FINAL
West Cliff Drive Adaptation and Management Plan

Adaptation Alternatives Analysis

Prepared for
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with

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Preamble

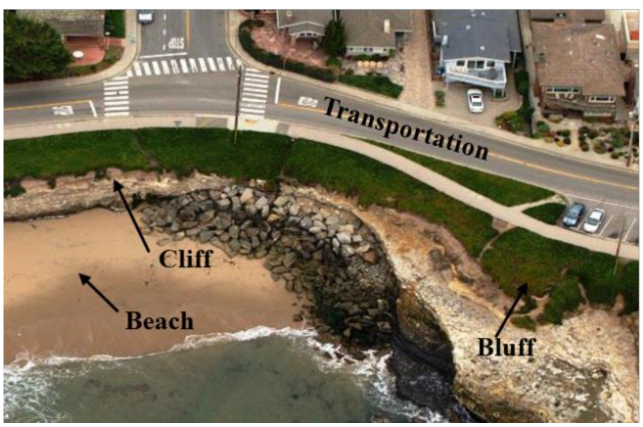
This Adaptation Alternatives Section builds upon results of the Existing Conditions and Vulnerability report (Sections 1–9) and associated Appendices. This section lays out the full range of Adaptation Strategies, identifies the prioritization criteria identified by the TAC and City Department leadership to narrow the options. Finally, following community outreach efforts, this section identifies a narrow range of preferred alternatives that will be used in future cost–benefit and conceptual design tasks that inform the development of specific adaptation pathways in future tasks.

10. Adaptation Alternatives Analysis

In the context of this report, adaptation is defined as a response to existing or anticipated climate-induced impacts, and can include policy, programmatic, and adaptation project-level measures. Along West Cliff Drive, consideration of the current uses of limited cliff top public space for vehicular traffic, parking, and the recreational trail must be balanced with the community vision, coastal resources, and priorities for future generations.

This section builds on the existing conditions inventory, specifically the predicted areas of erosion concern, expected lifespan of existing coastal armoring structures and projected future vulnerabilities found in previous sections. This section summarizes the wide variety of potential adaptation approaches (Section 10.2) and then provides a screening level evaluation of the range of potential adaptation measures for both the transportation aspects of West Cliff Drive corridor (e.g., roadway and recreational trail) as well as the coastal resources (e.g., access, beaches, habitats, surfing, swimming, and other recreational activities), to identify feasible adaptation approaches for the short and long term (Section 10.3). Using results from outreach efforts on the management goals and evaluation criteria (Section 10.4) and preferred short and long term adaptations from the TAC, City leadership, and the public, this alternatives analysis identifies priority short and long term adaptation strategies to reduce coastal erosion and adapt each of the four West Cliff Drive zones (Section 10.5). Results of this Adaptation Alternatives Analysis are summarized and the prioritized adaptation approaches are identified which, after city and public consultation, will be refined and integrated into future stages of the project including conceptual design, and a cost–benefit analysis (Section 10.6).

Adaptation approaches can be implemented in many ways to reduce coastal erosion hazards, redesign the transportation corridor, and address secondary impacts from adaptation strategies over time. Thus, adaptation approaches must consider both reduction of coastal hazards and modifications to the transportation corridor to address short term and long term changes to different areas including the beaches, cliffs, bluffs, and transportation corridor (Figure 10-1).



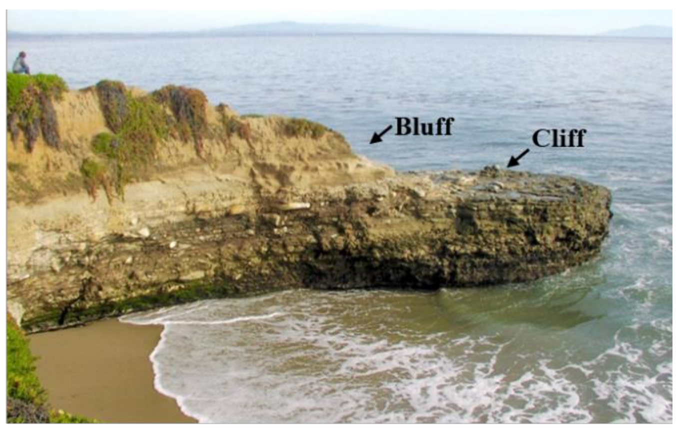


Figure 10-1. West Cliff Drive areas considered for coastal adaptation include the beaches, cliffs, and bluffs; while transportation strategies focus on the cliff top roadway and Recreational Trail (left), coastal adaptation strategies focus on reducing erosion to the hard cliffs and soft bluffs (right).

As part of the funding agreement with Caltrans, the City and this Adaptation Alternatives Analysis must specifically conduct both a transportation and a coastal adaptation alternatives analysis and specifies the types of adaptations that must be considered. These two analyses are closely linked. The coastal adaptation alternatives analysis focuses on stopping, reducing, or allowing coastal cliff erosion. The extent of future cliff erosion will determine the available public space on the cliff top to adapt the West Cliff Drive transportation corridor consisting of the roadway and the Recreational Trail. The ultimate goal of the West Cliff Drive Adaptation and Management Plan is to identify the least environmentally damaging alternatives for coastal and transportation adaptation consistent with the Santa Cruz community vision over time.

The transportation alternatives analysis must include evaluation of seven transportation alternatives by considering each alternative's likely effect on the existing transportation infrastructure over time and how it relates to coastal access. The transportation alternatives consider transportation needs: coastal access, community safety, residential access, and tourism. The multimodal nature of the West Cliff Drive corridor blends the use of the multi-use Recreational Trail and the adjacent Class III roadway shared between automobiles and bikes. The transportation adaptation alternatives analysis evaluates multimodal access, circulation and available parking including:

- One-way alternative, where one directional vehicle lane converts to two-way bicycle facility
- Partial one-way alternative, where car travel lane converts to two-way protected bicycle facility
- Partial relocation of various transportation infrastructure
- Full closure to automobiles
- Partial closure to automobiles
- Status quo
- Other (i.e., reroute traffic).

The coastal adaptation alternatives analysis must include evaluation of the following adaptation strategies to address coastal erosion and include:

- **Prevention Measures** are aimed at reducing the rates of erosion and can include stormwater management, coastal access controls, rodent/pest management, or replacement of invasive vegetation types that likely exacerbate erosion by weighing down erosion prone bluff sediments.
- **Managed Retreat Policies prioritize moving assets and development over time when they are threatened and** can be implemented many ways including purchase of property, relocation, phasing of directional road closures and additional setbacks, and changes to public access.
- **Protective Structures** are aimed at stopping erosion and include existing engineering approaches such as revetments, seawalls, or soil nail tie back walls. This could include maintaining, repairing or renovating structures, or constructing new ones.
- **Next Generation Structures** could replace or retrofit existing structures to enhance or mitigate secondary consequences to access, coastal recreation, ecology, and aesthetics such as adding roosting habitats, or connecting lower cliff segments to promote lateral access.
- **Shoreline Restoration/Enhancement** includes measures that utilize natural processes or geomorphology to reduce erosion and mitigate secondary consequences such as sediment management, offshore breakwaters, sand retention, or increasing the elevation of some of the lower cliffs segments
- **Least Environmentally Damaging Alternative** evaluate the suite of coastal adaptation alternatives for each West Cliff Drive zone that minimizes secondary consequences and maximizes coastal habitats, species, and recreational opportunities over the longest time span.

The adaptation alternatives analysis summarizes the relative costs, life expectancy, and potential secondary consequences of the feasible range of potential adaptation strategies to help the community prioritize future adaptation decisions affecting the transportation corridor, infrastructure, habitats and ecosystem, and recreation and tourism. This analysis also includes evaluation of the regulatory feasibility consistent with the Coastal Act and City LCP policies in addition to the various State agency sea level rise guidances below. In addition, a wide variety of public outreach and engagement efforts with key stakeholders has been used to narrow the wide range of potential adaptation strategies into prioritizing up to three potential strategies for each of the four zones along the West Cliff Drive corridor for more detailed future modeling, conceptual design, and cost benefit analysis to inform adaptation pathway development, as well as short and long term adaptive management and policy recommendations. The deliverable will be an evaluation matrix of the alternatives and a summary of the selection process for the three preferred alternatives for the conceptual design alternative analysis.

Because none of these existing State guidance documents provide direction or necessary information to scale analyses and planning to the neighborhood or transportation corridor scale, there are significant challenges in fully implementing the various State guidances along West Cliff Drive. Lessons learned here may have implications for and be transferable to other locations in the state with similar existing conditions. All efforts have been made to integrate the State regulations, sea level rise guidance principles, and stakeholder and public input into this West Cliff Driving community planning initiative focused on the transportation, coastal resources, and cultural identity.

10.1 State of California Adaptation Guidance

The California Coastal Commission (CCC), Ocean Protection Council (OPC), and Natural Resources Agency (NRA) have released sea level rise and adaptation planning guidance documents that are to be used by local jurisdictions to update land use planning documents.

10.1.1 OPC State of California Sea-Level Rise Guidance (2018)

In March 2018, the California Natural Resources Agency and OPC released an updated *State of California Sea-Level Rise Guidance* including eight preferred sea level rise planning and adaptation approaches:

- Adaptation planning and strategies should prioritize social equity, environmental justice, and the needs of vulnerable communities
- Adaptation strategies should prioritize protection of coastal habitats and public access
- Adaptation strategies should consider the unique characteristics, constraints, and values of existing water-dependent infrastructure, ports, and Public Trust uses
- Consider episodic increases in sea level rise caused by storms and other extreme events
- Coordinate and collaborate with local, state, and federal agencies when selecting sea level rise projections; where feasible, use consistent sea level rise projections across multi-agency planning and regulatory decisions
- Consider local conditions to inform decision making
- Include adaptive capacity in design and planning
- Assessment of risk and adaptation planning should be conducted at community and regional levels, when possible.

10.1.2 CCC Sea Level Rise Policy Guidance (2018)

In November 2018, the CCC adopted the 2018 Sea Level Rise Policy Guidance – Final Science Update (CCC 2018b). The guidance update recommends use of the State of California Sea-Level Rise Guidance:

2018 Update (OPC 2018) for sea level rise scenarios. Both the CCC 2018 and OPC 2018 guidance documents are complementary and utilized across the state for planning and adaptation strategies.

Sea Level Rise Policy Guidance (CCC 2018) outlines 20 guiding principles based on Coastal Act policies that address sea level rise in the coastal zone and fall under four categories:

- Use science to guide decisions (Coastal Act Sections 30006.5; 30335.5);
- Minimize coastal hazards through planning and development standards (Coastal Act Sections 30253, 30235; 30001, 30001.5);
- Maximize protection of public access, recreation, and sensitive coastal resources (Coastal Act Chapter 3 policies); and,
- Maximize agency coordination and public participation (Coastal Act Chapter 5 policies).

10.1.3 Natural Resources Agency Safeguarding California Plan (2018)

The *Safeguarding California Plan: 2018 Update* (NRA 2018) describes the State's climate change adaptation plan and actions state agencies should take to adapt communities, infrastructure, services, and the natural environment to climate change. This Plan outlined programmatic and policy responses as well as seven overarching principles:

- Consider climate change in all functions of government
- Partner with California's most vulnerable populations to increase equity and resilience through investments, planning, research, and education
- Support continued climate research and data tools
- Identify significant and sustainable funding sources to reduce climate risks, harm to people, and disaster spending
- Prioritize natural infrastructure solutions that build climate preparedness, reduce greenhouse gas (GHG) emissions, and produce other multiple benefits
- Promote collaborative adaptation processes with federal, local, tribal, and regional governments;
- Increase investment in climate change vulnerability assessments of critical built infrastructure.

10.1.4 Transportation/Caltrans Adaptation Guidance

California adopted an Adaptation Planning Guide in 2012 which identified a nine-step process highlighting flexibility while incorporating local and regional characteristics into adaptation projects. This project has followed the guidance and the first six steps (Figure 10-2). The next three steps are identifying adaptation strategies, evaluating and prioritizing them, and eventually developing a phased implementation plan. Caltrans has produced some high-level guidance on adaptation projects; however, it has been focused primarily on Caltrans-operated facilities and not local roadways.

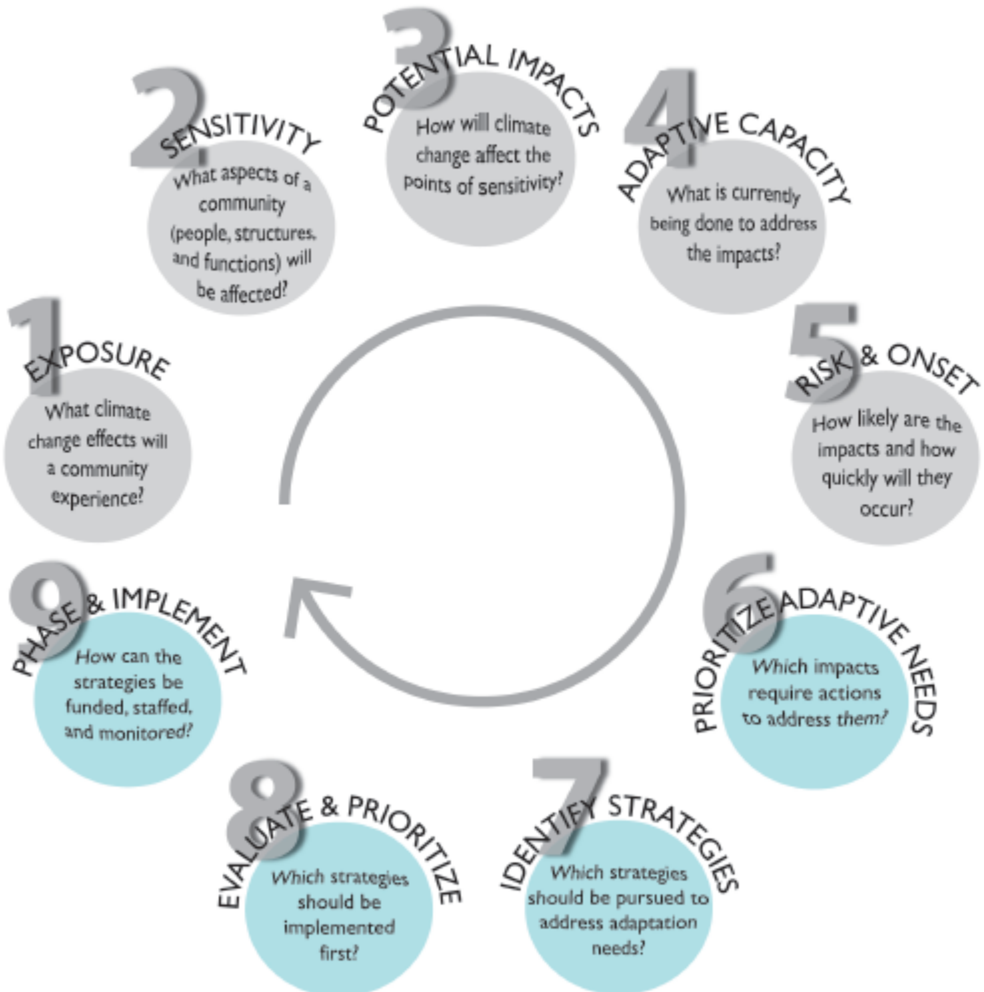


Figure 10-2. The nine steps in adaptation planning development. The gray steps are part of vulnerability assessment (steps 1–5) and blue steps are adaptation planning (steps 6–9). Source: California Adaptation Planning Guide 2012.

Since the funding source of this project is from the Caltrans Adaptation Planning Grant Program, it is relevant to mention Caltrans' ongoing efforts in climate adaptation and resiliency. Currently, each district is conducting its own vulnerability assessment for climate change with the primary goal to create a database of geospatial data which indicates current and future locations of natural hazards and their impacts to Caltrans roadways. These data are intended to be shared with local and regional agencies to assist in the evaluation of the vulnerabilities of other transportation modes.

In 2016, the Federal Highway Administration (FHWA) released the Adaptation Decision-Making Assessment Process (ADAP) to assist transportation planners and designers to account for climate change in civil transportation projects. The decision tree (Figure 10-3) assists with all types of adaptation projects, including flooding, erosion, sea level rise and in general evaluating the impacts and secondary consequences from climate change. In addition, FHWA published the Vulnerability Assessment and Adaptation Framework in 2017 citing examples of adaptation work from around the country and citing the use of Multi-Criteria Analyses and Risk Matrices to evaluate adaptation alternatives.

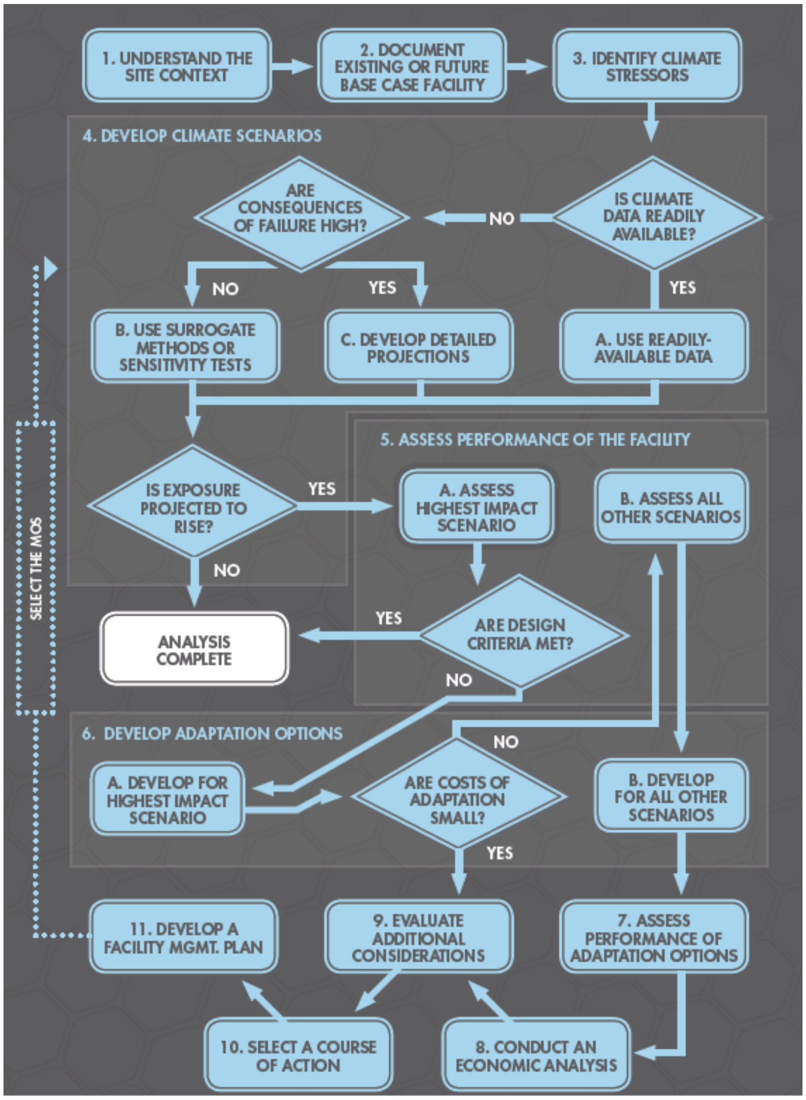


Figure 10-3. FHWA Adaptation Decision-Making Assessment Process

10.1.5 Local Transportation Planning Initiatives

Given the absence of neighborhood scale adaptation guidance, it is important to align transportation adaptation strategies to existing transportation studies and plans that the City of Santa Cruz has previously developed. This consideration of local transportation studies incorporates near term and long-term direction for the future of West Cliff Drive consistent with the City of Santa Cruz General Plan completed in 2012, the City of Santa Cruz Active Transportation Plan (ATP) completed in 2017, and the City of Santa Cruz Climate Action Plan (CAP) completed in 2012 and updated in 2018. Reviewing the existing conditions assessment and referencing the aforementioned plans helps to guide selection of adaptation alternatives for conceptual design alternative analysis. The ATP serves as a guide for improving active mobility in and around the City of Santa Cruz. The ATP also identified potential future projects, including enhancements of bicycle infrastructure for connecting streets to West Cliff Drive such as Almar Avenue. In addition, a project to stripe additional crosswalks providing formal pedestrian access from West Cliff neighborhoods to the Recreational Trail is identified as well as increasing the number of available bike racks. The ATP also cites the City of Santa Cruz General Plan Policies including:

- M 1.2, Create livable streets. “Livable streets” support the intent of Section 65302(b) of the California Government Code to create “complete streets” planned, designed, operated, and maintained to provide safe mobility for all users, including “bicyclists, children, persons with disabilities, motorists, movers of commercial goods, pedestrians, users of public transportation, and seniors.”
- M2.3, Increase the efficiency of the multi-modal transportation system.
- GOAL PR4, An integrated system of citywide and regional trails.
- PR4.1, Provide and maintain an accessible citywide trail system within the city and connect it to regional trails.
- PR4.1.1, Provide trails for a range of uses.
- PR4.1.2, Update and maintain trails in accordance with the City’s Bicycle and Pedestrian Master Plans. Cf. CD5.1, M4.1, M4.2, CC8.4.
- PR4.1.3, Maintain and enhance the recreational value of the San Lorenzo River walkway and East and the West Cliff Drive pathways.
- PR4.1.4, Create a continuous pathway along the coast by enhancing the physical links between West Cliff and East Cliff Drives and the Beach Promenade.
- PR4.1.6, For special events, examine the feasibility of periodically closing the street or limiting vehicular access along West Cliff Drive.
- M4.3.2, Develop bike commute routes along railroad rights-of-way (while ensuring the ability to develop rail transit) and along West Cliff Drive, Broadway, King, and other streets.

The annual fall Santa Cruz Open Streets, which closes West Cliff Drive to vehicular traffic for a day has been a great success (Figure 10-4).

Figure 10-4. West Cliff Drive Open Streets, Fall 2019

10.2 Approaches to Transportation and Coastal Adaptation

Transportation adaptation strategies should attempt to maximize the available space in the cliff-top right of way (ROW). The ROW extends from the sidewalk easement on the inland side of the road to the cliff edge. Short to mid-term adaptation strategies along West Cliff Drive are likely to largely focus on reducing or stopping coastal erosion of the cliff or overlying bluff. However, over longer time scales and continued erosion, the narrowing ROW may require that the City utilize or expand the available cliff top public space, change allowable uses, or realign the transportation corridor based on community priorities and transportation requirements and plans. Much of the development of the transportation adaptation alternative analysis is drawn from best practices learned from the implementation of Complete Streets and Vision Zero planning philosophies. These types of projects focus on reducing multimodal conflicts and enhancing corridor-wide multimodal safety.

According to CCC Sea-Level Rise Policy Guidance, sea level rise adaptation generally falls into five main categories: do nothing, protect, accommodate, retreat, or a hybrid approach described below (Table 10-1). The City has already protected 48 percent of West Cliff Drive. A do nothing scenario into the future would allow erosion in non-armored locations and allow existing structures to fail and erode landward. Given the City's historical response to repair armoring failures under emergency permit, conducting technical vulnerability assessments and updating the adaptation plan, followed by securing funding for this and other climate related studies to continue advancing adaptation and management approaches, the do nothing category is not considered to be a viable option. These categories can further be described based on a more nature based or soft solution strategy that mimics natural processes, or a more engineered approach or hard solution. Implementation of any category of adaptation strategies can be accomplished through an infrastructure project (e.g., build a seawall) and/or through policies (e.g., increasing setbacks). Different coastal adaptation strategies have different lifespans that can accommodate various levels of sea level rise and coastal hazards. Each strategy has secondary consequences that must be considered and compared with community priorities, vision to provide an equitable and least environmentally damaging alternative.

Different types of strategies are appropriate depending on community priorities, coastal hazards, specific location, backshore type, resource protection goals, development intensity, and the certainty of effectiveness over time. Strategies for addressing sea level rise hazards require proactive planning to balance protection of coastal resources with physical development. No one category or specific adaptation strategy is considered the "best" option forever. The effectiveness of different adaptation strategies varies across spatial and temporal scales with different strategies able to accommodate various types of coastal hazards and elevations of sea level rise.

Over time, the City is likely to use many of these approaches along a pathway over time in implementing a hybrid long term adaptation strategy that evolves based on actual observed changes or triggers (see Section 11). In the future, physical changes (e.g. erosion within 2 feet of the Recreational Trail) or economic costs (e.g., City spends $1 million per year) will trigger future planning efforts to change from existing approaches to another adaptation approach and shift the City's focus toward a different adaptation path.

Table 10-1. Categories of Adaptation Strategies

Strategy	Description
Do Nothing	A policy of non-intervention, including allowing existing armoring to fail
Protect	Engineered structures (hard) or natural measures (soft) such as sand management to protect existing transportation infrastructure and coastal resources in their current location
Accommodate	Modify existing areas or design new corridor or infrastructure features to decrease future erosion hazard risks
Managed Retreat	Relocate or realign existing transportation and critical public infrastructure out of erosion hazard areas to maximize access and uses of coastal resources
Hybrid	Employ strategies from multiple categories

The following discussion describes the three main approaches—protect, accommodate, and managed retreat (see Table 10-1); however, the City is investigating hybrid approaches over various time scales as they would provide the broadest array of adaptation measures and preserve the City's flexibility to implement strategies through time as science continues to advance and physical changes are observed.

There are three tiers of coastal adaptation measures:

1. Strategies that stop erosion by protecting the cliffs or bluffs
2. Strategies that reduce the rates of erosion by preventing or managing factors that cause? erosion
3. Strategies that mitigate some of the secondary adverse consequences of higher tiered strategies

It is likely that over time, the City will utilize all of the adaptation approaches to address erosion and adapt the West Cliff Drive corridor to changing circumstances. It is the goal of this section to narrow the range of potential adaptation alternatives to those most feasible and prioritized by the Santa Cruz community for detailed cost–benefit analysis and conceptual design in the future. Results of this further analysis will inform the development of adaptation pathways which help to identify differences and triggers between short-term and longer-term adaptation approaches.

The West Cliff Drive Adaptation and Management Plan is intended to provide enough specificity to identify a vision for the West Cliff Drive corridor, Recreational Trail, and coastal resources. The intent for the Plan is to be approved by the Coastal Commission and other regulatory agencies to allow the City to manage areas of erosion concern and maintain existing levels of protection and coastal access and resources while planning for future adaptation steps.

10.2.1 Protect

> Protection strategies typically employ engineered structures or other measures to stop or reduce erosion and maintain existing upland infrastructure and development in its current location.

In accordance with the Coastal Act and *Safeguarding California Plan* (NRA 2018), priority should be given to options that protect, enhance, and maximize coastal resources and access. Protection strategies can range from "grey" to "green" and include either "hard" or "soft" defensive measures. A "grey" or "hard" approach refers to an engineered structure located either alongshore such as a seawall, revetment, artificial reef, or offshore breakwater, or cross-shore (i.e., shore-perpendicular) such as a groin, headland enhancement, or jetty (Figure 10-6 on p. 10-16). A "soft" protection approach may be to use natural sediments to reduce erosion. A "green" soft approach may be to restore sensitive bluffs with native vegetation. While the Coastal Act provides for potential protection strategies when required to serve coastal dependent uses or "existing development" in danger of erosion (i.e., California Coastal Act Section 30235), it also directs new development be sited and designed not to require future protection that may alter a natural shoreline (California Coastal Act Section 30253).

Protection devices can also be positioned either parallel to the shoreline such as a seawall or perpendicular to the shoreline such as the Santa Cruz Harbor jetty. The location of the protective device also determines the function. For example, an offshore breakwater is intended to stop wave energy while a revetment is intended to dissipate the wave energy at the shoreline and protect the cliffs, and a bluff top retaining wall is intended to protect the softer marine terrace deposits from wave overtopping that causes erosion.

Shore parallel structures such as offshore reefs or breakwaters are intended to dissipate wave energy and consist of various materials placed in the surf zone to reduce wave energy at the beach and along the base of the cliffs. Many shoreline protective devices (e.g., seawalls, revetments, soil nail tie back walls) can adversely affect a wide range of coastal resources over time and negatively impact recreational uses, such as surfing, that the California Coastal Act protects. Placement of a "hard" shoreline protective device on the landward side of a beach ultimately leads to loss of the beach over time. Furthermore, hard shoreline protective devices often exacerbate erosion on adjacent unarmored beach areas. They often impede or degrade public access and recreation along the shoreline by occupying beach areas or tidelines, by accelerating adjacent erosion, and reducing shoreline sand supply. Shoreline protective devices also raise serious concerns regarding marine resources and biological productivity, can degrade the scenic qualities of coastal areas and alter natural landforms. Secondary consequences of coastal armoring are further discussed in detail in Section 10.5.1.

