to retain community charm, diversity and economic vitality.

Different pathways incur different costs but all pathways appear to be expensive and will require the focused investment by the municipality, residence, businesses and visitors to achieve the desired result. Construction of protective structures and the long term management of sand on selected beaches comes with large initial construction costs and long term operation costs. Pathways that allow for incremental retreat of cliffs will benefit beach and ocean resources but impact the cliff top infrastructure many within the community and those visiting Santa Cruz value. That infrastructure will need to be relocated and replaced at additional cost to retain coastal resources important to that portion of the community. These necessary coastal resource upgrades are also expensive as are programs to reclaim lost coastal access and use where cliff retreat is allowed.

This beach adaptation study is intended to provide a standard level of information on hazards, actions, costs and benefits, and implications of various adaptation pathways. The community and the state will need to select a set of pathways and programs that can best lead to a 2100 coastline we can be proud to leave to our children's children.

7. References

California Coastal Commission. 2018a. Draft Coastal Adaptation Planning Guidance: Residential Development. Interpretive Guideline for Sea Level Rise in Local Coastal Programs. https://documents.coastal.ca.gov/assets/climate/slr/vulnerability/residential/RevisedDraftResidentialAdaptationGuidance.pdf

California Coastal Commission. 2018b. Staff Report: CDP Hearing 3-16-0345. https://documents.coastal.ca.gov/reports/2018/7/th14b/th14b-7-2018-report.pdf

Cardenas, C. Six figures for six feet: Some Harvey victims in Houston spend huge sums to elevate their homes. *The Texas Tribune*. https://www.texastribune.org/2018/03/14/harvey-elevate-homes-flood-houston-money-costs/

Carey, J., 2020. Core Concept: Managed retreat increasingly seen as necessary in response to climate change's fury. Proceedings of the National Academy of Sciences. https://www.pnas.org/content/117/24/13182

Center for Ocean Solutions, Stanford Woods institute for the Environment. 2018. Coastal California Adaptation Policy Briefs. https://oceansolutions.stanford.edu/sites/default/files/publications/Coastal%20Adaptation%20Policy%20Brief%20Compilation_WEB.pdf

City of Santa Cruz. 2015. Local Coastal Program and Coastal Land Use Policies and Maps. https://www.cityofsantacruz.com/home/showdocument?id=51167

City of Santa Cruz. 2018a. City of Santa Cruz 2018 Climate Adaptation Plan Update, An Appendix to the 2018-2023 Local Hazard Mitigation Plan. https://www.cityofsantacruz.com/home/showdocument?id=63040

City of Santa Cruz. 2018b. Public Works Department Capital Improvement Projects. https://www.cityofsantacruz.com/home/showdocument?id=60730

City of Santa Cruz. 2019. Public Works Department Capital Investment Projects. https://www.cityofsantacruz.com/home/showdocument?id=71808

Diehl, P. 2019. Group faces uphill battle to get sand-retaining groins on Oceanside beaches. *San Diego Union-Tribune*. https://www.sandiegouniontribune.com/communities/north-county/story/2019-07-05/group-working-to-get-groins-on-oceanside-beaches-to-hold-sand-against-sea-currents

EPA and ABAG. 2019. Regional Resilience Toolkit. 5 Steps to Build Large Scale Resilience to Natural Disasters. https://www.epa.gov/sites/production/files/2019-07/documents/regional_resilience_toolkit.pdf

ESA. 2014. Coastal Resilience hazard models. https://maps.coastalresilience.org/california/

Gentile, A. 2010. Needed fix completed for Mission Bay channel jetty. *SD News*. http://www.sdnews.com/view/full_story/7878664/article-Needed-fix-completed-for-Mission-Bay-channel-jetty

Georgetown Climate Center. 2011. Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use. https://www.georgetownclimate.org/files/report/Adaptation_Tool_Kit_SLR.pdf

Griggs, G.B. 2012. Santa Cruz Main Beach Coastal Processes, and the Historic Course of the San Lorenzo River Mouth. Prepared for the City of Santa Cruz

Griggs, G.B. and Haddad, B. 2011. City of Santa Cruz Climate Change Vulnerability Assessment. https://www.cityofsantacruz.com/home/showdocument?id=57096

Hoppin, J. 2011. Santa Cruz: Some residents fear East Cliff Drive project will mean loss of neighborhood's spirit. *Mercury News.* https://www.mercurynews.com/2011/06/12/santa-cruz-some-residents-fear-east-cliff-drive-project-will-mean-loss-of-neighborhoods-spirit/

Monterey Peninsula Regional Parks District. 2005. Dune Habitat Restoration Plan Marina Dunes Preserve. https://mprpd.specialdistrict.org/files/220300ef0/Restoration%26AccessPlan.pdf

Moore, JT. 1972. A case history of the Santa Cruz Harbor, California: University of California Hydraulic Engineering Lab. Technical Report HEL 24-14, 42p.

NOAA Office of Ocean and Coastal Resource Management. 2015. Shoreline Management: Managed Retreat. https://web.archive.org/web/20150905055350/http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html

Ocean Protection Council. 2018. State of California Sea Level Rise Guidance, 2018 Update. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf

Ray, P. A., & Brown, C. M. 2015. Confronting climate uncertainty in water resources planning and project design: The decision tree framework. The World Bank. https://openknowledge.worldbank.org/handle/10986/22544

Urban Land Institute. 2018. Exploring transfer of development rights as a possible climate adaptation strategy. https://seflorida.uli.org/climate-change/exploring-transfer-development-rights-possible-climate-adaptation-strategy/attachment/uli_tdr_focus_group_report-2/feed/

University of Santa Cruz, Digital Collections. Aerial Photographs. http://digitalcollections.ucsc.edu/cdm/landingpage/collection/p16019coll5