Cross-shore structures such as a groin or harbor jetty structures are built perpendicular to the shoreline and extend into the surf zone to trap sand and widen the beach upcoast for some distance (to the west) of the structure. Often erosion downcoast has been observed from the loss of sand moving along the coast, thus, cross shore structures typically must incorporate an upcoast pre-fill of sediment (or charge) to reduce the duration of sand trapping to prevent secondary impacts from downcoast erosion or require ongoing sand movement such as the sand bypass at the Santa Cruz Harbor. Most "hard"/grey structures must be accompanied by "soft" defensive measures such as sediment management to mitigate secondary consequences.

Most hard/grey protection strategies are costly to construct, require increasing maintenance costs, and may result in secondary consequences to beaches, recreation, and habitat. The following options are considered protection strategies listed within the CCC *Sea Level Rise Policy Guidance* that could be applicable to West Cliff Drive:

- Use of hard protection such as seawalls or revetments under special considerations to serve the public and preserve the function of critical facilities and public infrastructure which the West Cliff Drive corridor may be considered.
- Use of sand retention structures such as the West Jetty at the Santa Cruz Harbor which impound sand and widen upcoast beaches.
- Implementation of living shorelines, or other soft, green solutions to reduce erosion and enhance coastal resources.
- Implementation of the Santa Cruz Coastal Regional Sediment Management Plan or other sediment management practices that restore or mimic natural sediment supply and consider the entire sandshed.
- Beneficial reuse of sediment through dredging and placement on beaches.

10.2.2 Accommodation

> Accommodation strategies employ methods that modify existing or design new developments or infrastructure to decrease erosion hazard risks and thus increase the resiliency of transportation infrastructure and coastal resources to the impacts of sea level rise.

At the West Cliff Drive scale, accommodation strategies could include elevating transportation infrastructure or increasing setbacks. Some policy approaches could include amendments to land use and zoning designations, or measures that require various adaptive types of actions, such as increasing oceanside setbacks to reduce erosion risk or curb setbacks to provide more space for public transportation and mobility facilities. Other approaches could require mitigation actions to provide for protection of natural areas. On an individual project scale, these accommodation strategies include standards such as expanding ROW easements, elevating structures, performing structural retrofits, using materials to increase the durability of development from additional coastal erosion impacts, building structures that can easily be moved and relocated, or using additional setback distances to account for acceleration of erosion. The following options are considered accommodation strategies listed within the CCC *Sea-Level Rise Policy Guidance* and applicable to West Cliff Drive:

- Consider sea level rise in site-specific development proposals.
- Update development siting, code, and design standards to avoid, minimize, or reduce risks from coastal hazards and extreme weather events.
- Elevate structures or transportation infrastructure above base flood elevations using caissons.
- Design coastal-dependent infrastructure to withstand coastal hazards.
- Increase the capacity and ability to use capture or divert stormwater in stormwater projects.
- Retrofit outfalls and wastewater treatment systems that could damage water quality and reduce the amount of stormwater discharged into the ocean.
- Realign or retrofit transportation infrastructure to better withstand sea level rise impacts.

10.2.3 Managed Retreat

> Managed retreat is an adaptation measure that realigns or moves at-risk infrastructure to allow for natural cliff erosion to maintain coastal infrastructure to allow for natural cliff erosion to maintain coastal resources. There are many ways to implement managed retreat which are typically phased over time.

Managed retreat is not an evacuation, but rather a phased strategy to methodically relocate or move existing development and/or transportation infrastructure away from erosion hazard areas and limit the construction of new development or infrastructure in vulnerable areas. Implementation strategies include fee simple acquisition, amendment of land use designations, and zoning ordinances to reduce development potential or encourage siting and alignment of infrastructure, transportation corridor, and amenities toward less hazardous areas. Repetitive loss programs, development setbacks, and modification or relocation of structures are examples of strategies designed to manage retreat from areas with existing and projected coastal hazards.

The following are managed retreat strategies listed within the CCC *Sea-Level Rise Policy Guidance*:

- Project future erosion hazard zones and overlays that guide new infrastructure and transportation enhancements away from current and future coastal hazard zones.
- Develop adequate setbacks for new development.
- Develop a plan to move or relocate transportation infrastructure and coastal amenities that become threatened by or face imminent, foreseeable coastal hazards.
- Plan to replace loss of land uses that could be lost to increasing erosion damages associated with sea level rise through a transfer of development rights program.
- Identify alternative transportation routes or consider one-way traffic to reduce width of vulnerable roadways.
- Coordinate planning and regulatory decisions with other appropriate local, state, and federal agencies.
- Consider purchase of erosion easements or portions of yards to expand available public space.

10.2.4 Transportation Related Adaptation

Adaptation of the transportation network is largely dependent upon how effectively the coastal adaptation strategies for reducing coastal erosion are implemented, and the available public space along the publicly owned West Cliff Drive corridor; thus, a variety of transportation approaches are possible. Two strong requirements for the West Cliff Drive transportation infrastructure are to maintain access for emergency first responders and support coastal access for residents and visitors. Public feedback through the extensive outreach process identified that the preservation of, and enhancement to, the Recreational Trail is a top community priority. The method or mode of access may shift depending on the specific coastal adaptation approach taken in each zone. Thus, over time, parking may shift or be lost, or a lane of travel may need to be converted from vehicles to active transportation modes such as bicycling. Directional travel may change or be lost outright and less traveled roads may gain additional traffic and become reclassified as a collector road (e.g. funneling traffic) from a local road (e.g., residential). It is best to consider the West Cliff Drive transportation corridor with a holistic approach and consider all modes and users within the network collectively. Each zone has slightly different geology and ROW dimensions, which encourage different alternatives to be developed; however, zone-to-zone flow and connectedness must be a priority.

10.3 Adaptation Considerations

10.3.1 Transportation Safety Considerations

During community engagement efforts, the public provided feedback regarding safety concerns during use of the Recreational Trail and observing frequent conflicts between walkers and e-bike riders at times over 20 mph. This information provides context to the type of transportation adaptations alternatives that should be analyzed. The approach to best improve the safety and usage of the Recreational Trail, particularly balancing of the types of cyclists and pedestrians who use the corridor may best align with the City of Santa Cruz's Active Transportation Plan's classifications and characteristics. The City's ATP mentions the four types of users who should be considered for the Recreational Trail and the shared roadway. The four types of users are 1) Strong and Fearless, 2) Enthused and Confident, 3) Interested but Concerned, and 4) No Way No How. The four types of Recreational Trail users are identified based on their comfort with and around bicycling as well as preferred conditions for bicycling, which can include the age of user as well (Figure 10-5).

To enhance access for residents and tourists, the West Cliff Drive Adaptation and Management Plan should focus on the types of bike riders who fall in the "Interested but Concerned" and "No Way No How" categories, as these two groups constitute more than 90 percent of the population on average. The "No Way No How" group are the pedestrians who prefer to walk along the current corridor and experience safety concerns and user conflicts between themselves and other active transportation modes, such as e-bikes (Jump Bikes) and regular cyclists. Some members of these No Way No How residents fall into the historically underrepresented populations in the community including the elderly, very young, and people living with disabilities.

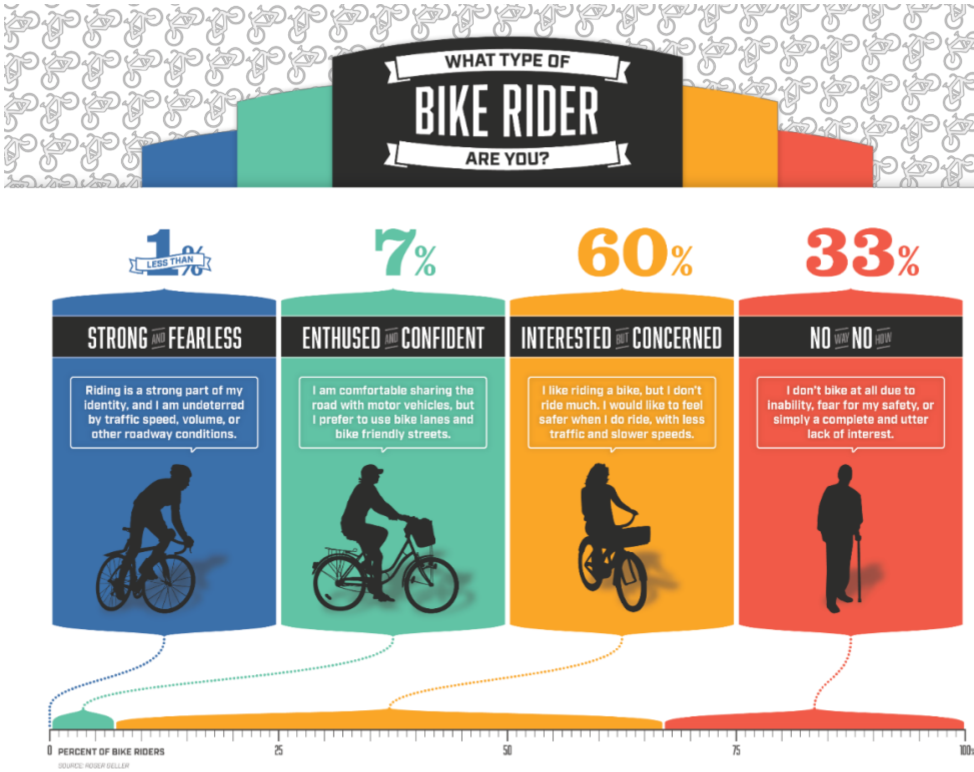


Figure 10-5. Four types of Users adapted from the "Four Types of Cyclists" (2009). ***Roger Geller, City of Portland Bureau of Transportation.***

10.3.2 Maladaptation

Adaptation measures that reduce the ability of people and communities to respond to climate change over time are called maladaptation. Maladaptation has several characteristics that help identify when it is occurring. One of the most significant concerns with maladaptation is that it reduces incentives to adapt while it simultaneously diminishes the capacity to adapt in the future. Maladaptation measures may:

- Result in sustained or increased hazardous conditions including added emergency response time
- Result in additional vulnerabilities, disruption of transportation continuity, and degraded coastal resources
- Create a more rigid system with severe consequences such as a cave failure
- Increase greenhouse gas emissions
- Reduce incentives to adapt.

Maladaptation occurs when efforts intended to protect communities and resources result in increased vulnerability, often realized indirectly or too late after a direction has been set. For instance, previously unaffected areas can become more prone to climate-induced hazards if the system that is being altered is not sufficiently understood. Likewise, if too much focus is placed on one time period—either the future or the present—effects on the other can be ignored, resulting in an increased likelihood of impacts from climate-induced hazards. Avoiding maladaptation is critical to a successful climate adaptation strategy. To do so, the City must make informed decisions based on an accurate vulnerability assessment, detailed cost–benefit analysis, effective evaluation of secondary consequences, and clear vision and acceptance of future risk and vulnerability. Flexibility and a precautionary approach combined with a "no-regrets" approach are key to avoiding maladaptation in the adaptation planning process.

When identifying appropriate adaptation responses, the City should use the following principles to reduce the risk of maladaptation:

- The strategy should support the protective role of ecosystems and sustain their physical processes.
- The strategy should avoid disproportionately burdening the most vulnerable citizens and prioritize social equity and environmental justice.
- The strategy should avoid high costs, unless holistic economic work (including ecosystem services, infrastructure upgrades, and damages) demonstrates a strong net benefit over time.
- The strategy should increase flexibility and not lock the community into a single long-term solution.
- The strategy should reduce decision time to better incorporate evolving science of sea level rise.
- The strategy should account for long-term maintenance costs over time, and those costs should be lower than they would be without use of the identified strategy.

10.3.3 Adaptive Capacity and Risk Tolerance

Adaptive capacity is the ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to address consequences. For purposes of this discussion adaptive capacity is categorized as:

- **High**—Strategy, asset, or resource can easily be adapted or has the ability to adapt naturally.
- **Medium**—Strategy, asset, or resource can be adapted with minor additional cost or effort.
- **Low**—Strategy, asset, or resource has limited ability to adapt without significant changes, cost, or additional engineering.

A guiding principle of adaptation planning is to limit the risk to vulnerable assets from coastal hazards. Risks to the City's vulnerabilities increase with sea level rise. The City must choose what level of risk it is willing to tolerate. Risks that present the most serious consequences and are projected to occur first should be elevated to top priorities for the City. Risks can be addressed by reducing vulnerability or exposure. Given limited resources, it is important that risks be prioritized and phased to maximize the use of community resources while avoiding a costly emergency response to the maximum extent feasible.

10.3.4 Secondary Consequences

Almost all adaptation strategies have secondary consequences associated with them. Many of these consequences will take years to realize. Often secondary consequences result from a choice between protecting existing cliff-top development and infrastructure at the long-term expense or degradation of coastal resources. These secondary consequences often degrade coastal resources including beach and nearshore recreation, access, ecology, aesthetics, or reduce wave quality.[1] Other consequences may include fiscal impacts associated with the loss of tourism revenues, property taxes, or capital construction or escalating maintenance costs. Additional transportation consequences could result in changes in access

[1] Santa Cruz has self-identified as Surf City USA and its unique setting provides a cultural identity, mental health benefits, as well as fuels a substantial part of the local economy. It serves as a destination deriving revenues from visitors around the world. The waves are irreplaceable with no substitution in the United States and provide a substantial economic benefit to be considered more rigorously in the future cost/benefit analysis.

to residential and recreational areas, altered travel times, GHG emissions, and changes in vehicle traffic patterns. Finally, others can affect community aesthetics, property values, or displace portions of the community, which often impacts frontline and historically underrepresented residents within the community. Usually, one of the most controversial impacts is associated with the long-term preservation of coastal access to the beaches, intertidal habitats, and coastal recreation opportunities, which often pits private and public interests against each other with strong concerns over traffic intensity, social justice, and community inequality.

Secondary impacts could affect Coastal Act-protected resources including short-term habitat impacts during construction or maintenance activities. Others can be quite long lasting and expensive, such as the burial of many of the small pocket beaches along West Cliff under rocks following construction of revetments. Another example is the potential impacts to visual resources associated with shoreline protection or amenities such as fences that may increase heights or density to protect against elevated levels of wave overtopping.

Along West Cliff Drive, secondary impacts will be associated with both the coastal adaptation strategies and the transportation approaches utilizing the limited cliff-top public space allocated to vehicular traffic, parking, and the Recreational Trail. Directional traffic may change, and road closures and rerouting may occur changing traffic patterns through neighborhoods previously less traveled. These secondary impacts must be evaluated separately based on the goals, objectives, and vision of the City and community.

Secondary consequences are associated with each adaptation approach. The sections below dives deeper into more specific tradeoffs for each of the most likely adaptation approaches.

10.3.4.1 Shoreline Protective Devices

Shoreline protective devices (e.g., seawalls, revetments, tie back or soil nail walls) can adversely affect a wide range of other coastal resources and uses that the California Coastal Act protects. They often impede or degrade public access and recreation along the shoreline by occupying beach area or tidelands and by reducing shoreline sand supply.

Protecting the back of the beach through shoreline protective devices ultimately leads to the loss of the beach as sea level rise and coastal erosion continues adjacent to unarmored sections (Figure 10-6). Shoreline protective devices therefore raise serious concerns regarding consistency with the public access and recreation policies of the California Coastal Act. Such structures can also be placed in coastal waters or tidelands and harm marine resources and biological productivity, which is in conflict with California Coastal Act Sections 30230, 30231, and 30233. In addition, while California Coastal Act Section 30235 allows for shoreline protective devices in certain circumstances when designed to eliminate or mitigate adverse impacts on local shoreline sand supply, shoreline protective devices can degrade the scenic qualities of coastal areas and alter natural landforms potentially affecting sand transport, coastal ecology as well as wave quality and consistency. These circumstances may create conflicts with Section 30251. By halting or disrupting landscape connectivity, structures can prevent the inland migration of intertidal and beach species during large wave events as well as reducing public access. In urbanized areas, this disruption could prevent intertidal habitats, salt marshes, beaches, and other low-lying habitats from advancing landward as sea levels rise over the long-term.

Shoreline protection devices such as seawalls and revetments have several inevitable secondary impacts:

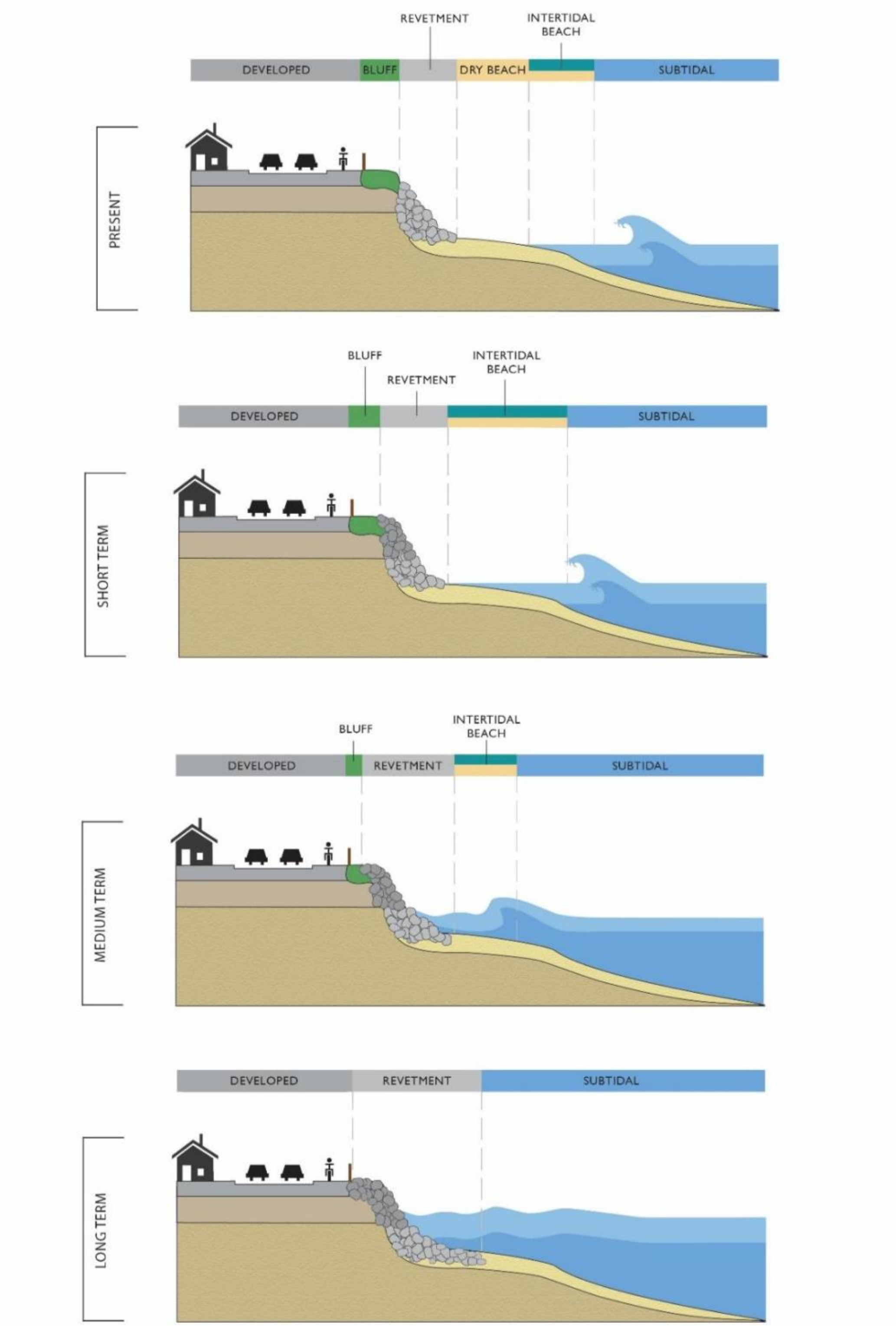


Figure 10-6. Evolution of a protection adaptation approach through time. This example uses a revetment, but could also be a seawall, or soil nail tie back wall. Initially, the beach is narrowed by the placement of the structure and over time, the beach is lost and the surf quality deteriorates.

Placement Loss

Wherever a hard structure is built, there is a footprint of the structure that results in a loss of coastal area known as placement loss. This inevitable impact can bury the beach beneath the structure and reduce the usable beach for recreation or habitat purposes. For example, a 30-foot high revetment may cover up to 60 feet of dry sandy beach. A vertical seawall or soil nail tie back wall typically has a smaller placement loss than a revetment.

Passive Erosion

Wherever a hard structure is built along a shoreline undergoing long-term net erosion, the shoreline will eventually migrate landward to (and potentially beyond) the structure. The effect of this migration will be the gradual loss of beach in front of the seawall or revetment as the water deepens and the shore face moves landward. While private structures may be temporarily saved, the public beach is lost. This process of passive erosion is a generally agreed-upon result of fixing the position of the shoreline on an otherwise eroding stretch of coast and is independent of the type of seawall constructed. Passive erosion will eventually destroy the recreational and habitat beach area unless this area is continually replenished. Excessive passive erosion may impact the beach profile such that shallow areas required to create breaking waves for surfing are lost.

Active Erosion

“Active erosion” refers to the interrelationship between coastal structures and at the beach, whereby due to wave reflection, wave scouring, enhanced "end effect" erosion, and other coastal processes, the shoreline protection may actually increase the rate of loss of beach in front of the structure, decrease the quality and consistency of the surfing waves and escalate the erosion rate along adjacent unprotected sections of the coast. Active erosion is typically site-specific and depends on sand input, wave climate, specific design characteristics, and other local factors. A good example is the 2016 sinkhole on West Cliff east of Woodrow Avenue in an area that was “protected” by both a seawall and revetment where active erosion scour undermined the structures and resulted in a substantial failure of the Recreational Trail requiring closure and rerouting during emergency repairs at an expense to the City of about $250,000 (Figure 10-7).

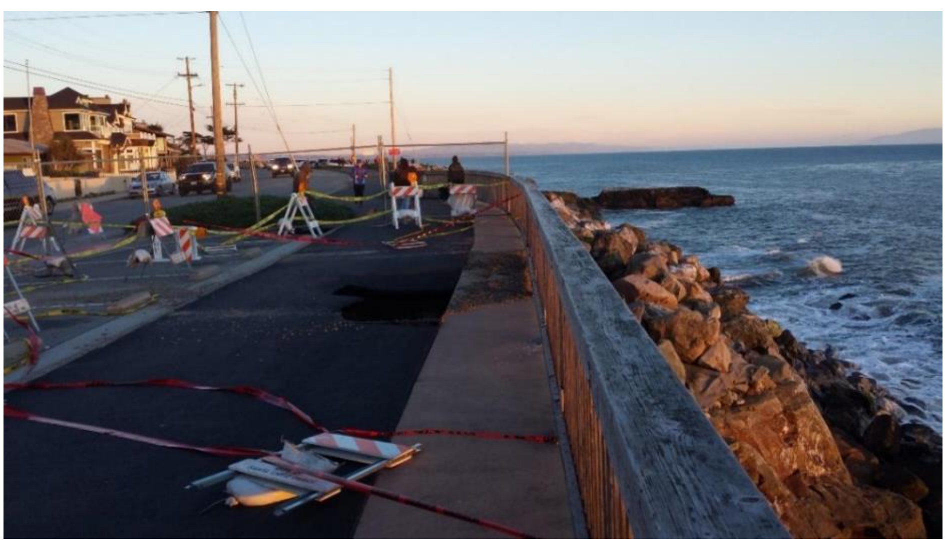


Figure 10-7. Sink hole resulting from active erosion scour of the revetment and seawall in front of the Recreational Trail and West Cliff Drive, $250,000 emergency repair expense to the City for a 20 foot stretch of coast to protect three parking spots.

Loss of Sand Supply
The reduction of erosion of the cliffs and soft bluffs can also reduce some of the supply of sediment to the coast. The loss of sediment supply is relatively small along West Cliff, but the cumulative impact of armoring the entire corridor may significant to the small pocket beaches.

Downcoast Erosion
Some cross-shore structures such as groins and breakwaters are effective at trapping sand as it moves along the coast. This trapping (or impoundment) reduces the amount of sand supplied downcoast. These sediment retention structures can cause downcoast impacts. The County has already experienced this type of erosion as a result of the construction of the Santa Cruz Harbor affecting sand supply to downcoast County beaches.

Recreational Impacts
Depending on the type of structure, impacts to recreation may vary. Over time, any vertical structure that stops erosion will result in the loss of recreational beaches. This loss of beach over time from passive erosion typically impacts lateral access (ability to move along the coast). Typically, vertical beach access (ability to get to the beach) is particularly impacted for vertical seawalls unless there are special features integrated into the engineering design of the individual structure. Revetments often also reduce beach access, or make it extremely treacherous. However, in several locations along West Cliff Drive, surfers depend on the revetment for access, which would be lost with a vertical seawall. Shoreline protection devices also affect nearshore physical processes. Vertical seawalls and revetments can increase wave reflection and accelerate nearshore ocean currents. Both of these changes can affect the quality and character of waves and change surf recreation. Already along West Cliff Drive, many surf breaks are rideable only at low tide. As sea levels rise, the impact from protection strategies will further reduce tide windows at which surf breaks function. Accelerated nearshore currents caused by armoring structure interactions may also affect diving conditions and increase marine safety risks to swimmers and waders.

Ecological Impacts
Scientific studies have documented a loss of ecosystem services, loss of habitat, and reduction in biodiversity where protection strategies have impacted beaches compared to natural beaches. Given the negative ecological impacts of coastal armoring solutions, more attention is now being focused on the implementation and resulting effectiveness of natural green or soft solutions. Soft solutions involve creation or restoration of shoreline ecosystems using nature-based management techniques. These techniques rely on natural physical, biological, geologic, and chemical processes to enhance the natural ability of coastal landforms to buffer erosion and flooding. Nature-based features can be artificially designed, engineered, and constructed to mimic nature and may include sediment management. When implemented correctly, soft solutions can be more self-sustaining after an initial establishment phase, resulting in lower ongoing maintenance costs. Soft options may be required as mitigation for construction of hard structures, are more favorably looked upon by permitting agencies, and offer added benefits such as water filtration, wildlife habitat, and recreational opportunities. These benefits will be considered in the future cost–benefit analysis of prioritized adaptation strategies.

Social Justice and Impacts to Underrepresented Communities
Another impact of shoreline protection is that it can create environmental justice issues, as shoreline protection can lead to a loss of public access and beach narrowing. For example, the City and State beaches are free resources that serve low-income, minority, and underrepresented populations from the local area, the Bay Area, and the Central Valley. Shoreline protection devices could result in a loss of this public coastal access and reduce the number of people able to enjoy the coast for free or at a low cost.

Economic and Fiscal Impacts of Coastal Armoring
The potential economic impacts (both private and public) of coastal armoring include the following:

- Changes to private property values, which typically increase when shoreline protection is in place
- Capital costs from seawall construction and recurrent costs associated with seawall maintenance and managing any offsite erosion impacts
- Loss of tourism revenue from changes in coastal management business as usual practices
- Erosion impacts on adjacent properties
- Visual amenity, beach access, and coastal resource impacts.

These fiscal impacts depend on the value of the existing use which typically requires counts of different users and surveys of willingness to pay. This West Cliff Drive project has conducted both intercept surveys and user counts to estimate potential changes in visitation along with the corresponding spending and taxes from each proposed alternative. Future economic cost–benefit analysis will evaluate the potential gains or losses in visitation and corresponding gains/losses in economic activity and taxes (local sales taxes, transient occupancy taxes) resulting from these changes to visitation.

10.3.4.2 Sediment Management

Sediment management is another option to reduce erosion and maintain or enhance recreation by building wider beaches. Secondary consequences of sediment management vary depending on the volume, frequency, number of locations, and method of sediment placing. Large scale nourishment construction can be costly and tend to have a short to medium life expectancy, often requiring repeated sand placement intervals that will shorten over time. In addition, ongoing sand supplies for large projects can become scarce over time. Secondary consequences from sediment placement typically scale with the volume placed which results in initial temporary degradation to the sandy beach ecosystem and may also cause temporary changes in surfing resources and recreational use. The frequency of placement is also a secondary consequence to consider as routine disturbance does not allow the ecosystem to recover and can create a slow longer-term degradation to habitat. In more routine sediment management programs, secondary impacts can be focused in a single location, and have positive benefits by providing downcoast beaches with sand. Many harbors including the Santa Cruz Harbor simply bypass sediment over the navigation channel and feed downcoast beaches. In other instances, backpassing sediment accumulated upcoast of the harbors such as Seabright Beach can minimally narrow the beach temporarily, reduce required dredging volumes, and provide short term recreational benefits.

10.3.4.3 Managed Retreat

Managed retreat has several secondary consequences, the severity of these consequences to the City will depend on the means in which managed retreat is implemented. Generally, managed retreat allows erosion of the upland to occur which would initially disrupt the continuity of the West Cliff Drive corridor and Recreational Trail. Over time as erosion continued there could be anticipated impacts to infrastructure and reduced roadway access to private property along West Cliff Drive. Longer term impacts from erosion on available public space within the West Cliff Drive corridor may require land use changes and potentially affect longer-term tax revenues. The primary beneficial secondary consequence though of managed retreat is that it maintains coastal resources and recreational opportunities into the future.

10.3.5 Economic Impacts and Issues

The costs of adaptation often get lost over time, particularly when spent in emergency reaction without a longer term strategy. Santa Cruz has expended funds for decades in response to emergencies to stabilize the shoreline along West Cliff Drive from erosion. Sea level rise threatens to expand the need for such expenditures by orders of magnitude over the next several decades. But a focus on the expenditures that may be needed can obscure attention on the broader set of economic issues that must be addressed. These include:

- What are the costs of not taking action? Most likely erosion will accelerate, deteriorating the transportation and recreation infrastructure along the top of the cliff to the point where it will become periodically and then regularly unusable. City expenditures for maintenance and "emergency" repairs will increase along with sea levels, possibly rising to the stage following a major erosive wave event occurring at high tide where West Cliff Drive repairs becomes a substantial demand on the City's public works budget.
- The high quality recreation opportunities provided by the access to and along the coast of West Cliff Drive are available essentially for free, available to residents and visitors of all income groups. The losses to these groups would be disproportionately higher because they would have need to spend larger portions of their income to find substitute recreational sites. In some cases, there are no substitute recreational spots with similar favorable characteristics in the region. A good example are the world class surf spots that receive wave energy all year coupled with a south facing coast where typical winds are favorable to surfing.
- The effects of a deteriorating cliff and transportation infrastructure on West Cliff Drive will be felt much more broadly than only on the city budget. The loss of recreational opportunities will affect residents and visitors for whom the West Cliff Drive recreation area is one of the major amenities in Santa Cruz. Resultant losses in economic value from recreation may possibly lead to a loss in revenues to the tourism industry in both Santa Cruz and surrounding communities. Changes in marine and terrestrial ecosystems could also reduce the quality of an array of cherished recreational activities and ecosystem goods and services.
- West Cliff is also an important transportation link and its loss will divert traffic onto local streets that are not designed to serve through-traffic, increasing road maintenance costs, and changes to neighborhood character that could affect property values. Existing connecting public streets could represent a low-cost and equitable transportation solution to whole or partial loss of West Cliff Drive. Other infrastructure, such as water and wastewater systems could also be affected.

Another important economic issue is raised by the uncertainty surrounding the extent and pace of sea level rise. Projections of sea level rise provided by various State agencies, such as the California Ocean Protection Council and California Coastal Commission, acknowledge the uncertainties concerning sea level rise and offer several possible forecasts and risk aversions required to consider as the basis for planning. However, this uncertainty creates a particular economic challenge for making adaptation decisions: when to implement adaptation actions. Taking actions too soon may divert funds from other priorities that need to be met; taking them too late almost certainly increases the costs of adaptation and risks economic losses that could occur if sea level rises faster than anticipated. Finding the best time to make investments in adaptation is one of the most difficult aspects of planning for adaptation. The approach of the West Cliff Drive Adaptation and Management Plan is to identify specific measurable triggers (e.g., cliff top distances, sea level rise changes) that can be observed and when reached, will catalyze the next phase of adaptation planning with enough lead time to avoid major impacts. Section 11 provides more information on triggers and approaches to identifying an eventual adaptation pathway.

10.4 Adaptation Planning Specific to West Cliff Drive

As our understanding of climate science continues to evolve, it is important for the City to maintain flexibility and monitor sea level rise as part of adaptation planning and consider updated climate science, predictions, scenario probabilities, and diverse adaptation strategies. Adaptation planning provides the City with a toolbox of options to carry out its long-term vision for the community with consideration of sea level rise. It is most likely that the City will utilize a range of adaptation projects and policy approaches over time along an adaptation pathway to minimize costs, improve resiliency and balance coastal resources, transportation, recreation and risk. The goal of this Adaptation Evaluation is to prioritize using stakeholder input, City preferences, public prioritization and professional judgement to identify 3 priority coastal and transportation strategies for further cost/benefit and conceptual design tasks in order to identify a preferred adaptation pathway is the least environmentally damaging. These three preferred coastal and transportation adaptation alternatives by Zone will be analyzed in a more-detailed analysis of traffic, transportation, and cost benefit analysis in the subsequent conceptual design phase.

10.4.1 Alternative Evaluation

The goal of the alternative evaluation is to present the full range of possible adaptation approaches to those preferred by the City leadership and the community at large based on the development of a community vision, evaluation criteria, and community prioritization. Alternatives were identified for further evaluation over time based on selected cliff erosion distances and sea-level rise scenarios. Comparisons were presented during the stakeholder process which evaluated relative capital and maintenance costs, multimodal transportation implications, secondary impacts to coastal resources, and effectiveness at balancing management objectives, and social, technical, and environmental dimensions. A regulatory review for consistency with the General Plan and Local Coastal Program (LCP) as well as other regulatory authorities was also included.

10.4.2 Stakeholder Engagement and Outreach Process

The City and consulting team participated in an extensive outreach effort which included engagement with focus groups, TAC, City department directors, and the public through a myriad of diverse engagements (Figure 10-8). The goal of this engagement was to educate and gain insights from a wide variety of perspectives to filter potential adaptation strategies down to those most preferred by the community for short term and long term adaptation approaches for further analysis in subsequent phases of the project.

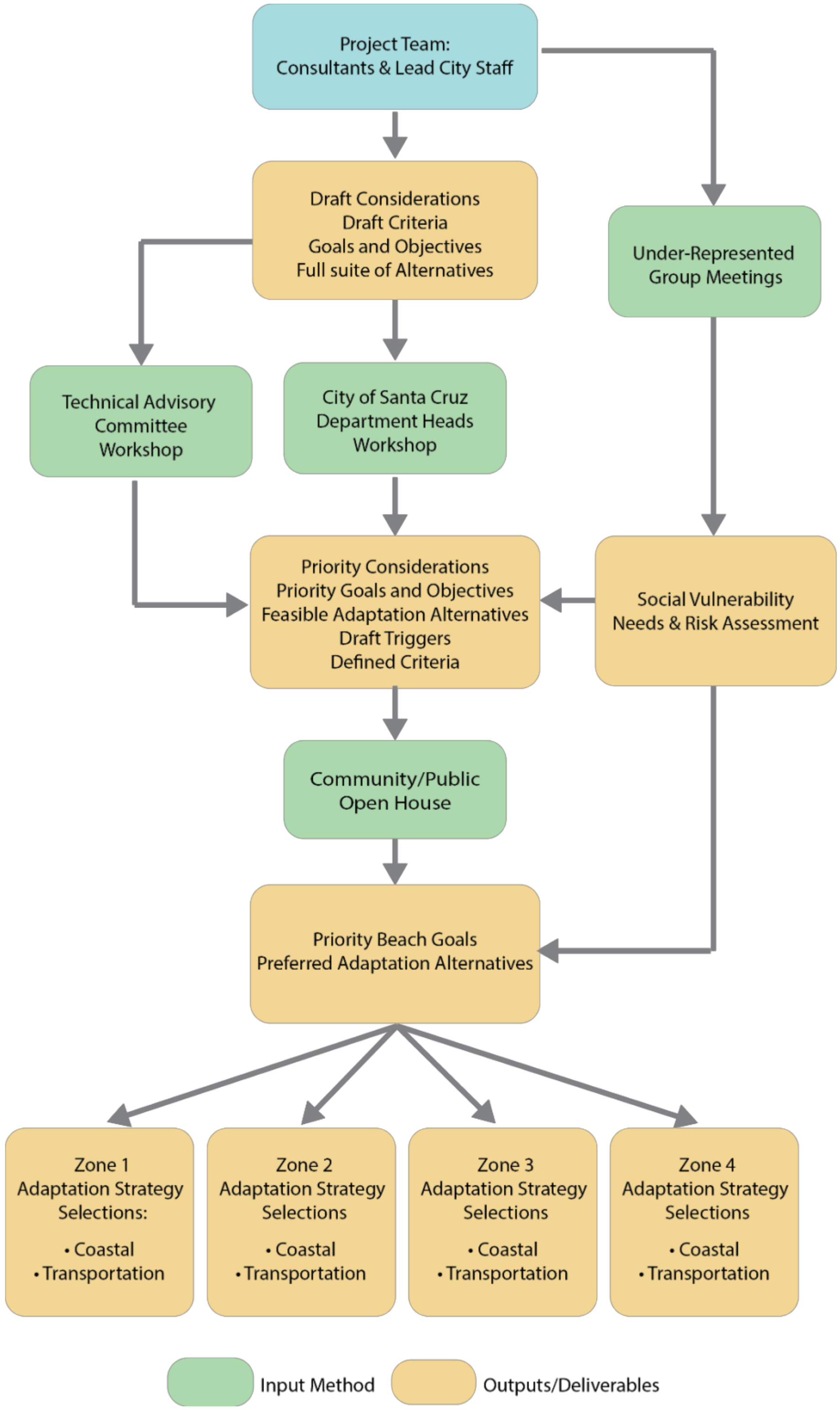


Figure 10-8. Approach to stakeholder and public engagement for the West Cliff Drive Adaptation and Management Plan.

10.4.3 TAC and City Department Head Workshops

In late January and early February, the Project Team, in collaboration with the Santa Cruz Resilient Coast Initiative, held workshops for the Technical Advisory Committee (TAC) as well as City of Santa Cruz

Department Heads. During these workshops, attendees broke into groups to discuss sea level rise related hazard issues at each West Cliff Drive and Beach site to focus on potential short and long term adaptation strategies to address the coastal erosion and sea level rise issues. The workshops were followed up with a survey intended to clarify and define workshop attendee's top choice of beach management goals, considerations for selecting strategies, and selection of preferable adaptation strategies for each West Cliff Drive Zone for short and long term preferred approaches. Twenty-three responses were collected from the follow-up survey. Results are found in the pie charts in for each of the individual West Cliff Drive segment sections below in Section 10.4.5.

10.4.3.1 Community Open House Workshop

Outputs from the TAC and Department Head Workshops were synthesized along with other useful information about each feasible adaptation strategy by beach site and used as a resource for the community to provide input on during a community open house workshop on March 5, 2020. Tables of this information were compiled and analyzed and used to prioritize adaptation strategies in future work tasks which are described in Section 10.6. Over 100 people attended the open and house and provided input on preferred adaptation strategies in the short and long term. Results of preferred adaptation strategies are shown in bar graphs in the individual beach segment sections below.

10.4.3.2 West Cliff Drive Planning Objectives

Overarching goal: Recognize the need to prioritize coastal-dependent resources and equitably balance competing resource needs over changing long-term conditions.

Sense of place and cultural identity

- Continue to honor and uphold the unique places along West Cliff Drive where people may live, play, worship, and work
- Retain (in place or relocate), or enhance key local features that contribute to the historical and contemporary cultural identity of West Cliff Drive (surfing, coastal resources, Lighthouse and museum, sculptures, memorial benches, and scenic views)
- Increase education and awareness of coastal change (sea level rise and erosion) and its potential community impacts to local ecosystems, recreation, transportation and infrastructure

Recreation and access

- Maintain or enhance public access so as to distribute access to ocean, beaches, and along cliff top to promote use across the entire West Cliff Drive corridor
- Maintain or enhance public access so as to distribute access to ocean, beaches and along cliff top to promote visitation across the entire West Cliff Drive corridor
- Prioritize lateral access along West Cliff Drive cliff tops and in the Main Beach area so that all groups of people have access to recreation opportunities
- Maximize access, especially for most vulnerable populations
- Mitigate the need for emergency repairs by adopting a plan allowing necessary maintenance and upkeep of City facilities
- Maintain and enhance emergency access for marine rescue operations
- Monitor coastal access infrastructure and beach width long term and in response to extreme storm events; monitor how coastal change is impacting coastal use

- Maintain/protect pocket beach width where feasible
- Maximize beaches for as long possible

Transportation

- Improve transportation safety, aiming to resolve multi-modal transportation conflicts, especially for underrepresented populations within the community (e.g., elderly, disabled, linguistically isolated)
- Prioritize lateral access along West Cliff Drive cliff tops and in the Main Beach area so that all groups of people have access to recreation opportunities
- Maximize access, especially for most vulnerable populations
- Mitigate the need for emergency repairs by adopting a plan allowing necessary maintenance and upkeep of City facilities
- Maintain and enhance emergency access for marine rescue operations
- Monitor coastal access infrastructure and beach width long term and in response to extreme storm events; monitor how coastal change is impacting coastal use
- Maintain/protect pocket beach width where feasible
- Maximize beaches for as long possible
- Maintain first responder access to coastline, beaches, and residences
- Maintain and improve the corridor for active transportation modes (e.g. walking, cycling)

Ecosystems and habitats

- Maintain and enhance biological and species diversity, water quality, minimize coastal habitat loss and maintain ecosystem connectivity
- Reduce erosion by managing sediments, recreational uses, amenities, and stormwater systems
- Maintain and enhance biological and species diversity, water quality, minimize coastal habitat loss and maintain ecosystem connectivity
- Minimize coastal armoring, prioritize living shoreline adaptations, and reduce beach area loss from placement footprint of shoreline protection structures.

Based on the TAC and City department head feedback, the top ranking West Cliff Drive resource and management goals are (Figure 10-9):

- Increase education and awareness of coastal change (sea level rise and erosion) and its potential community impacts to local ecosystems, recreation, transportation and infrastructure (13 votes, 59.1 percent)
- Monitor coastal access infrastructure and beach width long term and in response to extreme storm events; monitor how coastal change is impacting coastal use (9 votes, 40.9 percent)
- Minimize coastal armoring, prioritize living shoreline adaptations, and reduce beach area loss from placement footprint of shoreline protection structures (8 votes, 36.4 percent)
- Provide increased multi-modal options to increase coastal access, if parking and automobile access changes (7 votes, 31.8 percent)

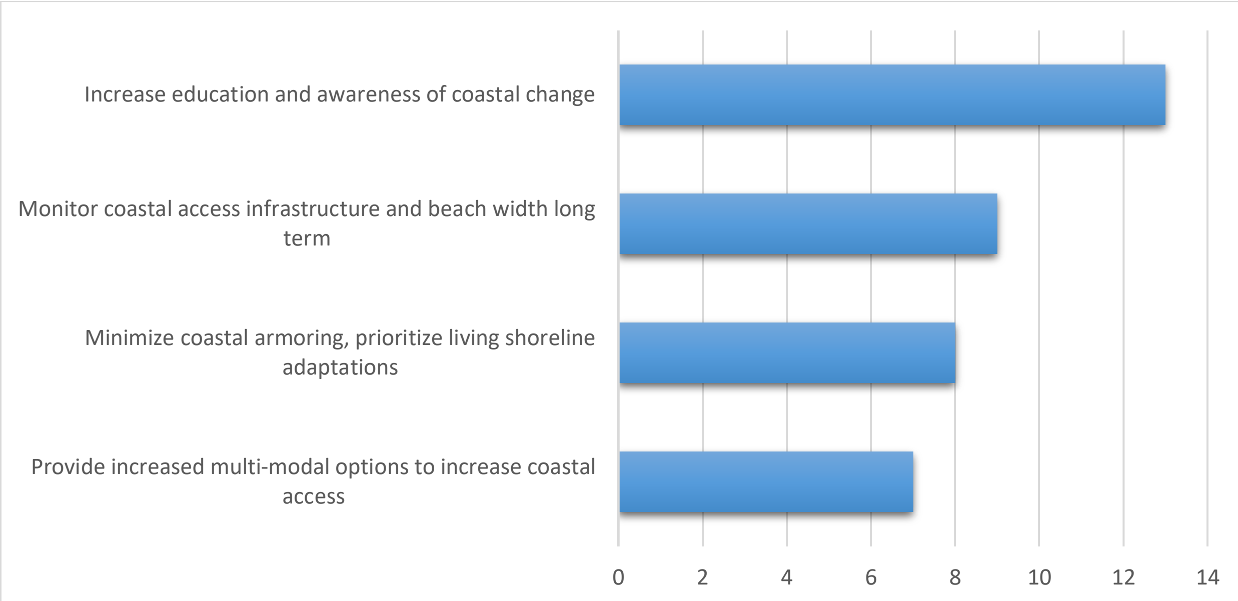


Figure 10-9. TAC and City Department head priorities for West Cliff Drive management goals.

10.4.4 Coastal Adaptation Criteria

Using community and City priorities, State guidance, and professional judgment and experience informed by community engagement, a set of criteria was developed to help prioritize the wide variety of potential adaptation strategies for short and long term adaptation approaches. The prioritized criteria and preferred short and long term adaptation approach was identified for each zone to address future coastal erosion hazards. These criteria help compare and contrast all of the strategies and synthesize the overall evaluation of adaptation alternatives. The criteria include the following:

- **Adaptation Category**—Protect, Accommodate, Retreat
- **Adaptation Tier**—does it stop erosion (1st), reduce erosion (2nd), or mitigate secondary impacts (3rd)
- **Adaptive Capacity**—ability of strategy to naturally respond to sea level rise, reduce erosion, maintain coastal resources, and minimize secondary impacts (High = adapt naturally, Medium = low cost with minor alterations, Low = substantial cost and engineering)
- **Lifespan**—relative lifespan of the strategy in general Short is <10 years, Medium is up to 30 years, and Long is 30+ years
- **Maladaptation**—Not adaptable to future conditions and/or results in potentially higher future risk
- **Construction Cost**—relative construction cost ($$$ = high, $$ = medium, $ low)
- **Maintenance Cost**—relative cost over the lifespan of the project
- **Certainty of Success**—certainty that strategy will function as intended for prescribed life span
- **Secondary Impacts**—(+ positive improvement, = no change, - negative changes)
    - Beaches or coastal recreation (such as surfing, sunbathing, or skimboarding)
    - Recreational Trail impacts
    - West Cliff Drive vehicles
    - Safety and Public Access

- Aesthetics
- Ecology

- **Underrepresented**—does strategy disproportionately affect specific underrepresented groups/ or change the level of service
- ***Legal Risk*** [1]—potential to result in a private property takings claim against the City
- ***Regulatory Viability*** [2]—permittable under existing regulations

The TAC and City department heads ranked the evaluation criteria as follows (Figure 10-10).

- Financially Feasible/Reasonable (costs and benefits, construction, maintenance, funding potential, etc.) (15 votes, 68.2 percent)
- Consistent with coastal resource and management goals (14 votes, 63.6 percent)
- Effective strategy over time/SLR elevation (13 votes, 59.1 percent)
- Balances Public and Private Benefits (11 votes, 50 percent)
- Legal to undertake (9 votes, 40.9 percent)
- Enhances public safety and health (9 votes, 40.9 percent)

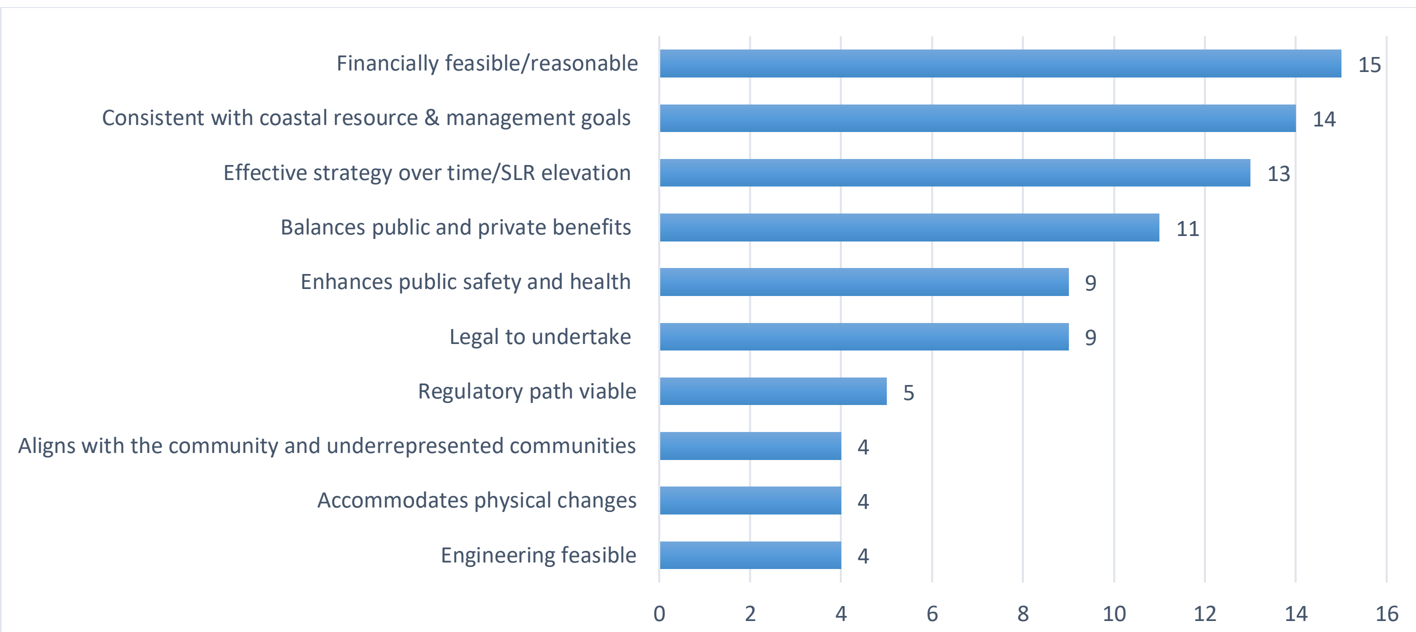


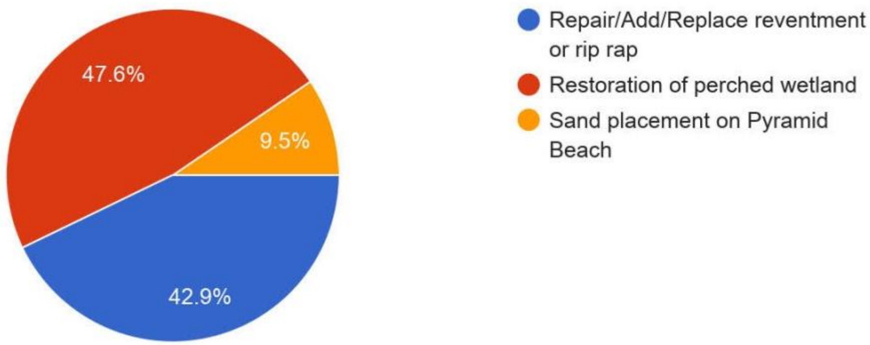
Figure 10-10. TAC and DH Ranked Evaluation Criteria

[2] Initial perspective, team expertise is not in regulatory processes or legal analysis and this interpretation should be vetted with qualified experts that can evaluate the specific facts in each situation to determine the regulatory viability and legal risk.

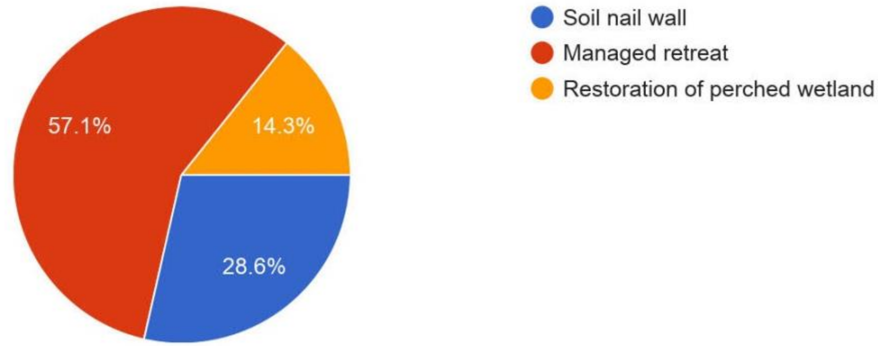
10.4.5 City Leadership and TAC Adaptation Priorities for Short and Long Term

Zone 1:

Short Term

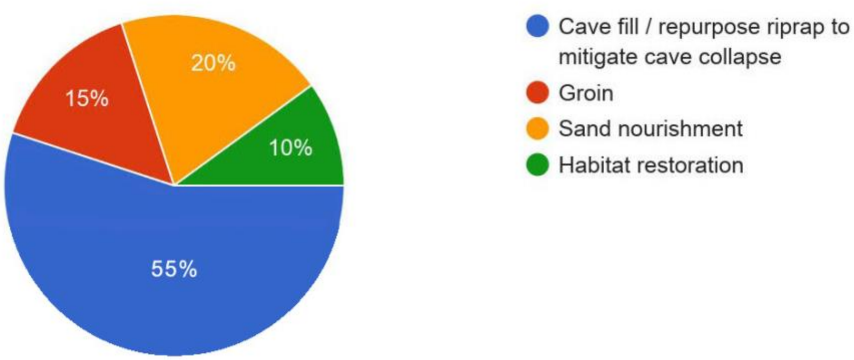


Long Term

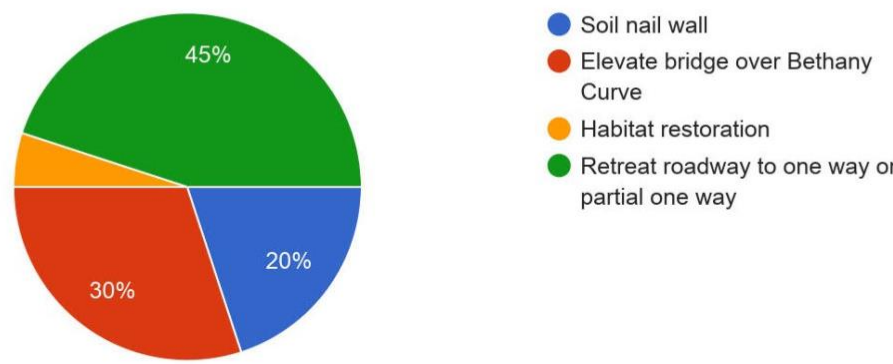


Zone 2:

Short Term

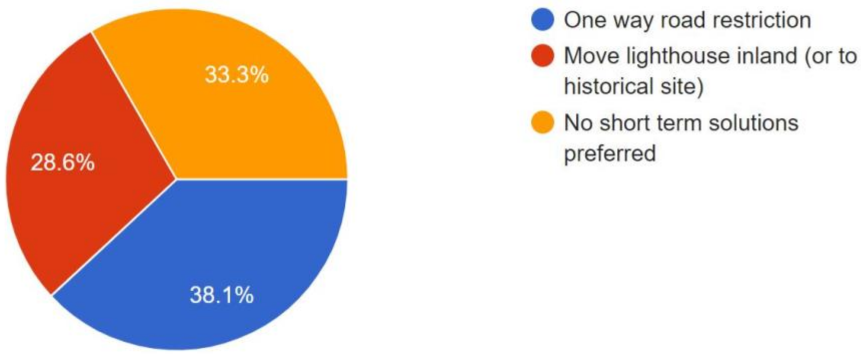


Long Term

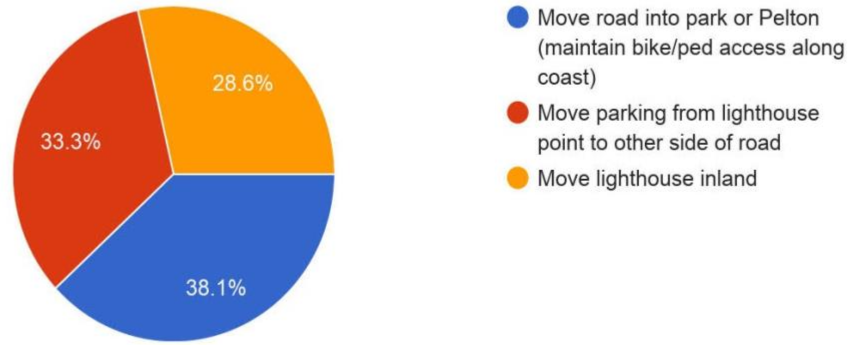


Zone 3:

Short Term

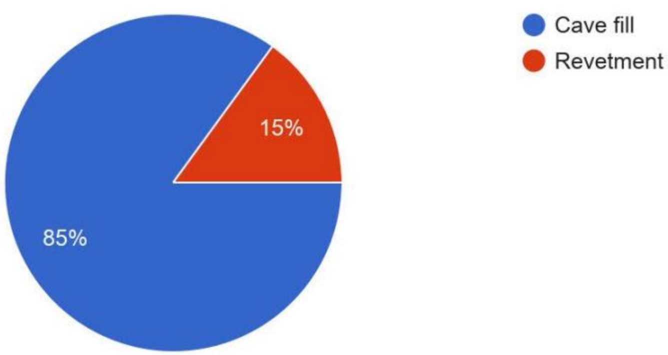


Long Term

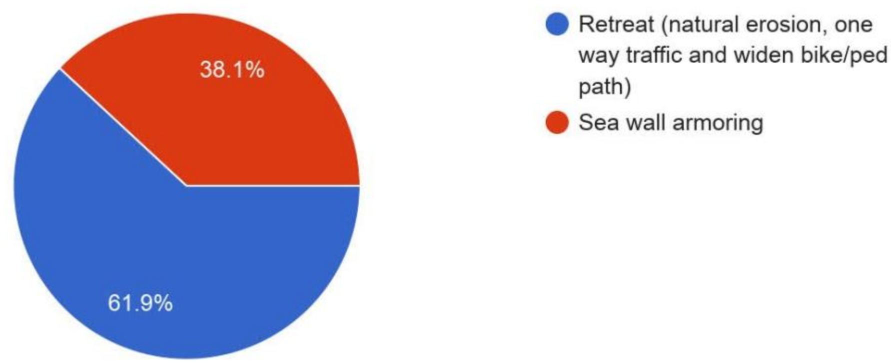


Zone 4:

Short Term



Long Term



10.4.6 Transportation Adaptation Alternatives Analysis

Through the evaluation of existing conditions, much of the transportation infrastructure was evaluated for its vulnerability. Transportation alignment is dependent upon the underlying geology and risks of erosion and sea level rise, thus making the transportation adaptation alternatives reliant upon the coastal adaptation strategies which may reduce, stop or allow erosion. Large erosion events may have dramatic and lasting effects on transportation infrastructure. Transportation alternatives are dependent on the width of West Cliff Drive and recreational ROW, and the additional public space from the Recreational Trail to the edge of the eroding cliff. Evaluating the approximate existing ROW widths for use in alternative development along West Cliff Drive and risk posed by potential short-term failures or current state of coastal armoring and identified areas of erosion concern such as sea cave collapse can assist in identifying short-term priority areas and long-term strategies for transportation focused adaptation measures.

The status quo along West Cliff Drive is a two-way shared variable-width roadway with a Class III bikeway and areas of on-street vehicular parking as well as 17 parking areas throughout the corridor. A Class III bikeway is a shared ROW between bicyclists and motorized vehicles and can sometimes be identified with signage and optional shared lane markings. At present, these additional optional features are not present along West Cliff Drive. Class III bikeways are typically on streets with a speed limit of 25 mph or less and have lower traffic volumes (<3,000 Average Daily Traffic [ADT]). This provides a more conducive environment for less experienced bicyclists to become comfortable with mixed traffic.

The Recreational Trail is a Class I transportation facility separated from the roadway. However, the Recreational Trail is currently compromised, narrowed by erosion in several locations, and overgrown vegetation covering the path along many segments. The Caltrans Highway Design Manual (Topic 1003 – Bikeway Design Criteria) specifies a minimum of 8 feet wide is required and 10 feet wide recommended for a Class I facility. In addition, the Class I facility should have a minimum 2-foot wide shoulder, and if high bicycle and pedestrian volumes are expected the path should be 12 feet wide or more. Class I facilities are also known as Separated [from roadway] Multi-Use transportation facilities, which are paved for use by bicyclists (including ebikes), pedestrians, and other non-motorized modes of transportation. They are separated from auto traffic to increase user safety and to optimize the comfort and safety of users. Presently, vegetation encroachment on the Recreational Trail has further reduced the usable surface area in some sections. If the City choses to do nothing, then there will be erosion and ultimately the loss of the Recreational Trail over time. This option however would be a community tragedy and is not the objective of the management plan as maintaining access to the coastal resources has been clearly stated as a high priority by all stakeholders.

Outreach associated with the West Cliff Drive Adaptation and Management Plan has clearly identified that improving and maintaining the Recreational Trail, even if a lane of vehicular traffic is lost, is a community priority, although there is a substantial minority which doesn't want anything to change. Thus, adaptation of the transportation corridor must either utilize existing public ROW space or acquire more land.

Traffic safety standards require certain widths of roads, sidewalks, and parking. An understanding of the minimum standards is important in evaluating the current alignments and the various transportation configurations and adaptation options along the West Cliff Drive corridor. Limited facility design options will be drafted in the conceptual alternative analysis. However, for final design and engineering of the selected alternative survey grade measurements of the existing public ROW could ultimately preclude certain transportation alignments.

Figure 10-11 provides a typical cross-sectional view of the current West Cliff Drive alignment highlighting that West Cliff Drive is a Class III bike route and the Recreational Trail is a Class I bike facility. Figure 10-12 provides a generic example with Caltrans recommended widths of a Class I facility similar to the Recreational Trail.

When evaluating which types of transportation alternatives are most appropriate by zone, it is best to consider how each zone connects to create a holistic corridor. A holistic corridor refers to the mindful approach of planning for all modes of transport. Ideally, West Cliff Drive would be a holistic corridor; however, there are existing and projected erosion risks and space limitations in some zones which present different challenges for conceptual analysis and design.

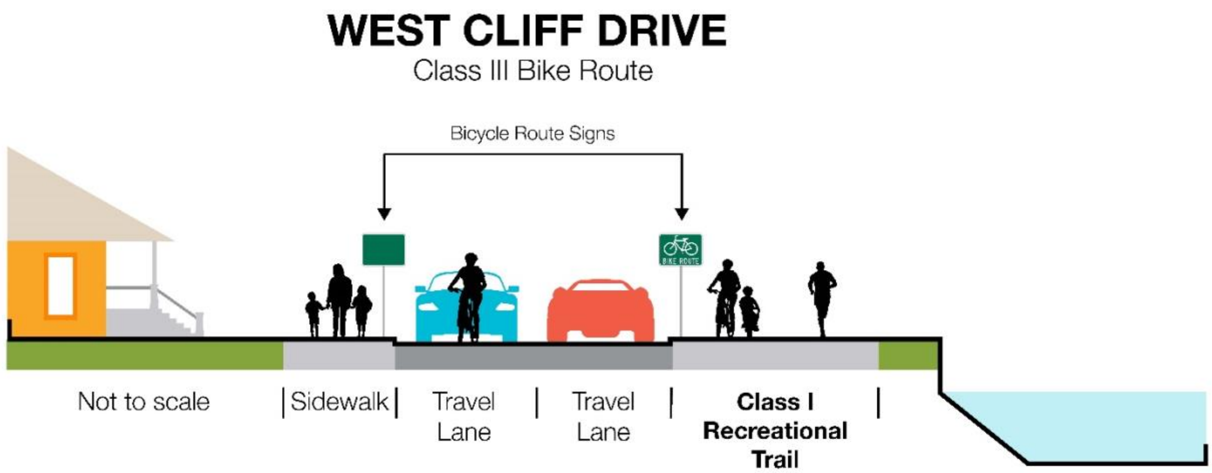


Figure 10-11. Typical cross section for West Cliff Drive

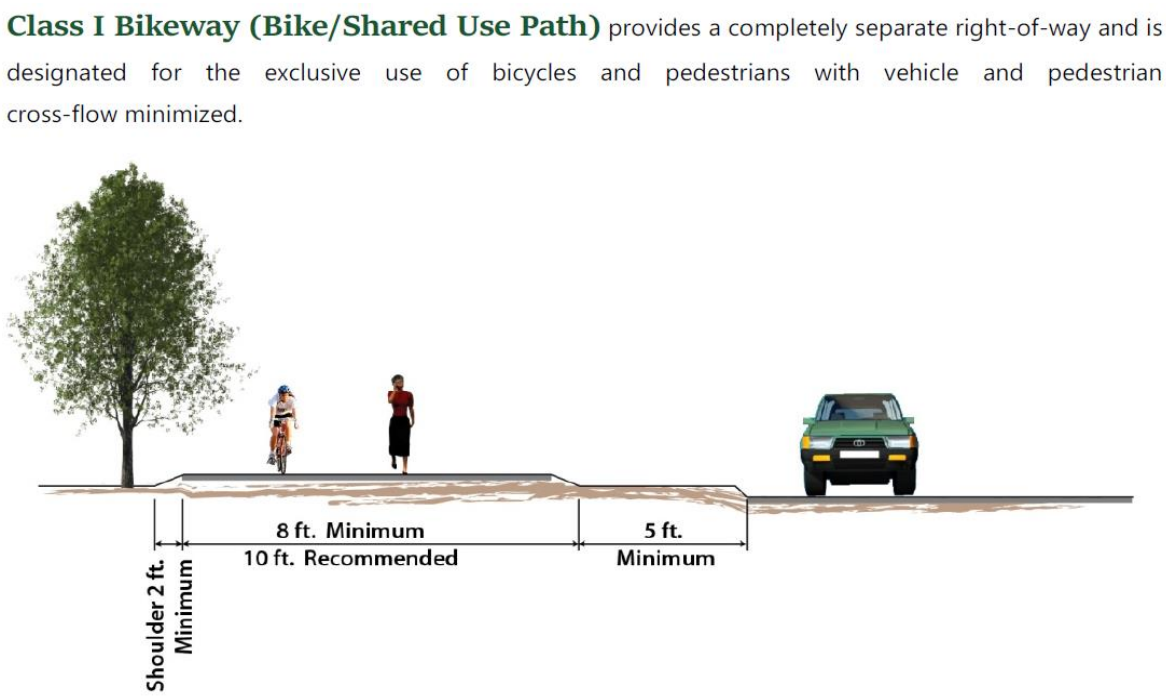


Figure 10-12. Recommended widths for the Recreational Trail.

Alternatives to improving the existing alignment are limited, largely due to the spatial limitations in the existing ROW. As erosion continues, the public ROW space for the transportation corridor will decrease from erosion without additional land, which may require changes in public space allocated to vehicular traffic patterns and the Recreational Trail. Of the seven transportation adaptation approaches identified for analysis in the Caltrans contract (listed in Section 10.2), City, TAC and community feedback helped to focus the future short-term and long-term transportation adaptation alternatives on the following:

- Maintaining two-way traffic
- Changing to one-way traffic with a redesigned Recreational Trail to reduce conflicts and improve coastal access
- Redirecting traffic while maintaining the Recreational Trail.

The following alternatives were not selected as viable transportation adaptation alternatives to analyze in conceptual design largely based on impact to the community and contradiction to the project objectives. In addition, they were not prioritized by members of the community, the TAC, or City leadership. The alternatives not chosen are described below with rationale provided.

- Partial one-way alternative, where car lane converts to two-way bicycle facility for portions of the corridor.
- Full closure to automobiles
- Partial closure to automobiles
- Other, (i.e. reroute traffic).

Maintaining contiguous traffic flow and consistent multimodal access creates a level of comfort for all users. For this reason, a Partial one-way alternative should not be selected as an alternative to consider for conceptual analysis. Because this corridor is heavily used by locals gazing distractedly at the ocean and tourists who are easily confused with changes in traffic patterns, a consistent traffic flow with applicable signage and wayfinding is required.

Full lane closures to automobiles at this time would eliminate coastal access for many people and create the need for a secure method of coastal and residential access particularly those residing in Zone 1 and 2 along West Cliff Drive. Depending on the chosen coastal adaptation strategies, significant erosion could cause partial closures and the need to identify alternate routes over longer time periods. However, at this time the community priority is to maintain some vehicular access, address some of the user conflicts along the corridor, and maintain or improve the Recreational Trail.

10.4.7 Transportation Network Comparison Criteria

Acknowledging that the coastal adaptation strategies to address coastal erosion will largely affect the ROW space available for transportation adaptation alternatives specific criteria to evaluate the transportation network was identified based on data considered during the existing conditions inventory and vulnerability assessment. The application of the transportation criteria will help to prioritize transportation approaches and allow the analysis to focus on the conceptual alternatives, and help to identify a least environmentally damaging alternative. Using a qualitative analysis to select the 3 alternatives for a conceptual analysis as in Table 10-2. Due to the reliance upon the underlying geology and future decisions to address coastal erosion specific criteria such as survey grade ROW measurements are reserved for final design of selected solutions prior to implementation. Some criteria from the coastal adaptation criteria are also applicable and summarized in the alternatives evaluation in Section 10.5.5.

- **Width of the Roadway**—Curb to curb distance approximated from available data
- **Width of the Recreational Trail**—Approximated from available data
  - Inland Sidewalk and Crosswalk to Recreational Trail
- **Parking**
  - **On-Street**—Parking on West Cliff Drive and first block inland on perpendicular streets
  - **Parking Lot**— Parking in City and State Park lots
- **Accessibility**
  - **Maintaining lateral and vertical access to coastal access points**
  - **Trail or Sidewalk widths applicable to ADA standards**—Do corridor widths comply with ADA?
  - **Curb Cuts and ramps at intersections**—Do curb cuts and ramps comply with ADA?
- **Lane Direction**—Direction of vehicular travel
- **Traffic Volumes**—Multimodal Traffic volume data collected
  - Auto
  - Bicycle
  - Pedestrian
- **First responder emergency access**—Are the required distances in compliance for future designs?
- **Safety of users**—Creating safe corridors for conceptual alternatives
  - Reduction of multimodal user conflicts
  - Roadway safety treatments, e.g. speed humps, signage, one way

Table 10-2. Transportation Adaptation Alternative Criteria

Alternative	Width of Roadway	Width of Recreational Trail	Inland Sidewalk	Certainty (on WCD)		Safety / Public Access	Parking		Underrepresented	Secondary Impacts		
Clarification				*Near Term*	*Long Term*		*Lots*	*On-street*	*Disproportionately affect or provide amenities for ADA, Low Income Communities, etc.*	*Beaches and Coastal Recreation Access*	*Recreation Trail*	*West Cliff Dr*
Criteria	*Minimum Width**	*Minimum width*^*	*Exists, Needs Crosswalk to Recreational Trail*	*Low, Medium, High*	*Low, Medium, High*	**+,-,=**	**+,-,=**	**+,-,=**	**+,-,=**	**+,-,=**	**+,-,=**	**+,-,=**
One-way alternative, where one car travel lane converts to two-way protected bicycle facility	**25'**	**8'**	Needs Crosswalk	High	High	**=**	**=**	**-**	**+**	**=**	**+**	**-**
Status quo	**25'**	**8'**	Needs Crosswalk	Medium-High	Low	**=**	**=**	**=**	**=**	**=**	**=**	**=**
Partial relocation of various transportation infrastructure	**25'**	**8'**	Needs Crosswalk	Medium	Medium	**-**	**-**	**-**	**-**	**-**	**+**	**-**
Full closure to automobiles	**-**	**8'**		Low to Medium	Low	**-**	**-**	**-**	**-**	**-**	**+**	**-**
Partial closure to automobiles	**-**	**8'**	Needs Crosswalk	Low to Medium	Low	**-**	**-**	**-**	**-**	**-**	**+**	**-**
Partial one-way alternative, where car travel lane converts to two-way protected bicycle facility	**25'**	**8'**	Needs Crosswalk	Medium - High	Medium	**=**	**=**	**-**	**+**	**=**	**+**	**-**
Other, (i.e. reroute traffic)	**-**	**8'**	Needs Crosswalk	-	-							

* Minimum Width is approximate as detailed engineering design should provide precise measurements
^ Recreational Trail Width should also include a 5' buffer with the roadway and a 2' shoulder on the cliffside
Upfront Cost is the relative construction cost ($$$ = high, $$ = medium, $ Low)
Maintenance Cost is the relative cost associated with the lifespan of the project
Plus (+) refers to improved access from existing conditions
Minus (-) refers to a loss of access from existing conditions
Equal (=) refers to a similar to existing condition

10.5 Potentially Feasible Coastal Adaptation Projects for West Cliff Drive

Using results from outreach efforts with the City and the TAC input, the comparison criteria, as well as the Team's experience in erosion control and adaptation, a subset of adaptation strategies was identified for incorporation into more detailed analysis in future sections of the report (i.e., the next project deliverable). These approaches are described in detail in this section with specific prioritized approaches for detailed analysis by zone in Section 10.6.

10.5.1 Protection Strategies

10.5.1.1 Revetments

Figure 10-13. Revetment along West Cliff Drive near David Way in Zone 2.

Description

Revetments are engineered structures made with riprap or large rock boulders. These structures are the most common defense structure along West Cliff Drive and are often found at the foot of cliffs or in front of existing vertical seawalls. These structures are designed to protect and stabilize areas vulnerable to erosion by absorbing and dissipating wave energy and minimizing wave runup. An engineered revetment typically has layers: a filter layer and base rock, followed by the biggest armor stone and then surface armor rocks placed in an interlocking pattern. Not all revetments however are engineered, as during emergency situations with an emergency permit, rocks have been simply dumped over the cliff with little engineering. These structures in particular have largely failed or are likely to in the short term and must be addressed.

Revetments require a wide footprint area, which can cover large areas of sandy beach and intertidal habitat. Most revetments are designed to be built at a 1:1.5 or 1:2 height to width ratio and thus a 30 foot high revetment can occupy a 45–60 footprint at its base. Some of the revetments however, built and permitted in the 1990s, were constructed at 1:3 or 1:4 height to width ratio which has a much more extensive footprint. This is especially problematic in the winter season or post El Niño years, when beach widths are naturally reduced in width.

Lifespan and Failure Mechanisms

The expected lifespan of these structures is about 20 years, a bit less than seawalls or soil nail walls, but is highly dependent on storm frequency, and the compounding effects of rising sea level, tides, and wave conditions. Riprap has several mechanisms for failure. One is a tendency to fail whereby "fugitive" rocks are liberated from their placement locations and fall to the foot of the structure. These fugitive rocks can then be mobilized during coastal storm events and loosen other rocks and create direct erosion. Fugitive rocks also pose a regulatory concern as they may fall into State lands or Federal waters. Riprap is vulnerable to wave overtopping, whereby the sloping structure acts more like a wave ramp, leading to erosion at the top of the revetment and the soil behind. In addition, as riprap is a semi-porous material, erosion of the underlying filter layer may occur, liberating underlying soil and causing settling and development of sinkholes behind the structure. Like seawalls, riprap can also experience flanking and scouring, this scouring can undermine the toe of the structure leading to settling and even collapse. While riprap is less expensive than other coastal armoring strategies such as seawalls and soil nail walls, it requires more constant maintenance to maintain adequate protection. Revetments may need to be supplemented with additional rock after large wave events. One outcome of the West Cliff Drive Adaptation and Management Plan in the short term could be an approved maintenance program of existing revetments that would reduce some of the costs, which historically have been done under emergency conditions at additional expense once the revetment has been compromised.

Adaptability and Certainty of Success
Riprap has a limited capacity to adapt to changing conditions but can be elevated and extended by adding new material to provide extended functionality. Sourcing additional material can also be problematic, as large boulders of adequate size and geology are not readily available in the local area, with some coming as far away as the Sierra Nevada. Thus, there are high transportation (and GHG emission) costs contributing to high construction and maintenance costs. In the future, with higher sea levels creating more exposure of the revetments to wave energy, repairs or new revetments will require larger armor stone.

Certainty of success in the short-term is highly dependent on the foundation on which the structure sits, as well as the size, slope, internal structure, and method of construction. Over the long term, the certainty of success diminishes over time, and revetments can be considered a maladaptive strategy as their construction can cause placement loss of the beach, increased passive erosion, have negative impacts to native habitat but provide habitat for invasive species, impair lateral coastal access, provide a false sense of security, incur high maintenance costs to maintain functionality, andencourage development in high hazard locations. Riprap is also difficult to remove once it is placed. These difficulties make it challenging to transition from revetments to another adaptation strategy.

Cost
The cost of initial revetment construction is relatively high and depends on the height, length, and engineering characteristics of the rock (e.g., rock size, volume of the structure). Along West Cliff Drive, most of the beaches are perched onto erosion-resistant bedrock, so settling of the structure is less of a concern. Some additional construction costs may include any in lieu fees that may be required (such as the sand mitigation, beach recreation, or beach ecology fees). Once constructed though, revetments tend to settle and move, so the maintenance costs are moderate and routine maintenance is recommended, particularly following major wave events. Additional lifespan costs to consider include the removal cost. These costs may be rather high depending on the accessibility and size of the rocks as well as environmental conditions at the time of removal. If the revetment needs to be augmented or retrofitted, then the cost is moderate and largely depends on the source and quantity of rock.

Secondary Consequences
Revetments tend to have substantial secondary consequences as described in Section 10.3.4. The placement loss or impacts from the footprint of the revetment on the beach can be extensive and several pocket beaches along West Cliff Drive have already been buried. Additional design considerations could improve vertical access.

Regulatory/Legal
Revetments are viable from an existing regulatory perspective, although the Coastal Commission typically frowns on the use of revetments except under emergency situations, or as part of a comprehensive management approach due to the substantial secondary consequences. In the future, the California State Lands Commission (CSLC) may also have regulatory authority over repairs and new armoring structures if the structures extend onto Public Trust

Lands (MHW). Revetments have already been applied widely and could potentially expand within all four West Cliff Drive Zones.

10.5.1.2 Seawalls

Description

Seawalls refer to a variety of typically vertical coastal armoring structures designed to stop erosion. At the base of the cliff, seawalls are designed to reflect and/or dissipate wave energy from the cliff, and along the bluff top, seawalls are designed to limit soil erosion from wave runup and splash. Along the open coast, seawalls are typically constructed using thick concrete blocks or poured concrete and are occasionally made from sheet piles or wood. Along West Cliff, some examples include bluff top sandbag walls and the bluff top seawall near the Lighthouse (Figure 10-14). Recurved seawalls have a lip, which helps to change the reflected wave energy dynamics and promote sand accumulation to maintain a recreational beach (Figure 10-15). A summary comparison of the coastal adaptation criteria described in Section 10.4.4 is shown in Table 10-2.

Figure 10-14. Upper bluff stabilization seawall at Lighthouse.

Figure 10-15. Recurved seawall in San Francisco designed to reduce wave reflection and support sand accumulation.

Lifespan and Failure Mechanisms

Seawalls are typically constructed with an expected lifespan of approximately 30 years; however, expected lifespan may vary depending on the specific locations, frequency of wave exposure, quality of construction, and whether the seawall undergoes regular monitoring, maintenance, and repairs to preserve their effectiveness. In the near-term, seawalls typically have a very high certainty of success; however, over time, the certainty of success diminishes as the frequency and duration of wave attack on the structure gradually accumulates.

Seawalls, like revetments, can experience active erosion impacts such as increased erosion at the end of the structure and scouring. This scouring can undermine the toe of the structure leading to settling and even collapse. Over time, the concrete and reinforcing rebar can corrode and lead to cracking and decay of the structure. Seawalls can also fail from the inland direction as well, by trapping water on their landward side leading to soil loss and deteriorating the support or foundation of the wall. Similarly, wave overtopping can lead to water buildup landward of the wall leading to the same water trapping issues.

Adaptability and Certainty of Success

Seawalls have a low adaptive capacity, with little ability to adapt to naturally changing conditions; however, with additional engineering and substantial cost, these structures can often be elevated or improved to provide extended lifespan functionality. Initial design and engineering of a more substantive footing and base of the structure may facilitate future refinements in crest elevation. Seawalls can be considered maladaptive as they are rigid, encourage continued use and development in hazardous erosion areas, and may create more catastrophic consequences when they fail.

Cost

The cost of initial seawall construction is relatively high and depends on the height, length, and specifics of the engineering of the structure. Some additional construction costs may include any in-lieu fees that may be required (such as the sand mitigation, beach recreation, or beach ecology fees). Once constructed though, seawalls tend not to require a lot of maintenance, so the maintenance costs are relatively low until the back half of the lifespan. Removal costs must be considered at the end of the sea wall lifespan. Given the low adaptive capacity, it is likely that the structure would have to be removed or substantially retrofitted in the future. These costs may be moderate to high depending on the access and conditions at the time of removal. If the seawall is to be retrofitted, then it may reduce some long-term costs to over-build the base of the structure to accommodate an increase in seawall elevation in the future.

Secondary Consequences

In addition, seawalls tend to have substantial secondary consequences. The placement loss or impacts from the footprint of the structure on the beach is less than that of a revetment, so a change from existing revetments to a seawall could be considered a positive for beach recreation. However, provisions for including vertical access into the seawall must be considered. Additional design considerations could be to integrate a bench or terrace into the structure that may support lateral access. Small pockets in the face could also provide some ecological benefits to roosting or nesting. This and other design factors such as a recurved aspect could be designed to help offset some of the secondary impacts.

Regulatory/Legal

In general, seawalls are viable from an existing regulatory perspective, although the Coastal Commission typically frowns on new coastal armoring, except under either emergency situations or as part of a more comprehensive management approach. Since any seawalls would be solely focused on reducing erosion and vulnerabilities to public property and ROWs, there is a minimal chance of any legal takings claims.

Seawalls could be potentially applied to all of the four West Cliff Drive Zones.

10.5.1.3 Soil Nail Tie-back Walls

Description

Soil nail tie-back walls are a type of coastal armoring protection constructed with an outer layer of sprayed concrete (Shotcrete or Gunite) and derive their structural strength from soil nails and tie-backs that are drilled into the cliff and used to bind the structure to the cliff behind. The sprayed concrete allows natural cliff forms to be maintained. These structures are designed to stop erosion and provide bluff stabilization. They can be more expensive to construct than riprap but have a much smaller horizontal footprint and can be designed with natural elements to improve access, enhance ecology, and reduce aesthetic concerns. A local example of a soil nail tie back wall is found along East Cliff Drive in Pleasure Point, Santa Cruz (Figure 10-16). A summary of coastal adaptation criteria described in Section 10.4.4 is shown in Table 10-2 (p. 10-33).

Some of the aesthetic concerns with seawalls and revetments can be mitigated for soil nail tie-back walls. Techniques can be used to mimic the color and texture of the surrounding natural cliffs, allowing the structures to blend into their surroundings. The Pleasure Point wall has significantly increased beach access with staircases as well as street end goat trails while additionally enhancing low tide intertidal beach recreation by removing failed revetments.

Figure 10-16. East Cliff Soil Nail Tie-Back Wall with Stairs for Coastal Access. Source: Surfrider Foundation.

Lifespan and Failure Mechanisms
Soil nail tie back walls are typically constructed with an expected lifespan of approximately 30 years; however, expected lifespan may vary depending on the specific locations, frequency of wave exposure, quality of construction, management of water behind the wall, and whether the wall undergoes regular monitoring, maintenance, and repairs to maintain its effectiveness. In the near-term, soil nail walls typically have a very high certainty of success; however, over time the certainty of success diminishes as the frequency and duration of wave attack on the structure gradually increases over time.

Soil nail tie back walls, like seawalls can experience active erosion impacts such as end flanking and scouring. Scouring can undermine the toe of the structure leading to settling and even collapse. Over time, the concrete and reinforcing rebar can corrode and lead to cracking and decay of the structure. Pleasure Point already has some scour of the footing and decay along some of the edges of the structure, both of these could potentially cause failure of the structure without maintenance. These walls can also fail from the inland direction as well, by trapping water on their landward side leading to soil loss, water pressure buildup, and deteriorating the support or foundation of the wall. As a result, adequate drainage is necessary to minimize these issues. Similarly, wave overtopping or misdirected stormwater can lead to water buildup landward of the wall leading to the degradation as well. The summary comparison of coastal adaptation criteria with other adaptation approaches described in Section 10.4.4 is shown in Table 10-2 (p. 10-33).

Adaptability and Certainty of Success
Soil nail tie-back walls have a low adaptive capacity with little ability to adapt naturally to changing conditions. These walls can be considered maladaptive as they are rigid, encourage continued use and development in hazardous erosion areas, and may create more catastrophic consequences when they fail.

Cost
The cost of initial soil nail tie-back wall construction is relatively high and depends on the height, length, quality, and quantity of concrete, aesthetic treatments, and specifics of the engineering of the structure. Some additional construction costs may include any in-lieu fees that may be required (such as the sand mitigation, beach recreation, or beach ecology fees). Once constructed though, these walls tend not to need a lot of maintenance, so the maintenance costs are relatively low until the back half of the lifespan. Additional lifespan costs to consider include the removal cost, given the low adaptive capacity, then it is likely that the structure would have to be removed or substantially retrofitted in the future. These costs may be higher than other protective structures due to the need to remove the tie backs which may further exacerbate future erosion as well as depending on the access and conditions at the time of removal.

Secondary Consequences
In addition, soil nail tie-back walls tend to have substantial secondary consequences. The placement loss or impacts from the footprint of the structure on the beach is less than that of a revetment, so a change from existing revetments to a soil nail wall could be considered a positive for beach recreation. Another benefit of the soil nail wall approach is that additional design considerations can be integrated to improve access, aesthetics, and ecology. In addition, a bench or terrace contoured into the structure may support or improve lateral access. Small pockets in the face could also provide some ecological benefits to roosting, nesting, or vegetation. This and other design factors such as a recurved top could be designed to help offset more of the secondary impacts than other protection approaches.

Regulatory/Legal
In general, soil nail tie-back walls are viable from an existing regulatory perspective, although the Coastal Commission typically frowns on new coastal armoring except under either emergency situations, or as part of a more comprehensive management approach. Because any seawalls would be solely focused on reducing erosion and vulnerabilities to public property and ROWs, there is a minimal chance of any legal takings claims.

Soil nail tie-back walls could be potentially applied to all of the four West Cliff Drive zones with Zone 2 identified by the community as a prioritized location to evaluate for enhanced recreational opportunities such as wider beaches, improved vertical and lateral beach access as well as providing some habitat enhancements.

10.5.1.4 Cave Fills

Description

Along West Cliff Drive, many sea caves have formed in areas of stratigraphic weakness in the cliff as documented in the Existing Conditions report with detail in Appendix 4. The highest risk sea caves with the most extensive depths threaten continuity of the West Cliff Drive corridor and are located near David Way (Figure 10-17), Lighthouse Point, and Cowells Beach.

Figure 10-17. Sea Cave near David Way.

The adaptation strategies addressing potential sea cave failures are highly context-dependent and vary based on cave depth, access, geology, wave exposure, and longevity of solution. Four common approaches to addressing sea cave erosion include grouting of overburden marine terrace deposits, building a revetment or seawall over the entrance of the sea cave to reduce erosion, blocking the entrance of the cave and fill the cave, and building a bridge over the cave. First, short-term solutions include chemically grouting the marine terrace deposits, which can increase the strength of the overlying deposits providing additional time to find a longer-term solution. Second, and most common along West Cliff, the entrance of the cave is blocked, usually by revetments to reduce the rate of erosion in the cave. Third, the sea cave can then be filled, often by sealing the entrance with a bulkhead, cap (Figure 10-18), or boulders and then filling the void behind with a sand/slurry concrete mix. This filling approach uses a sand/slurry mix that typically is unreinforced and more erodible. Finally, the least common and most expensive approach is to construct a bridge over the sea cave. Each approach to addressing sea caves has different construction and maintenance costs as well as life expectancy and secondary impacts. Historically, sea caves along West Cliff Drive have been addressed by either blocking the entrance to reduce erosion or filling the cave.

Figure 10-18. Cave fill near the Sea and Sand Inn above Cowells Beach.

One example of an emergency approach to cave fills recently occurred in La Jolla, California, as part of a two-phased project to address a sea cave in imminent risk of collapse that would undermine a primary coastal road corridor (Figure 10-19). The first phase was to inject an expanding structural polymer into the marine deposits and then to cap the sea cave and fill the void with unreinforced concrete which would be relatively erodible over time.

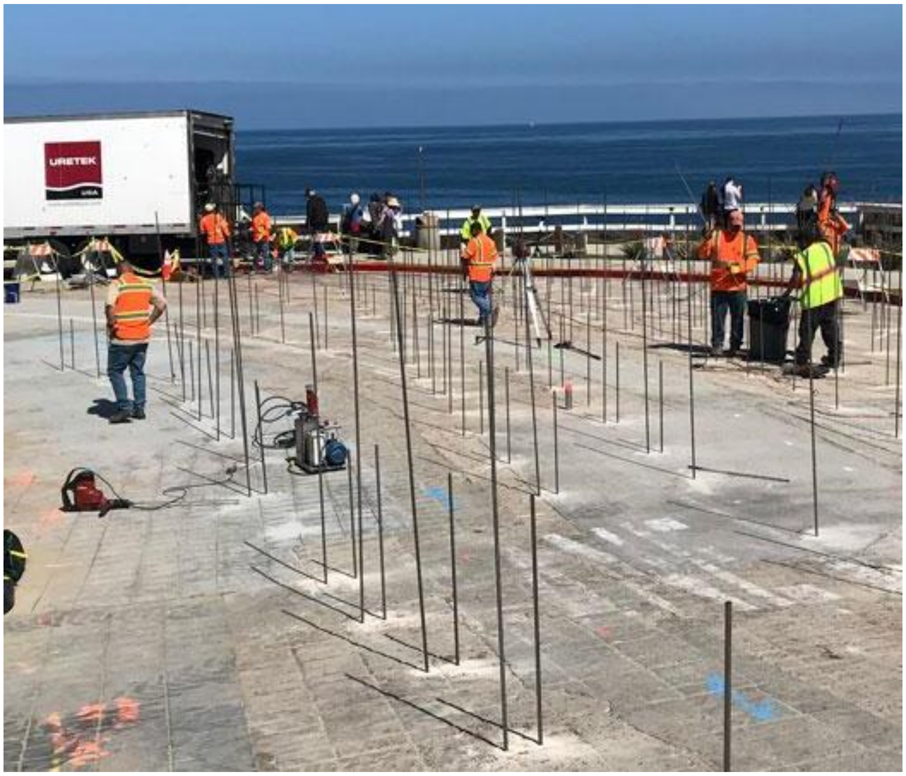


Figure 10-19. Work Crew in La Jolla, CA laying a pattern of grout injection sites into the Cook's Crack Sea Cave beneath Coast Blvd, 2019 (Photo: URETEK).

Lifespan and Failure Mechanisms

Cave fill approaches have varying lifespans ranging from an estimated 10 to 75 years depending on the approach. However, expected lifespans vary depending on the specific locations, frequency of wave exposure, quality of construction, management of stormwater, and whether the fill undergoes regular monitoring, maintenance, and repairs to preserve their effectiveness. In the near term, these approaches typically have a very high certainty of success; however, over time, the certainty of success diminishes as the frequency and duration of wave attack on the structure gradually increases.

Sea cave approaches that rely on armoring at the entrance can experience active erosion impacts and scouring if a cap or seawall is built that reflects wave energy, this can lead to settling or undermining and eventual collapse. Over time, the concrete and reinforcing rebar of the seawall or cap can corrode and lead to cracking and decay of the structure. Cave fills can also fail from the inland direction as well, by trapping water on their landward side, deteriorating the support or foundation of the cap or fronting wall and saturating the fill concrete increasing its erodibility.

Adaptability and Certainty of Success

Cave fill approaches generally have a low adaptive capacity, with little ability to adapt naturally to changing conditions. These approaches can be considered maladaptive as they are rigid, encourage continued use and development in hazardous erosion areas, and may create more catastrophic consequences when they fail.

Cost

Four common approaches to addressing sea cave erosion along with their associated cost[3] (Table 10-3) are:

- Grouting of overburden marine terrace deposits ($250–$300K)
- Building a revetment or seawall over the entrance of the sea cave to reduce erosion ($200K–$500K)
- Blocking the entrance of the cave and fill the cave ($1.5M–$3.5M)
- Building a bridge over the cave ($2M–$3M).

Table 10-3. Comparison of the various sea cave approaches and key criteria

Cave Approaches	Cost		Effectiveness Certainty	Secondary Impacts			Lifespan
	Upfront	*Maintenance*		*Beach, Coastal*	*Rec Trail*	*Road*	
Grouting of overlying bluff deposits	$$	$$	Medium	=	=	=	Short
Armor entrance of cave to reduce erosion	$$	$$	Medium	-	=	=	Medium
Block entrance of cave and fill the cave	$$$+	$	High	-	=	=	Long
Build a bridge over the cave	$$$	$	High	+	+	+	Long

Secondary Consequences

Most cave fill approaches, particularly those that rely on revetments or seawall caps tend to have substantial secondary consequences. The placement loss or coastal recreational impacts occur from the footprint of the structure on the beach. The grout or bridge approach does not have these same coastal recreational impacts.

Regulatory/Legal

All of these sea cave approaches are viable from an existing regulatory perspective, although the Coastal Commission typically frowns on new coastal armoring except under either emergency situations, or as part of a more comprehensive management approach. If the City can identify a preferred management approach to specific sea caves, then there are likely to be fewer regulatory hurdles. Because cave fill approaches along West Cliff are focused on reducing erosion to public property and ROWs, there is a minimal chance of any private property takings claims.

Cave fills could be potentially applied to all of the four West Cliff Drive zones with Zone 2 at the David Way sea cave identified by the community as a prioritized location to evaluate a fill approach to maintain transportation corridor connectivity over the short to medium term, while longer term adaptation strategies are developed.

[3] Cost estimates come from engineering analysis of emergency response to Carlsbad sea cave. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=2ahUKEwj_uKD176roAhUCXM0KHVz-DBoQFjADegQIBhAC&url=https%3A%2F%2Fwww.sandiego.gov%2Fsites%2Fdefault%2Ffiles%2Fk-20-1894-emr-3.pdf&usg=AOvVaw1g4k77TewtcLPTTgG-38DU

10.5.1.5 Sand Retention (Groins)

Description

Sand retention structures are oriented perpendicular to the coast in a cross-shore direction and are designed with the intention of trapping and retaining sediment to widen the beach and allow the beach to reduce wave energy and reduce erosion. Sand retention structures are effective only in areas where there is a dominant sand transport direction, which is fortunate for Santa Cruz as this occurs from west to east into Monterey Bay. The trapping of sand upcoast of the retention structures creates sand "fillets" or wider beaches, which act as protective barriers to wave energy and increase coastal recreational resources. However, obstructing the naturally occurring along shore transport of sediment can deplete downcoast beaches of their sediment supply and shift erosion to those areas.

The most notable example of sand retention is the Santa Cruz Harbor Jetty constructed in 1963. The jetty led to the trapping of a significant volume of sand at Seabright Beach which widened the beach and currently protects the Seabright neighborhood from erosion to some degree (Figure 10-20). The sand retention has also significantly widened the beaches at Seabright, Main, and Cowells with some impacts to the functioning of the San Lorenzo River lagoon, causing minor flooding issues throughout several neighborhoods. Currently, an active dredging program must be conducted at the harbor entrance to maintain the navigational channel and to assist the process of sediment moving downcoast.

Figure 10-20. Santa Cruz Harbor Jetty retaining sand upcoast (to the left) on Seabright State Beach. Source: KSBW, Steven Morgan.

Another local example of sand retention occurs at the Capitola groin, which serves similar sand retention functions and helps to maintain the beach in Capitola Village (Figure 10-21). It is uncertain as to the effect on cliff erosion downcoast of the Capitola jetties along Opal Cliffs, but the beach downcoast there is relatively narrow.

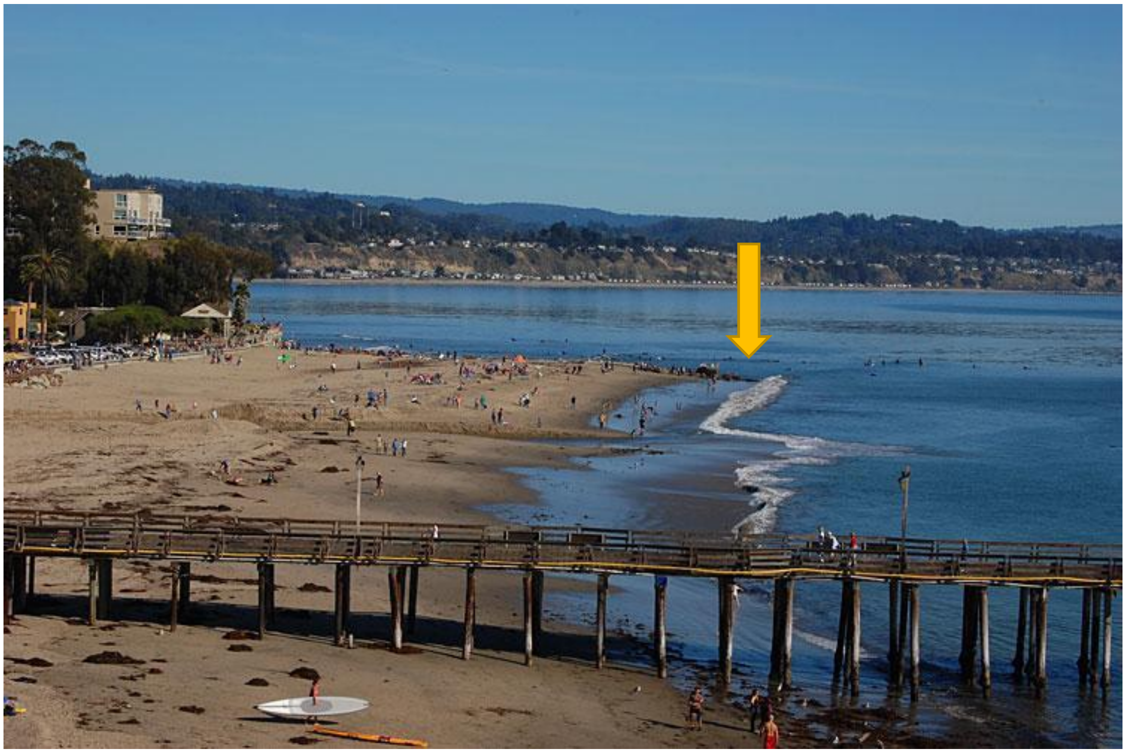


Figure 10-21. Capitola Village groin (in yellow) showing the widened recreational beach that also helps to reduce wave impacts.

Lifespan and Failure Mechanisms
Structurally, a groin must resist wave action, currents and scour effects, impact from debris, and pressures created by the differences in sand elevation both upcoast and downcoast. Expected useful lifespan of a rigid structure is highly dependent on its unique conditions.

Adaptability and Certainty of Success
The certainty of success in the short term is medium and highly dependent on local wave current conditions, as well as structure design such as porosity, height, and material strength.

Cost
The cost of sand retention structure construction varies depending on the height, length, quality, and source of materials, as well as specifics of the engineering of the structure. Some additional construction costs may include any in-lieu fees that may be required (such as the sand mitigation, beach recreation, or beach ecology fees). Once constructed though, these structures tend not to need a lot of maintenance, so the maintenance costs are relatively low until the back half of the lifespan. Additional lifespan costs to consider include the removal cost; given the low adaptive capacity, it is likely that the structure would have to be removed or substantially retrofitted in the future.

Secondary Consequences
Sand retention structures have the potential for substantial secondary consequences associated with downcoast erosion impacts. To minimize the downcoast impacts associated with sand retention, it is important to fill or “charge” the retention structure with sand so that sand moving alongshore in the system isn’t trapped, but rather continues along a filled beach or “sand fillet”. Occasionally, groins are used in conjunction with a sand placement program to help retain recreational beaches for longer periods of time. The placement loss or impact from the footprint of the structure is another consideration. However, sand retention structures also result in beach widening. So when resulting beach widening is considered with the

structure's placement loss, there is typically a net benefit for beach recreation. A summary comparison of the coastal adaptation criteria described in Section 10.4.4 is shown in Table 10-2.

Another potential impact of retention structures is a change in nearshore currents, which may affect marine safety and the wave quality. In some cases around the country, sand retention structures have created or enhanced surf spots such as the Newport Beach groins. While the potential exists to enhance surfing recreation in some locations, it is unlikely that retention structures would improve any of the identified surf spots along West Cliff Drive, based on the specific locations being considered. Additional secondary impacts could be associated with lateral access, aesthetics, and ecology.

Regulatory/Legal
The Coastal Commission has not approved any new sand retention structures in quite some time. However, it did recently approve substantial repairs to the Capitola groins and may be more willing to consider alternative adaptation structures such as groins that offset other coastal armoring impacts. The other regulatory agency that would have to grant approval would be the Monterey Bay National Marine Sanctuary, which could be a substantial regulatory hurdle. Because sand retention structures would be solely focused on reducing erosion and enhancing coastal recreation, as well as being located on public lands potentially granted by the State, there is minimal chance of any private property takings claims.

Sand retention could be potentially applied in Zone 2, downcoast of Mitchell's Cove with the potential identified by the community to evaluate enhanced beach and coastal recreational opportunities (Section 10.6.2).

10.5.1.6 Offshore Breakwaters and Artificial Reefs

Description
Offshore breakwaters and artificial reefs are constructed to reduce erosion by reflecting, breaking, and dissipating wave energy before waves impact the shoreline. The difference between these two types of structures is the elevation; breakwaters are visible through all tides and stop wave energy while an artificial reef tends to be submerged during most of the tides and causes waves to break offshore and dissipate the wave energy before it reaches shore. In some cases, these strategies can create calm conditions shoreward of the structure allowing sediments to deposit and form a tombolo or sand structure that can connect to the offshore structure creating a wider beach and buffering erosion (Figure 10-22). These structures are typically used for navigational purposes, particularly port and harbor construction, but in other locations have also been built to enhance habitat, surfing, and dive recreation. One close example of a reef is at Saber Jets just west of Lighthouse Point where a natural reef causes waves to break offshore of Its beach. The actual influence of that wave energy dissipation when compared with the retention of sand by Lighthouse Point is uncertain.

Figure 10-22. Breakwaters as erosion control (courtesy Virginia Institute of Marine Sciences).

Artificial reefs tend to be lower in elevation and designed to cause waves to break and dissipate wave energy offshore before it reaches the coast. Artificial reef structures have been constructed from riprap boulders, geotextile bags, oysters, used tires, concrete reef balls and even scuttled ships in an effort to reduce erosion, enhance habitat and improve surf, diving, and fishing opportunities. In sheltered locations, oyster reefs have shown promise as a living shoreline. But along the energetic open Pacific Ocean, oyster reefs and all of the other materials aside from riprap boulders would likely do nothing to reduce erosion along West Cliff Drive.

Artificial reef structures have been tested around the world as a means to improve local surf conditions and reduce erosion. Most of these experiments have been constructed in Australia, with others in India, the U.K., and the U.S. all using geotextile bags placed or anchored to the ocean floor. The U.S. example, “Pratte’s Reef” (aka Chevron Reef) was constructed using small geotextile bags in Santa Monica Bay in 2000 as mitigation for the loss of a surf spot from construction of the Hyperion Sewage Treatment Plant. It was removed in 2008 (as planned) for more than it cost to install after showing little to no success at recreating a surf spot or improving habitat. The most recent artificial reef was recently completed in 2019 on the Gold Coast of Australia at Palm Beach at a cost of $18.2M using layers of rock (Figure 10-23). Intended to focus wave energy and build a sand retention tombolo, its efficacy in reducing erosion is not yet known.

Figure 10-23. Recently constructed artificial rock reef at Palm Beach, Australia.

Lifespan and Failure Mechanisms
The lifespan of these structures and failure mechanisms depends on the type of materials, for instance the geotextiles can be ripped or punctured by debris of vandalism, while rock reefs and offshore breakwaters have lasted for many decades. Failure of the rock mound breakwaters is typically caused by settling or deterioration similar to a revetment in which the structure sheds fugitive rocks and or flattens its slope allowing additional overtopping or less effective wave energy dissipation.

Adaptability and Certainty of Success
The effectiveness of these structures and their lifespan is uncertain, and highly dependent on materials used in construction, wave conditions, bathymetry, and structural design.

Cost
Cost for any marine construction in an energetic wave environment is extremely high with maintenance costs varying based on the type of material and structure.

Secondary Consequences
Secondary impacts are also uncertain. These structures may be beneficial in reducing erosion, widening beaches, improving offshore marine habitat and enhancing surf, but also could concentrate waves, increasing erosion, narrowing beaches, and degrading surf spots and habitats.

Regulatory/Legal
From a regulatory perspective, particularly considering the Monterey Bay National Marine Sanctuary and the leases required from the CSLC, it is unlikely under current regulations to be a viable adaptation strategy. A summary comparison of the coastal adaptation criteria described in Section 10.4.4 is shown in Table 10-2 (p. 10-10-33).

However, it is possible in the future that augmentation of surf spots or reefs such as Saber Jets could be considered along West Cliff to reduce erosion and enhance recreation, but there remains a high level of uncertainty as to the secondary impacts, costs, lifespan, and feasibility. Any future considerations will require substantial investment in technical analysis before implementation should be considered.

10.5.2 Accommodate

Accommodation strategies refer to a range of adaptation strategies that employ methods that modify existing development or infrastructure or design new ones to decrease hazard risks and increase resiliency to the impacts of sea level rise. On an individual project scale, accommodation strategies include actions such as elevating structures, retrofits, and/or the use of materials meant to increase the strength of development, building structures that can easily be moved and relocated, or using extra setbacks.

10.5.2.1 Setbacks

Description
Setbacks are usually defined as a measurable distance from an identifiable location such as a cliff edge or roadway. Setbacks do not directly address coastal erosion, but rather accommodate more erosion by allocating more space for it to occur. In many jurisdictions with private ownership of the oceanfront land, setbacks and increasing setbacks to account for accelerated erosion reduces the likelihood that coastal armoring will be required. The present alignment of the Recreational Trail on the ocean side of West Cliff Drive means that it will be affected by erosion before the roadway. However, the community has identified the Recreational Trail as the most important component of the transportation corridor and is willing to reduce vehicular traffic to one way to maintain the Recreational Trail. However, there is a vocal large minority that prefers the corridor not change and the vehicular traffic in both directions be allowed. With this community vision in mind, the West Cliff Drive corridor and the cliff top ROW is publicly owned, with almost half of the corridor already armored. As a result, there are two types of setbacks to consider for maintaining public space in the ROW for the Recreational Trail:

- Offset distance from the oceanside edge of the Recreation Trail to the cliff edge
- Landward side setback for development from the curb or parcel boundary

To reduce Recreational Trail maintenance and avoid disruptions in connectivity from coastal erosion, adaptation strategies should attempt to incorporate the farthest ocean side setbacks within the existing ROW for the Recreational Trail. This may require removal of vegetation and realignment of the trail as well as other measures to reduce erosion of the soft bluff top sediments (see Section 10.5.4). Following cliff erosion, realignment of the Recreational Trail as far landward and adjacent to the West Cliff Drive roadway should be the highest priority.

Lifespan
The expected lifespan of an oceanfront development is typically used in the calculation of the setback. Often an annual erosion rate is multiplied by the expected life of the development on private property. Currently, the City does not have a setback calculation. The County of Santa Cruz and other jurisdictions are moving toward using an increased setback based on an assumption of accelerated erosion from sea level rise. However, given the predominantly public ownership along West Cliff Drive, the setback could be focused on maximizing available public space from the cliff edge to increase resiliency and transportation safety acknowledging that there are varying widths along the corridor.

The landward side of the West Cliff Drive roadway is privately owned. Most of West Cliff Drive is zoned R-1-5, which requires a 20-foot setback from the front property line. Currently there is a 5-foot ROW easement on each property to provide a space for an inland sidewalk triggered by new or redevelopment permits. However, there is an exception that allows new development to have a setback equal to the average setback on the block if the rest of the block is already developed. Because virtually all of West cliff is already developed and much of it with less than 20-foot setbacks, landward setbacks could be expanded along adjacent West Cliff Drive parcels or perhaps transferred or to expand the West Cliff Drive corridor, particularly in areas where erosion has narrowed the ROW and reduced the transportation corridor alternatives. At the very least, policies could be strengthened to prevent further setback exceptions occurring on West Cliff.

Figure 10-24. Example of setback where development has been moved to inland side of the road near Pismo Beach.

Adaptability and Certainty of Success
Setbacks have a moderate adaptive capacity as more space buys more time for erosion and options for space allocation that have a high certainty for success. However, over time, the adaptive capacity diminishes.

Cost
The cost of implementing setbacks is small with the expense usually in the form of staff and administrative time updating policies and revising easement agreements to allow for road relocation instead of sidewalks.

Secondary Consequences
Any secondary impacts from setbacks would be associated with monitoring and enforcement of the setbacks. From a regulatory perspective, setbacks have shown to be a viable and commonly used policy approach for oceanfront development in the coastal zone.

Regulatory/Legal
From a legal perspective, setbacks from either the cliff edge, or the parcel boundary are commonly placed on new development with little legal risk; setbacks from the cliff edge on public property pose little to no takings claim risk. The historic practice of providing variances to landward edge setbacks has been relatively common and enforcement of the existing standard poses little to no legal risk. However, if in the future strict adherence to setbacks results in no development being permitted on a private property without just compensation, then the legal risk of a taking claim may increase. Setbacks from both the oceanfront and the landward edge of West Cliff Drive are applicable to all zones.

10.5.2.2 Elevate

Description

Elevation as an adaptation strategy typically refers to the increase in elevation of low-lying buildings or infrastructure (bridges and roads) to accommodate increased flooding or inundation. Along West Cliff Drive, the approach would be to increase the elevation of the Recreational Trail. An example of where this approach has been implemented is in the City's adaptation approach to the erosion near Auburn Avenue where failure of the upper soft bluff sediments has caused a narrowing of the Recreational Trail. While not yet constructed, the City's solution to that failure is to engineer a caisson supported segment of the Recreational Trail. This segment will be founded on the hard bedrock of the Santa Cruz mudstone formation and allow for the cantilevering and widening of the Recreational Trail (Figure 10-12). Over time, as erosion continues, the Recreational Trail may become detached from the West Cliff Drive corridor but maintain viability as a transportation corridor.

Lifespan and Failure Mechanisms

The lifespan of this elevating approach at Auburn was not specifically included in the project design basis, but is likely to be 30+ years, but each specific project lifespan likely varies based on the elevation, foundation engineering and specifics of the site.

Adaptability and Certainty of Success

The adaptive capacity of this approach is much higher as long as the foundational supports for the elevated Recreational Trail do not rely on connection to the rest of the corridor.

Cost

The cost of this construction is relatively high and similar to construction costs of a revetment.

Secondary Consequences

Secondary consequences associated with an elevation strategy are highly dependent on the individual project and project area. Increases in elevation may affect aesthetics, but also may allow natural erosion processes to continue in support of habitat, access and coastal recreation.

Regulatory/Legal

From a legal perspective, any elevation of development or infrastructure would be focused on reducing erosion and vulnerabilities to public property and ROWs along the oceanside of West Cliff Drive; thus, there is a minimal chance of any private property takings claims.

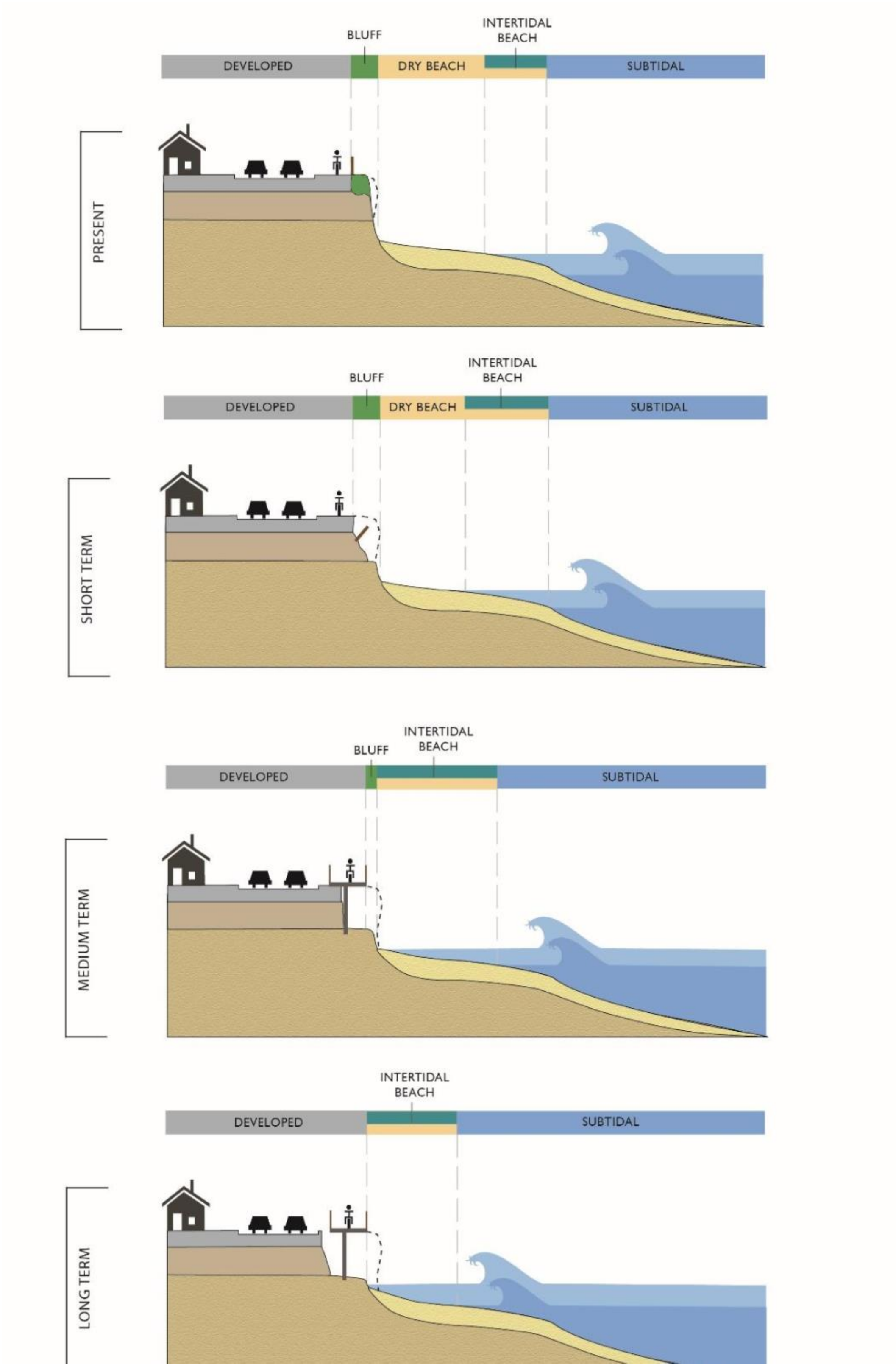


Figure 10-25. Example of an elevate strategy over time (e.g., at Auburn Avenue).

10.5.2.3 Sand Management Programs—Bypass or Backpass

Description

Sand management programs refer to efforts to maintain or increase the local sediment supply at various locations to widen beaches, increase coastal recreational opportunities, decrease coastal erosion, and offset the secondary consequences of coastal armoring. Sand management programs, which are cyclic, are different from one off beach nourishments, which tend to be a huge expense that episodically places large volumes of sand to widen beaches. Instead, a sand management program refers to a formal program that adds sand into the littoral system on a periodic basis. Such a program aims to create higher sand levels, improve coastal recreation and access, and encourage sediment to be transported to enhance downcoast beaches and coastal recreational opportunities.

Sand management in California has historically been of four types—large construction-related sand placements, spot specific beach nourishments, small opportunistic placements, and routine sand bypassing associated with harbor maintenance and navigation. There have been only a few large construction-related sand placements. For example, the Hyperion Sewage Treatment Plant in Los Angeles, where construction-related sand was excavated and placed between retaining structures to significantly widen the beaches in Santa Monica. There have been only two large scale beach nourishment projects, both in San Diego County (Regional Beach Sand Projects I and II) where 2.6 million cubic meters of sand was dredged from offshore and placed on multiple beaches to enhance recreation and reduce erosion. Both exhibited varying levels of success largely based on the grain size of the nourished sand, with larger grain sizes lasting longer. Small opportunistic placement programs have been conducted in San Diego and Santa Barbara in an effort to mitigate erosion hot spots (e.g., Goleta Beach), or deal with excess sediment (e.g., Montecito debris flow 2017). The most common sand management type in California is harbor bypassing, dredging sand from one side of a harbor to the other to maintain navigation channels and minimize erosion to downcoast beaches. Harbor bypassing such as at Santa Cruz or Santa Barbara Harbor typically depends on U.S. Army Corps of Engineers (USACE) annual funding.

The Santa Cruz Harbor was built in 1964 and immediately began retaining sand at Seabright Beach, which has since widened the State Beach and backed up sand all the way to Cowells Beach. Dredging of the Santa Cruz Harbor to maintain navigation began in 1965, just 1 year after harbor construction. Maintenance dredging operations were initially accomplished by USACE through contracts with private dredging operations until 1986, when operational dredging responsibilities for the harbor where assumed by the Santa Cruz Port District (SCPD). SCPD used a floating hydraulic dredge Seabright until the 2015–2016 dredging season when it was retired. Starting in the 2016–2017 season and in operation now, dredging is being conducted with the new dredge Twin Lakes (Figure 10-26), acquired by SCPD in 2016 and custom-designed for the Santa Cruz Harbor. Sand dredged from the navigational channel is placed downcoast to nourish downcoast beaches and protect transportation and other infrastructure. The average annual harbor dredging bypass volumes since 1997 are around 270,000 cubic yards per year.

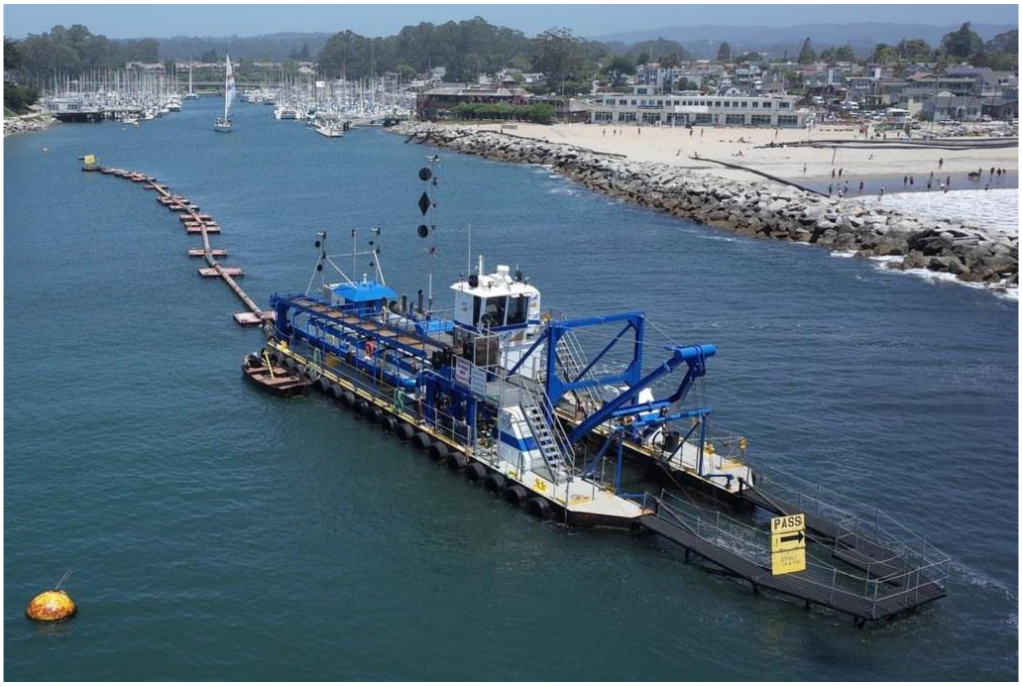


Figure 10-26. The Santa Cruz Harbor dredge, Twin Lakes.

Along West Cliff Drive and in particular, the small pocket beaches, there are significant natural variations in beach width from year to year and from season to season as a result of the natural variations in sediment discharge from rivers, wave energy and approach angle, and storm severity and frequency. Some of the larger beaches, such as Main Beach and Seabright Beach fluctuate in width between winter and summer, but these fluctuations remain relatively stable from year to year as these beaches are retained by the Santa Cruz Harbor Jetty with each beach recovering quickly after severe storm events. The beaches along Main Beach, which have also widened, have created a change in the natural breaching dynamics of the San Lorenzo River Lagoon, which has required extensive management by the City (Figure 10-27).

Figure 10-27. Sand management at the San Lorenzo River Lagoon addresses beach changes to lagoon opening and closing caused by the Santa Cruz Harbor sand retention.

One of the adaptation strategies prioritized for future investigation includes the development of a sand management program where some of the dredged harbor sand would be placed at Pyramid Beach in Zone 1 (Figure 10-38 in Section 10-6). Conceptually, placement at this semi-protected beach would slowly release sand along West Cliff, nourishing beaches, enhancing beach and surfing recreation, and partially mitigating the impacts of coastal armoring over time (Figure 10-28). A rough estimate of the sand volume required to backpass or opportunistically fill Pyramid Beach is ~28,000 cubic yards, about 10 percent of the annual average dredge records at the Santa Cruz Harbor. An equivalent volume of sand could also be taken from Seabright Beach and only narrow that beach by about 25 to 30 feet. This beach is currently about 800 feet wide next to the Harbor jetty and 250 feet wide by San Lorenzo Point. All volumes are well within the dredging permits and capabilities of the existing infrastructure.

Figure 10-28. Potential sand placement program location at Pyramid Beach with longshore transport direction shown in the arrow, with the intent to nourish and enhance downcoast beaches and offset some of the secondary impacts of coastal armoring.

Lifespan

The lifespan of a sand management program varies depending on the size, volume and location of placement. The backpassing sand management program proposed along West Cliff would have to be a commitment to a periodic placement program. This would be an innovative program in the U.S. and so lifespan is a bit uncertain, dependent on seasonal and annual variability in wave climate.

Adaptability and Certainty of Success

This program is relatively adaptable and could be moved to other locations along West Cliff as needed. The certainty of success though is low. The intent is not primarily to reduce erosion, although it would have an effect, but rather to mitigate coastal armoring impacts by increasing sand supply to the small pocket beaches along West Cliff Drive.

Cost

The cost of implementing the program and conducting it periodically is unknown. The City and Santa Cruz Harbor District own the dredge, which could be mobilized relatively easily; however, the cost of transporting the sand by barge and placing it on Pyramid Beach is unknown and requires more technical analysis beyond the scope of this study.

Secondary Consequences

Secondary consequences associated with this sand management program would be both positive and negative. On the positive side, improved beach widths, improved coastal and nearshore recreation, minor reduction in coastal armoring maintenance and temporary reduction in required harbor dredging could be expected. On the negative side, short term construction impacts, including noise, aesthetics, and potentially turbidity would occur, longer term, the ongoing cost of placing sand would likely escalate.

Regulatory/Legal

Legally, a sand management program is not likely to trigger any takings issues. The construction method of placing the sand which could be done by trucking or by barge and dredge may trigger nuisance complaints, with the barge placement less likely to disrupt traffic and recreation along West Cliff Drive.

From a regulatory perspective, the CCC and CSLC have previously permitted beach nourishment type activities in California. The Monterey Bay National Marine Sanctuary (MBNMS) however, currently has a regulation against the placement of sediment in Sanctuary waters defined as those below mean high water (MHW). This regulation though is currently under review in consideration of various proposed adaptation projects in both Monterey and Half Moon Bay and may be revised. It may also be possible to place the sand above MHW and reduce the impact and regulatory concerns. Additional discussions with MBNMS would be warranted if this strategy shows promise.

10.5.3 Managed Retreat

Description

Managed retreat is an adaptation approach that acknowledges natural cliff erosion and incrementally relocates, realigns, or moves at risk infrastructure. This comprehensively planned approach should be phased over time, and often refers to the gradual removal and relocation of structures and infrastructure from risk prone areas (Figure 10-29). Long term, managed retreat usually becomes the most cost-effective measure to avoid construction, maintenance, removal, and lost revenues associated with secondary impacts to coastal resources such as the loss of beach recreation and surf quality (Figure 10-30).

Managed retreat strategies can be implemented in a variety of ways some in the form of changed policy, zoning, or setback regulations. In others, purchase of property, transfer of development rights, or eminent domain could be used to acquire portions of properties to facilitate realignment of the West Cliff Drive corridor. The goal of managed retreat is to preserve the public interest and access to the coast while providing an equitable solution for private property owners and those that rent private property. Managed retreat tends to be highly dependent on economics, legal and property rights, and must balance public and private interests.

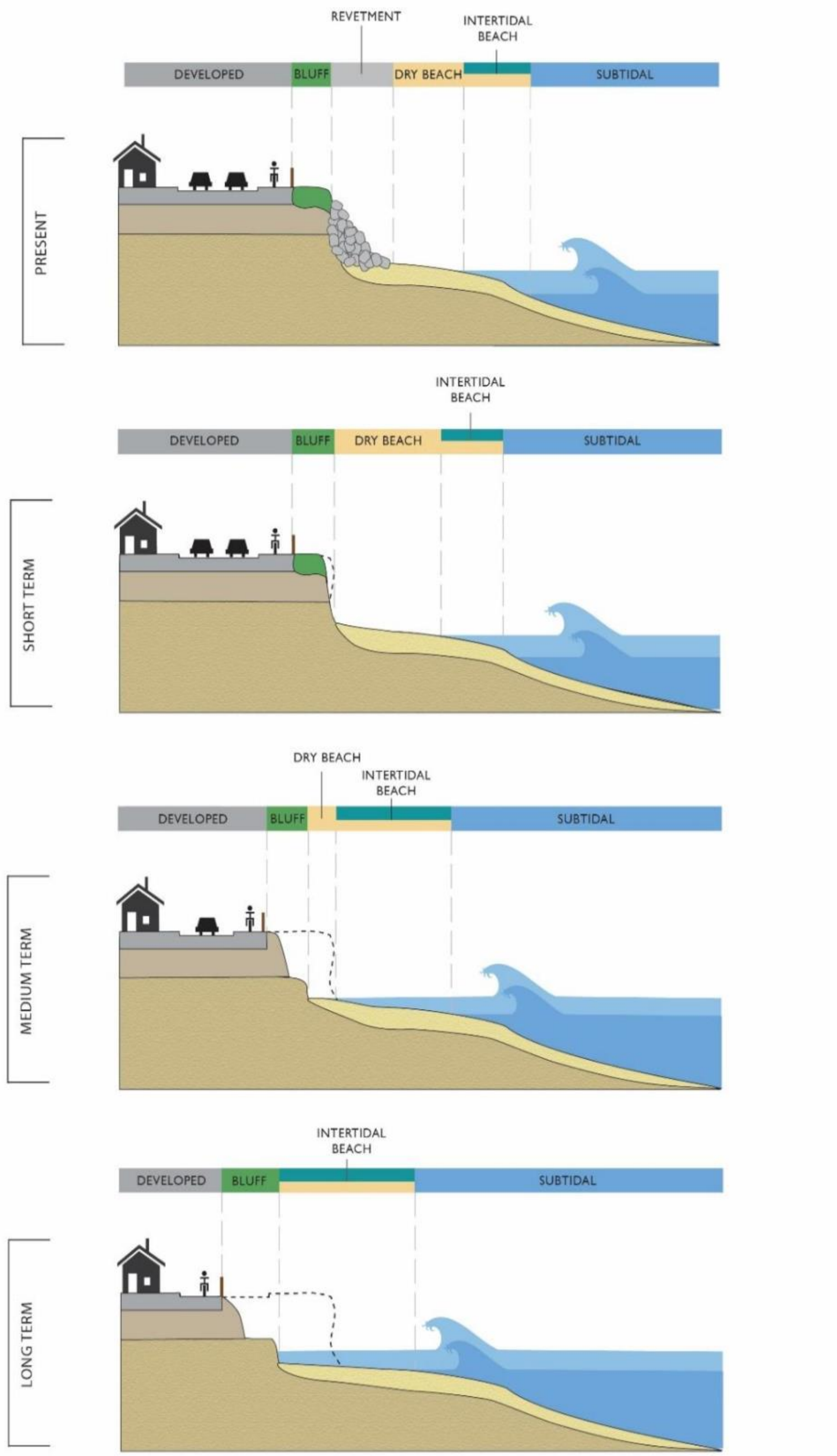


Figure 10-29. Example of a Managed Retreat strategy over time.

Figure 10-30. Coastal recreation with and without a sandy beach at Cowells Beach. Blue arrows show the approximately same location.

Lifespan
The lifespan of a managed retreat is potentially forever, each phase will require different mechanisms to implement, but the concept is to acquire or maintain oceanfront public space to allow for natural erosion to occur and maintain coastal resources, beach and nearshore recreation, and habitats.

Adaptability and Certainty of Success
To feasibly accommodate a managed retreat strategy along West Cliff Drive, there are many policy approaches. Some policy approaches could relocate the corridor into adjacent public open space such as Lighthouse Field State Park, others could consider purchasing some portion of private parcels to allow for additional space, or regulate development from the oceanside parcel boundary fronting West Cliff including through the use of disclosures, zoning, amortization of development rights and development setbacks. These policy implementing approaches as well as potential financing mechanisms will be explored further following the cost benefit and transportation analyses as to the feasibility of the managed retreat approach over time.

Cost
Prioritized City and community goals identified that maintaining connectivity along the Recreational Trail was of paramount importance. The cost of managed retreat depends on the value of the existing infrastructure and developments relative to the cost of land acquisition or armoring protect the coast and the secondary consequences associated those actions. In California, most managed retreat strategies have been planned for and enacted in undeveloped stretches of coast, where prioritizing sediment supply and maintaining a beach outweighs the land lost to erosion.

Secondary Consequences
See Section 10.3.4.3

Regulatory/Legal
From both a legal and regulatory viability standpoint, a managed retreat strategy is viable; however, it depends on the specific setting, facts, and details involved. By communicating a long term vision, establishing hazard disclosures, and providing incentives (and disincentives), it is possible to implement a managed retreat strategy over time, and realistically, this is likely the only truly feasible strategy over the long term. There are already clear examples of the City relocating infrastructure to avoid coastal cliff erosion such as the relocation of a West Cliff Drive parking lot near Columbia Avenue (Figure 10-31).

Figure 10-31. Relocation of a West Cliff Drive parking lot near Columbia Avenue due to cliff erosion in the mid-1970s.

10.5.4 Measures To Reduce Factors That Exacerbate Erosion

Measures that reduce factors exacerbating erosion are encouraged regardless of which adaptation alternative or approach is taken. These strategies described below merely will reduce natural erosion rates, but not resolve or address any of the short or long term erosion issues, but rather just buy time until different adaptation approaches will be required. As a result, these are only described below and estimates of costs, or secondary impacts, and regulatory/legal requirements are not discussed. In future phases, as the analyses begin to narrow on a least environmentally damaging preferred adaptation pathway, aspects of these will or should be integrated into more specific designs. Recommendations made in the management plan may also identify opportunities where these actions should be taken in the short, medium, and long term to increase the resiliency of West Cliff Drive.

10.5.4.1 Control Access

Controlling foot traffic is important to ensuring public safety, limiting erosion, and protecting natural resources. The cliff erosion hazards posed by steep unstable bluffs along West Cliff Drive are associated with visitor falls and rock falls, which endanger public health and can require EMS response. Foot traffic along coastal bluffs also causes erosion by channelizing water, decreasing vegetation cover, and direct sloughing of fragile soils and dislodging rock. Controlling public access can also benefit coastal habitat by reducing the spread of invasive plants, minimizing disturbance to wildlife, and protecting sensitive plants and animals. To improve bluff top stability and decrease soil loss, control of access and restoration/ revegetation of coastal bluffs can simultaneously be implemented. This will help to reduce channelization, increase vegetation cover, and increase water capture/percolation. Examples of controlling access include fencing (symbolic and physical), plantings, walls, signage, and public education.

Any formalization of public access must consider the Coastal Act's mandate for maximization of public access and recreation opportunities and thus not decrease the public's ability to access the ocean or beaches (Figure 10-32).

Figure 10-32. Galvanized steel fencing at Lighthouse (Revell Coastal), low-cost wood wire fence at Natural Bridges, fencing at Steamer Lane/Lighthouse Field, signage by Lighthouse Field, and hazardous visitor access by the base of Chico Drive (Groundswell).

10.5.4.2 Water Management

Stormwater drainage can accelerate soft bluff top erosion along West Cliff Drive and also degrade ocean water quality. Improvement opportunities include upgrading storm drains and enhancing landscape functionality. The total number of erosion-causing outfalls that protrude from the cliff could be reduced by rerouting and combining storm water systems. Outfalls that protrude from the bluff could be moved from the base of the cliff and outfitted with filtration devices and energy dissipaters to prevent erosion and reduce turbidity at the downstream end of the pipe. Landscape enhancements could include daylighting stormwater pipes to increase percolation and installation of curb cutouts with landscaped bioswales to capture and filter runoff. These actions may provide more water to cliff-top vegetation communities and potentially enhance restored or built coastal wetland habitats. Stormwater filters could also be added to reduce trash from entering the ocean.

Along West Cliff Drive, there may be opportunities to utilize stormwater by directing water to natural draws that have historically supported wetlands or vegetation adapted to increased water availability. This may help to extend the growing time of coastal cliff-top vegetation. Water from weep holes of coastal armoring could also be used to support native plant communities integrated into purposely engineered build ledges and vertical surfaces. One concern to increasing percolation is that groundwater and seeps can act to accelerate coastal erosion or weaken the coastal armoring structure. However, the small, shallow groundwater aquifers on the soft bluff top terrace result from many acres of percolation and the contribution of small local percolation areas likely represents only a small fraction of the total water budget received by coastal seeps along a given section of coastline.

Figure 10-33. Upper left and then clockwise: Runoff near Columbia Dr., drainage and abandoned infrastructure by Lighthouse Field, and stormwater outflow near Pyramid Beach.

10.5.4.3 Coastal Habitat Restoration

Coastal habitat restoration can be an effective nature-based tool for reducing erosion, building coastal resilience, ecosystem functionality, and biodiversity. Coastal restoration can also be used to mitigate construction of hard structures. The restoration process involves natural shoreline stabilization of sand and soils with native vegetation. Barring massive sediment nourishment projects there are few if any opportunities for coastal dune and strand (communities of flowering plants that grow along the coast) restoration along West Cliff. Thus, habitat and living shoreline approaches will primarily take place on the coastal bluffs with restoration activities largely focused on removing invasive iceplant, recontouring and stabilizing bluffs, and mitigating eroded pathways of bare soil with native plant communities.

Primary cliff-top restoration goals should include reducing coastal erosion and stormwater runoff by enhancing stormwater water filtration and increasing biodiversity. One of the highest adaptation solutions identified by the TAC and City department heads was to restore the perched wetland at the end of Auburn Avenue. While this would be a good improvement, the reduction in erosion is not likely. However, wetland, cliff top, and cliff face restoration can also support additional ecosystem services such as ecological connectivity of the coastal landscape, increase in pollinator and migratory bird habitat, and enhance recreational opportunities such as wildlife observation, photography, and a visitor experience that aligns with the area's unique native coastal ecosystems.

Restoration efforts should include diverse plant palettes selected from sustainably collected local native plant species to build redundancy and complexity into the vegetation community. These activities will be most effective when focused on areas where erosion hazards are medium- or low-risk to ensure longer restoration lifespans, project footprints are of sufficient scale to reduce edge effects from encroaching iceplant, consist of robust foundational native plant species, and include less common habitats such as coastal wetlands. Habitat restoration can also be incorporated into lateral areas where it has additional value of being buffered from human access and provides wildlife refugia from disturbance (Figure 10-34).

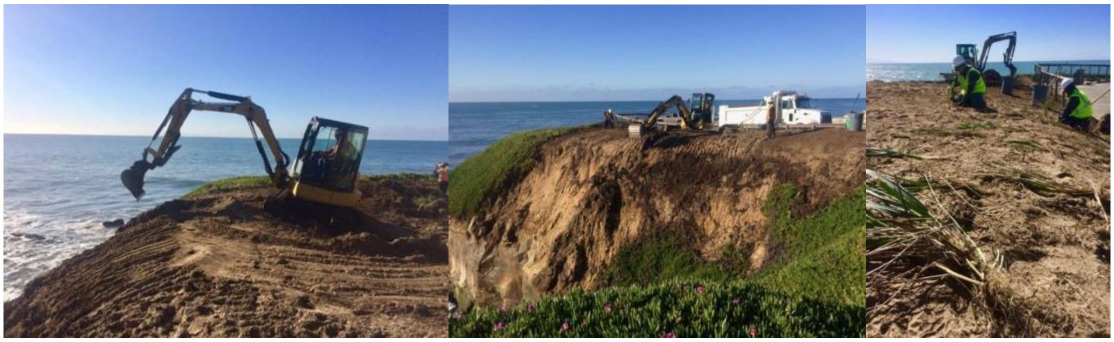


Figure 10-34. Recontouring the cliff top at Natural Bridges Head by laying back the head of a recent bluff failure followed by subsequent restoration (Source: Groundswell).

Coastal hardening and sea cave filling halts the erosion processes that create offshore rocks, important resting and breeding habitat for shorebirds, seabirds, and marine mammals. One option to mitigate for this loss is to integrate resting and breeding habitat into newly constructed shoreline protection structures by engineering ledges and crevices into hard structures. Such features need to be placed in favorable locations that facilitate use by intended beneficiary species. These engineered features can also be incorporated into offshore structures such as breakwaters. Integrating habitat into the adaptive process will ensure that coastal species are able to persist in the increasingly engineered and managed landscape.

Once established, native plant communities require infrequent, low-cost maintenance. A cost advantage of restoration is the reduced maintenance effort required to keep iceplant from encroaching on paths and roadways where it poses a hazard to coastal users narrowing the Recreational Trail.

Figure 10-35. Community-based restoration project at the base of Woodrow Avenue and West Cliff Drive (Groundswell).

10.5.5 Transportation Approaches

The transportation adaptation alternatives prioritized for further conceptual alternative and cost benefit analysis were identified from various outreach engagement efforts with community focus groups, the TAC, City leadership, and the public. For both short- and long-term transportation adaptation, the identified adaptation priorities for each zone include:

- Maintaining two-way traffic
- Changing to one-way traffic with a redesigned Recreational Trail to reduce conflicts and improve coastal access
- Redirecting traffic while maintaining the Recreational Trail

The next phases of the project will further develop conceptual design alternatives, generate cost estimates, and evaluate cost benefit tradeoffs using traffic models, erosion models and the economics of various recreational uses based on different coastal adaptation approaches and their impact on the future width of the public ROW. Table 10-4 provides an approximate measurement for the existing corridor and approximate measurements for potential future corridors.

- **Two way traffic:** Maintaining two-way traffic with the recreational trail in the long term will be extremely challenging due to the limitations of the ROW. This can be a viable short-term approach, but as mapped areas of coastal erosion concern and projections of future coastal erosion models indicate, it may be extremely costly to maintain in the long term. A traffic model of the existing configuration as a projected future scenario will provide a comparison of traffic flow with other adaptation alternatives. However, future erosion would likely result in loss of the Recreational Trail before impacts to the roadway and vehicular traffic so these tradeoffs need to be evaluated. In addition, an episodic erosion event such as a sea cave collapse must be evaluated in terms of tradeoffs that and may require rerouting of traffic in the event of such a large erosion event.
- **One way maintaining Recreational Trail:** A one-way alternative would use one of the existing lanes to expand or maintain the Recreational Trail and potentially create a two-way separated cycle-track to provide a safe corridor for cyclists and separate other active transportation users, while separating the pedestrian facility from the cyclists and automobiles. The one-way strategy would likely be from east to west as a preferred direction of travel in each zone based on stakeholder feedback with a holistic approach likely to maintain contiguous travel and reduce potential conflicts.
- **Redirect traffic, maintain Recreational Trail:** Redirecting traffic to alternate streets would change the composition of neighborhoods' streetscape and must be considered with serious community engagement. If there are no other options for at-risk areas of West Cliff Drive but to redirect traffic, specific roadway treatments can be created to minimize impacts of the increase of traffic (e.g., improved signage, lighting, elevated crosswalks, and bulb outs at intersections). In addition, the relocation of traffic may only be applicable for automobiles where this option potentially could create an authentic active transportation zone along the corridor. Any roadway used to relocate traffic from West Cliff Drive would also have applicable pedestrian and cycling infrastructure to accommodate a multimodal community and maintain coastal access. This will be further assessed in the Conceptual Design Analysis.

Table 10-4. Approximate widths of West Cliff Drive corridor features to be integrated into alternative conceptual designs

Facility Type	Auto Lane Width	Gutter Width	Striping Width	*Curb to Curb Width Subtotal*	Inland Sidewalk Width	Recreational Trail Width	Buffer Width	Outside Shoulder Width	Bicycle Lane Width	Parking Lane**	Barrier width	Seaside Sidewalk Width	Total
Two Lane Status Quo	*22*	*1*	*1*	*25*	*5*	*8*	*5*	*2*					***44***
One Lane with Separated Cycletrack*	*12*	*1*	*1*	*15*	*5*			*2*	*8*		*2*	*8*	***39***
One Lane with Separated Cycletrack* with onstreet parking	12	1	1	15	5			2	8	7	3	8	***47***
Two Lane with Cycletrack*	22	1	1	25	5			2	8		2	8	***49***
Two Lane with Cycletrack* with onstreet parking	22	1	1	25	5			2	8	7	2	8	***56***

All widths are in feet

All widths are recommended minimum widths

* Conceptual bidirectional Bicycle Lane to emphasize safe separation of cyclists and pedestrians but could be split to either side of the road

**Parking lane is optional and not applicable for most of West Cliff Drive

Curb to Curb width is also the Roadway width subtotal

Note: Lane widths often include gutter and or striping; these items were separated to provide context of space

The space limitations in the available ROW from curb-to-curb and along West Cliff Drive inevitably drives the opportunities and constraints for conceptual transportation adaptation alternatives. This public space is largely dependent on the coastal adaptation approaches aimed at reducing, stopping or allowing cliff erosion. The ROW width below identifies the narrowest areas along the West Cliff Drive corridor. This information will directly impact the potential transportation adaptation alternatives for the Recreational Trail and West Cliff Drive. The table and maps (Table 10-5; Figure 10-36, Figure 10-37) show eight spatially constrained sections along the corridor with 25 feet or less between the curbs. The 25 foot width was selected as representative of a constrained section where the corridor could not accommodate two vehicle lanes plus a bike lane or parking on one side. Using this minimal distance requirement to assess available curb-to-curb width, it is apparent that each of the respective West Cliff Drive zones have space restricted areas with limited ROW widths. Utilizing approximate distances calculated from geospatial analysis will help inform the design of conceptual alternatives.

Table 10-5. Segments of West Cliff Drive where the curb to curb width is less than 25 ft

Cross Street 1	Cross Street 2	Length (ft)	Zone
Entrance to Natural Bridges	Swanton Blvd	86	Zone 1
Swanton Blvd	Chico Ave	66	Zone 1
San Jose Ave	Stockton Ave	285	Zone 1
Almar Ave	Sunset Ave	109	Zone 2
Bethany Curve	Before Woodward	79	Zone 2
In front of Parking Lot B	West of crosswalk	45	Zone 3
In front of Cowells overlook parking lot	Manor Ave	99.9	Zone 4
Monterey St	Santa Cruz St	82	Zone 4

When evaluating West Cliff Drive ROW, we must consider not only the following curb-to curb distances, but also the space beyond the vehicular corridor, which contains the publicly owned area from the Recreational Trail all the way to the edge of the eroding cliffs. Another distance to consider in the future is the inland curb side sidewalk easement (~5 feet) as well as the setback distances for the residences on the inland side which are supposed to be 20 feet based on the zoning but variances to this have historically been granted. The Recreational Trail between the roadway and the cliff edge is already compromised in several locations due to erosion and projected future erosion impacts will contribute to additional disruptions. Understanding how the roadway and Recreational Trail will be aligned either together or separately does depend on the amount of space available.

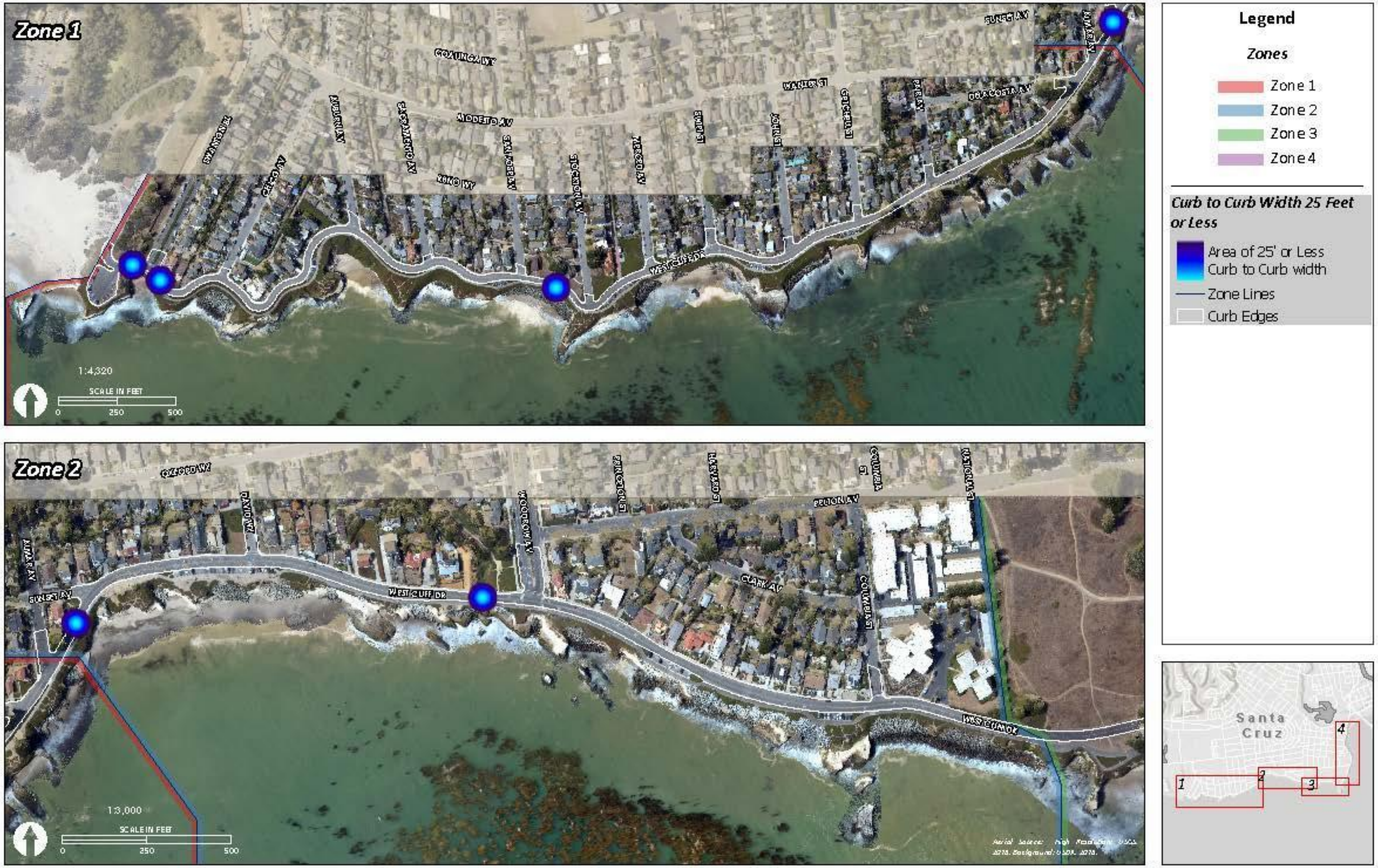


Figure 10-36. Western zones of West Cliff Drive with curb-to-curb ROW width of 25 ft or less.

Figure 10-37. Eastern zones of West Cliff Drive with curb-to-curb ROW width of 25 ft or less.

10.5.6 Matrix Comparison of Coastal Adaptation Alternatives

Table 10-6. Matrix Comparison of Adaptation Strategies

							Cost		Certainty of Success		Secondary Consequences							
Strategy	**Strategy**	**Effect on Erosion**	**Green vs Grey**	**Setting**	**Lifespan**	**Maladaptive**	**Construction**	**Maintenance**	**Near Term**	**Long Term**	**Beaches / Coastal Recreation**	**Rec Trail**	**Roadway**	**Safety / Public Access**	**Aesthetics**	**Ecology / Habitat**	**Legal Risk of Takings**	**Existing Regulatory Viability**
Criteria	***Protect, Accommodate, Retreat***	***Stop, Reduce, Allow, Mitigate Secondary***	***Green, Grey***	***Bluff, Cliff, Beach, Offshore, All***	***Short, Medium, Long***	***Y/N***	***$, $$, $$$***	***$, $$, $$$***	***Low, Medium, High***	***Low, Medium, High***	***+, -, =***	***+, -, =***	***+, -, =***	***+, -, =***	***+, -, =***	***+, -, =***	***Y/N***	***Y/N***
Revetments	Protect	Stop Erosion	Grey	Cliff, Bluff	Long	Y	$$	$$	Medium	Low to Medium	-	+	+	=	-	-	N	Y
Seawall	Protect	Stop Erosion	Grey	Cliff, Bluff	Long	Y	$$$	$	High	Medium	-	+	+	-	-	-	N	Y
Soil Nail Tie-Back Walls	Protect	Stop Erosion	Grey	Cliff, Bluff	Long	Y	$$$	$	High	Medium	-	+	+	+	+	-	N	Y
Cave Fill - Riprap Alone	Protect	Stop Erosion	Grey	Cliff	Short to Medium	Y	$$	$$	Low to Medium	Low	-	+	+	-	-	-	N	Y
Cave Fill - Riprap or Concrete Fill with Entrance Cap	Protect	Stop Erosion	Grey	Cliff	Medium to Long	Y	$$$+	$	High	Medium	-	+	+	-	-	-	N	Y
Cave Fill - Erodible Concrete (Sandy Slurry Mix) Cap	Protect	Stop	Grey	Cliff	Medium	Y	$$$+	$	High	Medium	=	+	+	-	-	-	N	Y
Sand Retention (Sheet-Pile, Concrete, Rubble)	Protect	Reduce	Grey	Beach	Medium	N	$$	$$	Medium	Low	+	=	=	+	-	-	N	?
Sand Retention (Cobbles or other Native Materials)	Protect / Accommodate	Reduce / Mitigate Secondary	Green	Beach	Short to Medium	N	$$	$	Low to Medium	Low	+	=	=	+	-	=	N	Y
Artificial Reefs/Offshore Breakwaters	Protect	Reduce	Grey	Offshore	Medium to Long	Y	$$$	$	Low	Low	+	=	=	+	=	Variable	N	N
Elevate Infrastructure	Accommodate	Mitigates Secondary	Grey	Upland	Variable	Y	$$$	$	High	Medium	=	+	+	=	-	=	N	Y
Sand Placement Program	Accommodate	Reduce / Mitigate Secondary	Green	Beach	Short	N	$$	$	Low to Medium	Low	+	=	=	+	Variable	Variable	N	?
Managed Retreat	Retreat	Allows	Green	All	Long	N	Variable	$	High	High	+	+	-	+	+	+	Depends	Y
Water Management stormwater, groundwater)	Accommodate	Reduce	Grey	All	Medium	N	$$	$	Medium	Medium	+	+	+	+	+	+	N	Y
Upgrade Stormwater Pipes	Accommodate	Reduce	Grey	All	Medium	N	$$	$	Medium	Medium	+	+	+	+	+	+	N	Y
Stormwater Energy Dissipators	Accommodate	Reduce	Grey	All	Medium	N	$$	$$	Medium	Medium	+	+	+	+	=	+	N	Y
Groundwater Management	Accommodate	Reduce	Grey	All	Medium to Long	N	$$$	$$	Medium	Medium	+	+	+	+	=	=	N	Y
Control Access (Signage, Fencing, Obstacles)	Accommodate	Reduce	Grey	Bluff	Short	N	$	$	Low	Low	=	=	=	+	-	+	N	Y
Closing Pathways (planting and obstacles)	Accommodate	Reduce	Green / Grey	Bluff	Short	N	$	$	Low	Low	-	=	=	+	+	+	N	Y
Dune Restoration	Accommodate	Reduce Erosion	Green	Beach	Short to Medium	N	$	½$	Medium	Low	+	=	=	+	+	+	N	Y
Coastal Habitat Restoration	Accommodate	Reduce / Mitigate Secondary	Green	All	Short to Long	N	Variable	$	Low	Low	+	=	=	=	+	+	N	Y

10.6 Prioritized Adaptation Alternatives for Further Analysis

Adaptation to coastal erosion and sea level rise along each zone of West Cliff Drive will likely require multiple approaches over time. Uncertainties in timing of large storm waves at high tides, elevation of sea level rise in the future, and projected extents of future coastal erosion, require consideration of feasible adaptation strategies over both short- and long-term time scales with an adaptation pathways approach.

Over the short term, priorities were determined based on the existing conditions report, which included mapped areas of erosion concern, coastal structures with less than a 10-year lifespan based on engineering evaluation, and areas identified as High Risk (short term erosion likely to impact West Cliff Drive or the Recreational Trail). To reduce uncertainties and evaluate adaptation strategies in enough detail to support the development of a West Cliff Drive Adaptation and Management Plan, a prioritized subset of feasible adaptation strategies over time for each of the West Cliff Drive zones was required.

Longer term, adaptation priorities for further analysis based on projections of future coastal erosion, community priorities and regulatory requirements to maintain coastal recreation and resources along the West Cliff Drive corridor were also required.

An extensive outreach and engagement effort was conducted in late 2019 and early 2020, targeting various focus groups, TAC, City leadership, historically underrepresented groups, and the community at large (Section 10.4.2). This process prioritized key objectives, evaluation criteria and ultimately provided a community focused list of up to three short and long term coastal and transportation adaptation alternatives for each West Cliff Drive zone. Both short term (<10 years) and longer term preferred adaption strategies were identified that will be considered in future conceptual design and cost–benefit analysis tasks. Results from these future tasks will support the completion of the West Cliff Drive Adaptation and Management Plan and identify monitoring triggers to support development of adaptation pathways.

A social vulnerability assessment completed as part of related ongoing coastal management and climate change studies, has identified specific shortcomings in existing facilities and amenities used by historically underrepresented groups for each of the zones found along West Cliff Drive (Table 10-6). Zone 3 provides the best suite of amenities to all historically underrepresented groups. Shortcomings in existing amenities should be considered in development of preferred adaptation strategies for all zones, but particularly those that don't currently provide a good level of access to all groups.

Table 10-6. Overall level of service and access to underrepresented community populations by Zone (adapted from City of Santa Cruz Social Vulnerability Assessment 2020).

Underrepresented Group	Zone 1	Zone 2	Zone 3	Zone 4
Elderly	High	High	High	High
Youth	Moderate	High	High	High
People with Disabilities	Moderate	Moderate	High	Moderate
Low Income residents	Low	Low	High	Moderate
Tribal	Low	High	High	Moderate
Homeless	Low	Low	High	Low
LGBTQ+	Low	Low	High	Low
Fishers	Moderate	High	High	High

Level of Service Provided to Group

High Moderate Low

The following sections identify prioritized coastal and transportation adaptation alternatives for the short and long term in each zone along West Cliff Drive for future analysis.

10.6.1 Zone 1—Natural Bridges Overlook to Almar Avenue

This westernmost Zone of West Cliff Drive has 21 different coastal armoring structures and 23 areas of erosion concern. Two areas of erosion concern were identified as high risk in the short term with erosion likely to impact the Recreational Trail and/or West Cliff Drive. These areas are associated with the existing failure affecting the Recreational Trail near Auburn Avenue and erosion at the end of Merced Avenue (Figure 10-38). In addition, there are three locations along West Cliff Drive where the curb-to-curb distance is less than 25 feet and traffic safety is already impaired (Figure 10-38).

Within the short term of the next 10 years, 8 of these coastal armoring structures are projected to fail and require attention, while 12 of the areas of erosion concern are deemed high hazard and likely to erode. The coastal armoring structures that need short term attention include two shotcrete sandbag walls and the failed revetment on Pyramid Beach which currently presents hazardous conditions with rusted rebar and impaired access.

The eroded Recreational Trail near Auburn has already been identified by the City for repair using an elevated approach (Figure 10-25) for an estimated cost of ~$320,000 for a 70 foot length of trail.

In addition to the short-term risk and hazards, there are several locations where management changes could improve upon existing conditions, by removing some of the extensive revetments covering small pocket beaches, improving lateral access along the wave cut platforms, restoring habitats including bluff top and the perched wetland on Auburn Creek, and reducing disturbance to sensitive species by improving management of recreational uses.

Through the TAC and City department head process (Section 10.4), priorities were determined for short term coastal and transportation preferences (Figure 10-39), and long term coastal adaptation and transportation preferences (Figure 10-40). The preferences in the short term included restoration of the perched wetland near Auburn Avenue; repair, replacement, and addition of revetments; and sand placement on pyramid beach. The preferences for long term coastal adaptation included managed retreat, construction of soil nail walls, and restoration of the perched wetland at Auburn Avenue.

These various strategies were presented at a community open house along with supporting materials such as maps and diagrams, and community members were encouraged to engage in dialogue with members of the team, city department heads, and other members of the public, many of whom reside along or within a few blocks of West Cliff Drive. Following these interactions, members of the public were asked to prioritize their preferred adaptation alternatives for both the short term and long term. The survey averaged 47 responses per question.

Based on those survey responses, the most highly prioritized short term coastal adaptation strategy was to maintain revetments, with more than 60 percent of respondents choosing this option, and the most highly prioritized long term coastal adaptation strategy was managed retreat, with close to 50 percent choosing this option (Figure 10-40). The most highly prioritized short and long term transportation adaptation priority was identified as converting West Cliff Drive to one-way traffic while maintaining the recreation trail, with close to 50 percent choosing this option over both the short and long terms (Figure 10-39B, Figure 10-40B). Over the long term, the community placed an extremely high priority on maintaining the Recreation Trail for this section, with one-third of respondents identifying relocating traffic in order to keep the Recreation Trail as a priority. This left approximately 18 percent of respondents prioritizing vehicular traffic over the trail.

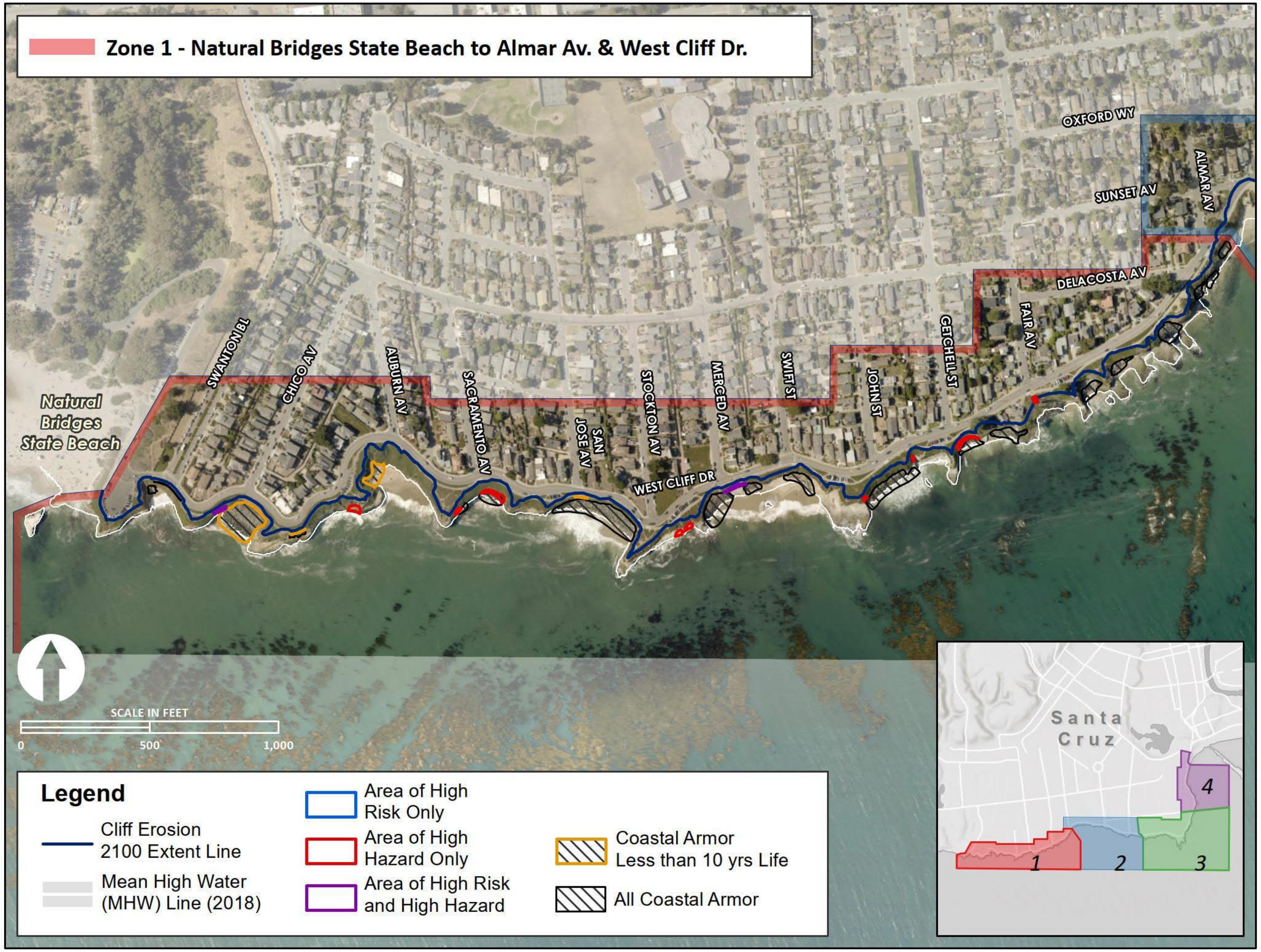


Figure 10-38. Short term priority areas for adaptation and management in Zone 1.

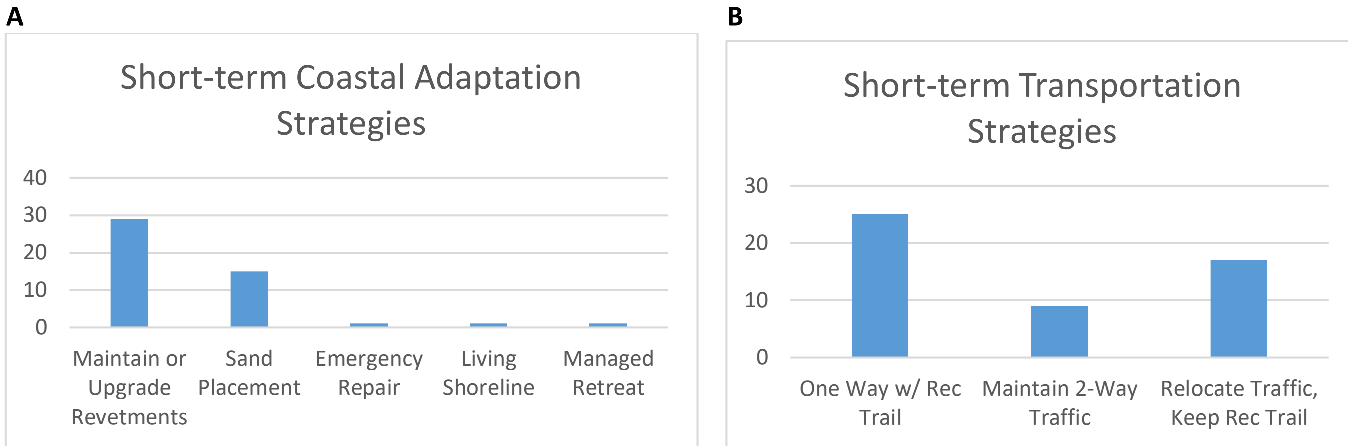


Figure 10-39. Short-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 1.

Longer term, projections of future coastal erosion, as well as already mapped areas of erosion concern are likely to cause additional disruption to the West Cliff Drive corridor. In addition, impacts associated with previously made adaptation decisions about protecting with revetments will degrade coastal access, beach recreation, and surf recreation. Based on community input, TAC guidance, and City leadership priorities, short and long term adaptation for the coast and transportation corridor are identified in Table 10-7.

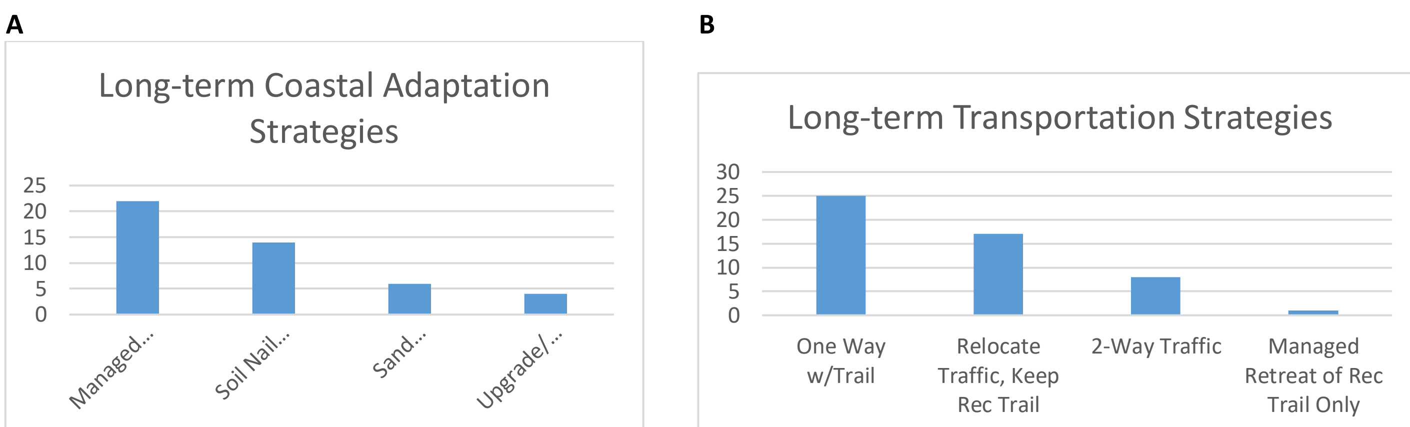


Figure 10-40. Long-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 1.

Table 10-7. Prioritized short term and long term adaptation approaches for detailed conceptual design and cost benefit analysis in Zone 1

Zone 1	Cost		Effectiveness Certainty	Secondary Impacts			Lifespan
	Upfront	*Maintenance*		*Beach, Coastal*	*Rec Trail*	*Road*	
Short term adaptation							
Maintain or upgrade revetments	$$	$	High	-	=	=	Medium
Sand placement program Pyramid Beach	$	$	Low	+	?	?	Short
Seawalls on cliffs providing lateral access	$$$	$	High	-	-	=	Medium
Short term transportation							
Maintain two-way with Rec Trail - Elevate	$$$	$	Low	-	-	=	Short
One-way with Rec Trail	$$	$	High	+	+	-	Medium
Relocate traffic keep Rec Trail	$$$	$	High	+	+	-	Long
Long term adaptation							
Soil nail wall	$$$		High	-	=	=	Medium
Managed Retreat	$	$	High	+	=	-	Long
Sand placement on Pyramid Beach	$	$	Low	+	?	?	Short
Long term transportation							
Maintain two-way	$$$	$$$	Low	-	-	=	Short
One-way with Rec Trail	$	$	High	+	+	-	Medium
Relocate traffic keep Rec Trail	$	$	High	+	+	-	Long

Upfront Cost: relative construction cost ($$$ = High, $$ = Medium, $=Low)
Maintenance Cost: relative cost associated with the lifespan of the project ($$$ = High, $$ = Medium, $=Low)
Certainty of Success: certainty that measure will function as intended for its projected lifespan (High, Medium, Low)
Secondary Impacts: consequences associated with the adaptation that could affect the beach or coastal resources, coastal access, or parking and roads. Plus (+) refers to an improvement from existing conditions, Minus (-) refers to a deterioration from existing conditions, Equal (=) refers to a similar to existing condition
Lifespan: relative length of time the adaptation strategy functions (Short is <10 years, Medium is up to 30 years, and Long is 30+ years)

10.6.2 Zone 2—Almar Avenue to Lighthouse Field State Beach

Zone 2 of West Cliff Drive contains 27 different coastal armoring structures and 8 areas of erosion concern. Eight of these short term high hazard areas of erosion concern were also identified as high risk in the short term with erosion likely to impact the Recreational Trail and/or West Cliff Drive. The most severe is the sea cave near David Way which undermines the Recreational Trail and both lanes of traffic on West Cliff Drive. The remainder of these high risk areas are largely associated with failures in the soft bluff top sediments where the cliff edge is in close proximity to the Recreational Trail. There are two locations along this zone of West Cliff Drive where the curb-to-curb distance is less than 25 feet and traffic safety is already impaired (Figure 10-41). This zone is also the only one where West Cliff Drive residences can access their properties directly from West Cliff Drive.

Within the short term of the next 10 years, 11 of these coastal armoring structures are projected to fail and require attention, while 10 of the areas of erosion concern mapped are deemed high hazard and likely to erode. Many of these structures are revetments built on the beach and the top of the cliff that show signs of deterioration with many fugitive rocks contributing to the burial of the beach and reduction of coastal recreational and habitat resources. The heavily used beach at Mitchell's Cove provides an important beach access used for surfing, beach recreation, and marine safety.

Through the TAC and City department head process (Section 10.4), priorities were determined for short term coastal and transportation preferences (Figure 10-42), and long term coastal adaptation and transportation preferences (Figure 10-43). The preferences in the short term included cave fills, sand nourishment, groin construction, and habitat restoration. The preferences for long term coastal adaptation included retreating West Cliff Drive to one way or partial one way, elevating the bridge over Bethany Curve, construction of soil nail walls, and habitat restoration.

These various strategies were presented at a community open house, and members of the public were asked to prioritize their preferred adaptation alternatives for both the short term and long term (Table 10-8).

Community workshop priority adaptation responses for Zone 2 resembled those of Zone 1, with the highest priority short term coastal adaptation strategy placed on maintaining revetments, with 40 percent choosing this option, and in the long term, managed retreat, with close to 60 percent choosing this option (Figure 10-43A). The most highly prioritized short and long term transportation priority was identified as converting West Cliff Drive to one-way traffic while maintaining the recreation trail, with 55 percent choosing this option in the short term, and 45 percent choosing this for the long term (Figure 10-43B). Similar to other zones, over the long term the community placed an extremely high priority on maintaining the recreation trail for this section, with 40 percent of respondents identifying relocating traffic in order to keep the recreation trail as a priority. This left approximately 15 percent of respondents prioritizing vehicular traffic over the trail.

Figure 10-41. Short term priority areas for adaptation and management in Zone 2.

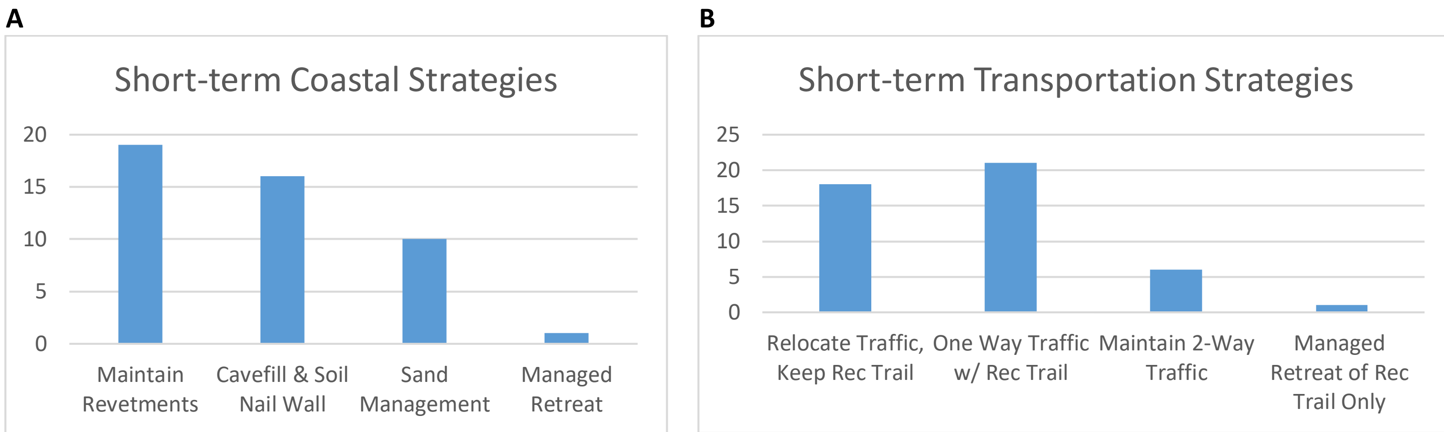


Figure 10-42. Short-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 2.

Longer term, projections of future coastal erosion, as well as existing mapped areas of erosion concern are likely to cause multiple disruptions to the West Cliff Drive corridor. In addition, erosion impacts could affect a critical wastewater pump station, as well as a low lying bridge near Woodrow Avenue at the mouth of the Bethany Curve Creek, which follows the alignment of the Ben Lomond Fault. This area already experiences substantial wave overtopping during high wave/high tide events, not currently documented by the City. This could be easily added to maintenance logs, or documented with a camera with a clear view of the area.

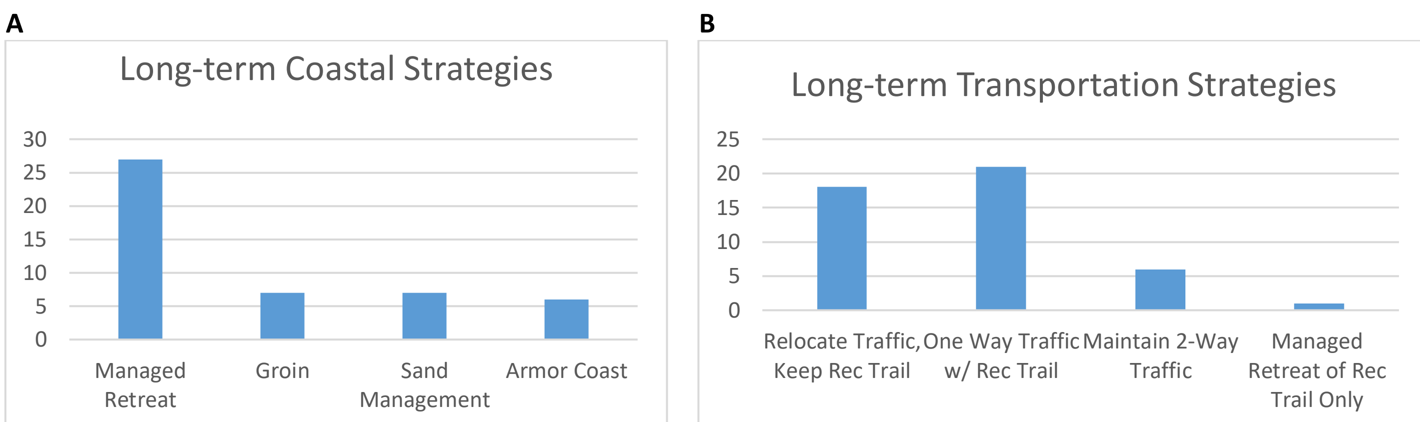


Figure 10-43. Long-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 2.

Continuing impacts associated with prior management decisions to protect with revetments will degrade coastal access, beach recreation, and surf recreation. Based on community input, TAC guidance, and City leadership priorities and all the other technical work, short and long term adaptation for the coast and transportation corridor are identified in Table 10-8.

Table 10-8. Prioritized short term and long term adaptation approaches for detailed conceptual design and cost benefit analysis in Zone 2

Zone 2	Cost		Certainty	Secondary Impacts			Lifespan
	Upfront	*Maintenance*		*Beach, Coastal*	*Rec Trail*	*Road*	
Short term adaptation							
Cave fill + Soil Nail Wall	$$$+	?	High	-	=	=	Medium
Sand management	$	$	Low	+	?	?	Short
Maintain revetments	$$	$	Medium	-	=	=	Medium
Short term transportation							
Maintain two-way	$	$$$	Low	-	-	=	Short
One way with Rec Trail	$$	$	High	+	+	-	Medium
Relocate traffic keep Rec Trail	$$$	$	High	+	+	-	Long
Long term adaptation							
Sand management	$	$	Low	+	?	=	Short
Groin	$$$	$	Medium	+	?	-	Medium
Managed Retreat	$	$	High	+	-	-	Long
Long term transportation							
Maintain two-way	$$$	$$$	Low	-	-	=	Short
One-way with Rec Trail	$	$	Medium	+	+	-	Medium
Relocate traffic keep Rec Trail	$	$	High	+	+	-	Long

Upfront Cost: relative construction cost ($$$ = High, $$ = Medium, $=Low)
Maintenance Cost: relative cost associated with the lifespan of the project ($$$ = High, $$ = Medium, $=Low)
Certainty of Success: certainty that measure will function as intended for its projected lifespan (High, Medium, Low)
Secondary Impacts: consequences associated with the adaptation that could affect the beach or coastal resources, coastal access, or parking and roads. Plus (+) refers to an improvement from existing conditions, Minus (-) refers to a deterioration from existing conditions, Equal (=) refers to a similar to existing condition
Lifespan: relative length of time the adaptation strategy functions (Short is <10 years, Medium is up to 30 years, and Long is 30+ years)

10.6.3 Zone 3—Lighthouse State Beach to Pelton Avenue at the Surfer Statue

Zone 3 of West Cliff Drive contains 7 different coastal armoring structures and 10 areas of erosion concern. Within the short term of the next 10 years, three areas of erosion concern were identified as high risk with erosion likely to impact the Recreational Trail and/or West Cliff Drive. These include a substantial sea cave at Lighthouse Point that could affect the Lighthouse and surf museum. In addition, several undercuts could likely undermine portions of the Recreational Trail. In Zone 3, none of the coastal armoring structures are projected to fail. However, many of the existing revetments create dangerous access conditions during high tides and require attention in the short term to remove slippery algae, and grout between rip rap to improve access. Four of the areas of erosion concern are deemed high hazard, and if they erode, would likely affect the Recreational Trail, parking, and potentially West Cliff Drive (Figure 10-44).

Through the TAC and City department head process (Section 10.4), priorities were determined for short term coastal and transportation preferences (Figure 10-45), and long term coastal adaptation and transportation preferences (Figure 10-46). The preferences in the short term included a one-way road restriction along West Cliff Drive and to retreat the lighthouse inland or to the historical location at Lighthouse Field. The preferences for long term coastal adaptation included to retreat West Cliff Drive into Lighthouse Field or merge into Pelton Avenue and maintain bike and pedestrian access along coast, move parking from the ocean side of West Cliff Drive at lighthouse point to the other side of road, and retreat the lighthouse further inland.

These various strategies were presented at a community open house, and members of the public were asked to prioritize their preferred adaptation alternatives for both the short term and long term (Table 10-9). This non-residential zone varied from the other three zones as a short term preference was placed on managed retreat rather than maintaining revetments. The most highly prioritized short and long term coastal adaptation strategy was managed retreat, with more than 45 percent prioritizing this option in the short term, and more than 80 percent prioritizing this in the long term. This represents a 20–30 percent higher favorability towards managed retreat in the long term over other zones (Figure 10-46). The most highly prioritized short and long term transportation priority was identified as converting West Cliff Drive to one-way traffic while maintaining the recreation trail, with close to 60 percent choosing this option in the short term, and more than 50 percent choosing this for the long term (Figure 10-46). Similar to other zones, over the long term, the community placed an extremely high priority on maintaining the recreation trail for this section, with 35 percent of respondents identifying relocating traffic in order to keep the Recreation Trail as a priority. This left approximately 12 percent of respondents prioritizing vehicular traffic over the trail. This zone represents the area with the highest community priority placed on managed retreat strategies and maintaining the recreation trail over vehicular traffic.

Figure 10-44. Short term priority areas for adaptation and management in Zone 3.

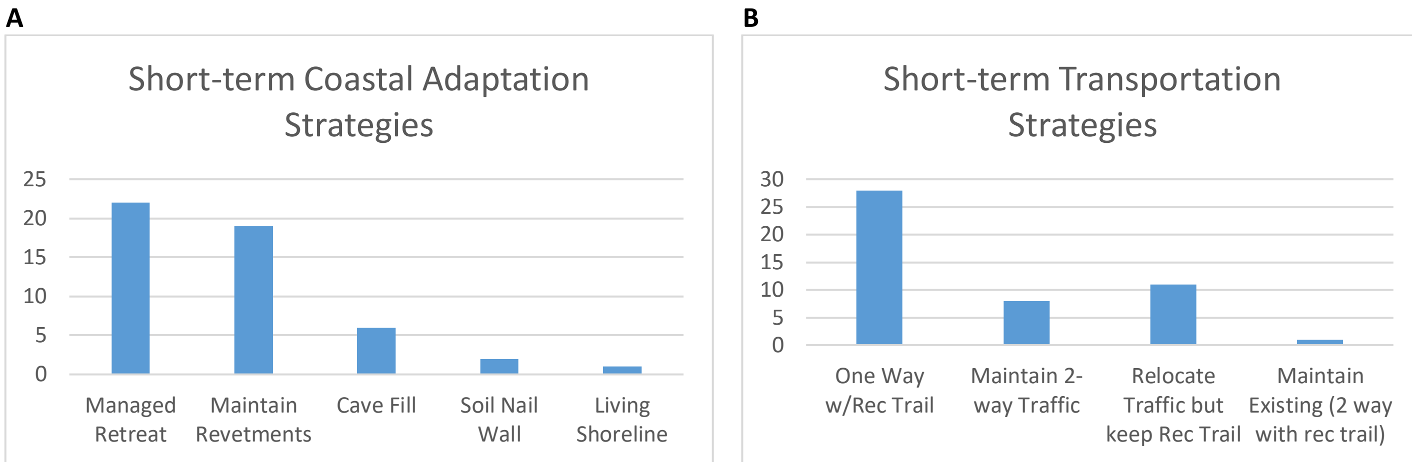


Figure 10-45. Short-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 3.

Longer term, projections of future coastal erosion as well as already mapped areas of erosion concern are likely to cause multiple disruptions to the West Cliff Drive corridor including loss of public parking. In addition, erosion impacts could affect a cultural landmark in the Mark Abbott Memorial Lighthouse.

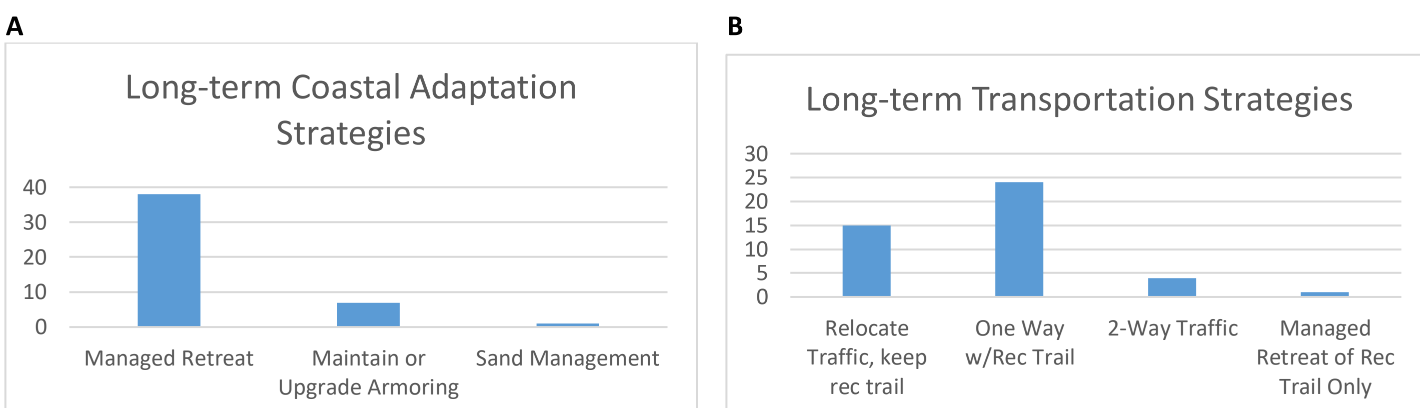


Figure 10-46. Long-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 3.

Continuing impacts associated with protecting with revetments are likely to impact and potentially destroy the world famous surf spot known as Steamer Lane. Based on community input, TAC guidance, and City leadership priorities, and the technical work short and long term adaptation for the coast and transportation corridor are identified in Table 10-9.

Table 10-9. Prioritized short term and long term adaptation approaches for detailed conceptual design and cost benefit analysis in Zone 3

Zone 3	Cost		Certainty	Secondary Impacts			Lifespan
	Upfront	*Maintenance*		*Beach, Coastal*	*Rec Trail*	*Road*	
Short term adaptation							
Cave fill	$$$+	?	High	-	=	=	Medium
Maintain revetments	$$	$	Medium	-	=	=	Medium
Managed Retreat	$	$	High	+	+	-	Long
Short term transportation							
Maintain two-way	$	$$$	Low	-	-	=	Short
One way with Rec Trail	$$	$	High	+	+	-	Medium
Relocate traffic keep Rec Trail	$$$	$	High	+	+	-	Long
Long term adaptation							
Managed Retreat	$	$	High	+	+	-	Long
Long term transportation							
Maintain two-way	$$$	$$$	Low	-	-	=	Short
One way with Rec Trail	$$	$	Medium	+	+	-	Medium
Relocate traffic keep Rec Trail	$$	$	High	+	+	-	Long

Upfront Cost: relative construction cost ($$$ = High, $$ = Medium, $=Low)
Maintenance Cost: relative cost associated with the lifespan of the project ($$$ = High, $$ = Medium, $=Low)
Certainty of Success: certainty that measure will function as intended for its projected lifespan (High, Medium, Low)
Secondary Impacts: consequences associated with the adaptation that could affect the beach or coastal resources, coastal access, or parking and roads. Plus (+) refers to an improvement from existing conditions, Minus (-) refers to a deterioration from existing conditions, Equal (=) refers to a similar to existing condition
Lifespan: relative length of time the adaptation strategy functions (Short is <10 years, Medium is up to 30 years, and Long is 30+ years)

10.6.4 Zone 4—Pelton Avenue and the Surfer Statue to Bay Avenue

Zone 4 of West Cliff Drive contains three different coastal armoring structures and four areas of erosion concern. Within the short term of the next 10 years, three areas of erosion concern were identified as high risk so when erosion does occur, it will likely impact the Recreational Trail, parking and/or West Cliff Drive. These locations are all associated with sea caves, with only one of them identified as a high hazard likely to fail in the short term. Presently, none of these coastal armoring structures are projected to fail nor require attention (Figure 10-47). This area however does have the highest traffic and Recreational Trail usage of the West Cliff Drive Corridor.

Through the TAC and City department head process (Section 10.4), priorities were determined for short term coastal and transportation preferences (Figure 10-48), and long term coastal adaptation and transportation preferences (Figure 10-49). The preferences in the short term included cave fills and to repair, replace, and add revetments. The preferences for long term coastal adaptation included to retreat West Cliff Drive and convert to one-way to prioritize the bike and pedestrian travel, and sea wall armoring strategies such as soil nail walls.

These various strategies were presented at a community open house, and members of the public were asked to prioritize their preferred adaptation alternatives for both the short term and long term (Table 10-10). The most highly prioritized short term coastal adaptation strategy was to maintain revetments, with close to 50 percent choosing this option, and the most highly prioritized long term coastal adaptation strategy was managed retreat, with 55 percent choosing this option (Figure 10-49). Construction of soil nail walls was also a high priority in the long term, with the remaining 45% of respondents choosing this option (Figure 10-49A). The most highly prioritized short and long term transportation adaptation priority was identified as converting West Cliff Drive to one-way traffic while maintaining the recreation trail, with 55 percent choosing this option in the short term, and 40 percent choosing this in the long term (Figure 10-49B). Similar to all other zones, over the long term the community placed an extremely high priority on maintaining the recreation trail for this section, with 40 percent of respondents identifying relocating traffic in order to keep the recreation trail as a priority. This left approximately 15 percent of respondents prioritizing vehicular traffic over the trail.

Figure 10-47. Short-term priority areas for adaptation and management in Zone 4.

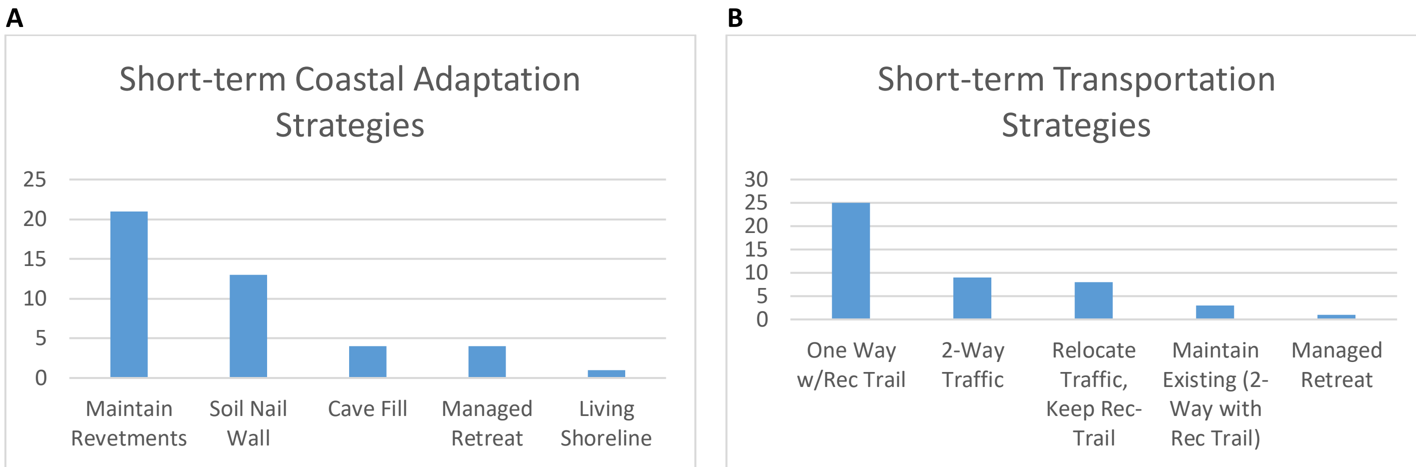


Figure 10-48. Short-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 4.

Longer term, projections of future coastal erosion, as well as already mapped areas of erosion concern are likely to cause multiple disruptions to the West Cliff Drive corridor including loss of public parking.

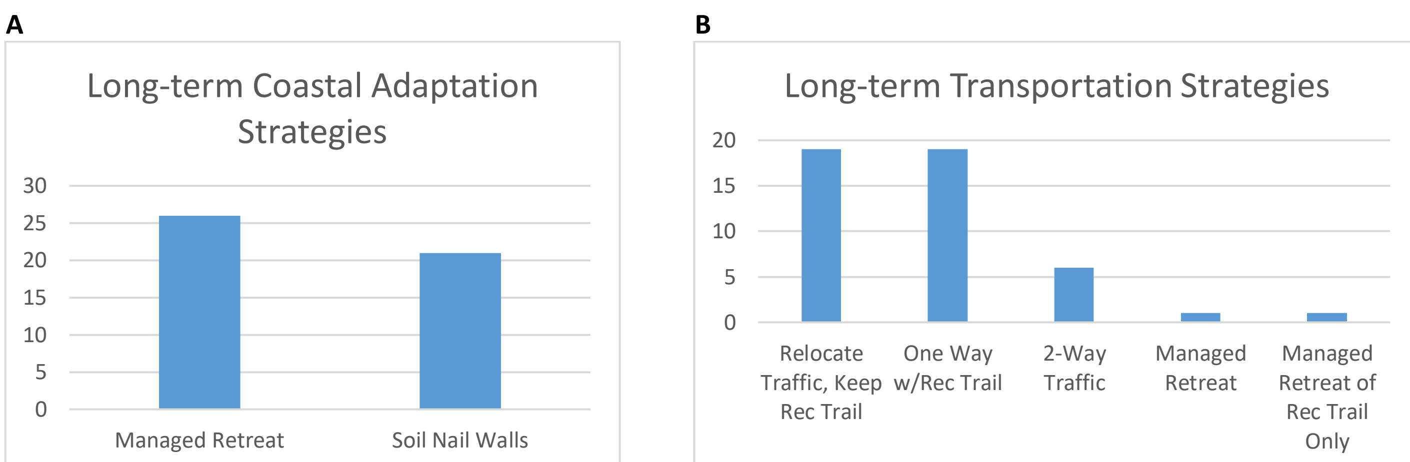


Figure 10-49. Long-term coastal adaptation strategies (A) and priority areas for transportation strategies (B) in Zone 4.

Continuing impacts associated with previously made adaptation decisions about protecting with revetments are likely to impact beach recreation and potentially degrade one of the key beginner surf spots, due to increased interaction of waves with the existing revetments at Cowells. Based on community input, TAC guidance, and City leadership priorities, short and long term adaptation for the coast and transportation corridor are identified in Table 10-10.

Table 10-10. Prioritized short term and long term adaptation approaches for detailed conceptual design and cost benefit analysis in Zone 4

Zone 4	Cost		Certainty	Secondary Impacts			Lifespan
	Upfront	*Maintenance*		*Beach, Coastal*	*Rec Trail*	*Road*	
Short term adaptation							
Cave Fill	$$$+	?	High	-	=	=	Medium
Maintain revetments	$$	$	Medium	-	=	=	Medium
Soil Nail Walls	$$$	?	High	-	=	=	Medium
Short term transportation							
Maintain two-way	$	$$$	Low	-	-	=	Short
One way with Rec Trail	$$	$	High	+	+	-	Medium
Relocate traffic keep Rec Trail	$$$	$	High	+	+	-	Long
Long term adaptation							
Soil Nail Walls	$$$	?	Medium	-	=	=	Medium
Managed Retreat	$	$	High	+	+	-	Long
Long term transportation							
Maintain two-way	$$$	$$$	Low	-	-	=	Short
One-way with Rec Trail	$$	$	Medium	+	+	-	Medium
Relocate traffic keep Rec Trail	$	$	High	+	+	-	Long

Upfront Cost: relative construction cost ($$$ = High, $$ = Medium, $=Low)
Maintenance Cost: relative cost associated with the lifespan of the project ($$$ = High, $$ = Medium, $=Low)
Certainty of Success: certainty that measure will function as intended for its projected lifespan (High, Medium, Low)
Secondary Impacts: consequences associated with the adaptation that could affect the beach or coastal resources, coastal access, or parking and roads. Plus (+) refers to an improvement from existing conditions, Minus (-) refers to a deterioration from existing conditions, Equal (=) refers to a similar to existing condition
Lifespan: relative length of time the adaptation strategy functions (Short is <10 years, Medium is up to 30 years, and Long is 30+ years)

The adaptation alternatives evaluated in this section have been initially screened and prioritized using community identified goals and evaluation criteria. Each of the prioritized adaptation alternatives will change the possible costs if the business as usual approach remained the status quo creating “avoided costs.” These avoided costs are defined as the benefits of adaptation and will be compared with the expenditures associated with each adaptation option. This comparison must be done in the context of the different possible sea levels that might occur. The objective is to find the alternatives whose benefits are most likely to exceed the costs for adaptation over different short-term and long-term time frames. Based on extensive community engagement this section has identified priority approaches to both coastal and transportation adaptation alternatives The goal of the West Cliff Drive Adaptation and Management Plan will be to select the least environmentally damaging adaptation alternative informed by the economically “best” alternatives defined by those with the largest net benefits and aligned with City goals, objectives, and priorities. The future cost–benefit analysis will be conducted in future stages of the project.

11 Adaptation Pathways, Monitoring, and Potential Triggers

11.1 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., offset from the cliff edge or elevation or rate of sea level rise) rather than a time (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 into the future is the time allowed for extensive feedback on future 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. By using monitored changes in physical conditions, triggers can be identified which catalyst planning processes with enough lead time to avoid emergency response. During this planning phase, the City can explore policies and projects needed to implement adaptation strategies, and design, permit, finance, and implement adaptation strategies before an emergency situation arises.

Currently, West Cliff Drive is largely following a protection strategy. However, over time, the wider range of protection, accommodation, and managed retreat strategies will likely be implemented to reduce vulnerabilities and adapt the West Cliff Drive corridor over time. Engaging the community in the adaptation pathways process can foster a 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, anticipated costs, that can be saved for in advance to promote community resiliency. The community priorities for further analysis for both coastal and transportation related approaches were identified in Section 10.6 based on an extensive stakeholder and community engagement described in Section 10.4. From this further analysis, a preferred set of adaptation pathways will be identified by zone based on the cost/benefit analysis and depicted in the conceptual designs developed in the next deliverable.

11.2 Triggers and Monitoring

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

In cases where short term coastal hazards pose an existing threat such as sea cave collapse, adaptation planning initiatives may be warranted regardless of future sea level rise, as adaptation implementation can take several years to implement and any amount of sea level rise could exacerbate existing coastal threats. Redesigning and changing the direction and use of traffic, for example, may take staff time to plan and develop followed by decision-maker approval—a process that may require a couple of years. However, other approaches such as relocating the Lighthouse or constructing a new bridge over Bethany Curve could take a decade or more.

Potential triggers need to be monitored and assessed to inform adaptation decisions, and triggers should be reevaluated and updated in the future to capture advances in sea level rise science and changing conditions. Figure 11-1 provides examples of various categories of triggers that can be used to develop adaptation pathways. Monitoring data can be collected by the City during routine maintenance activities, extracted from remote sensing data such as cameras, or collected in partnership with local research institutions such as USGS, NOAA, or UC Santa Cruz.

Triggers are an important component of the implementation of climate adaptation plans and pathways and help guide adaptation actions. If properly selected, triggers should identify an environmental or temporal signal that provides adequate time in which to plan for the anticipated hazard and take action. Well defined triggers can be an important tool in avoiding maladaptation (taking unplanned or emergency actions counter to the selected pathway) and can help prevent the premature implementation of costly adaptation actions. By defining trigger points early, needed data collection and research can be completed to better inform and guide future actions.

Triggers may be used to initiate adaptation strategies such as hard armoring policies as well as inform the modification, repair or removal of existing structures. These triggers may be determined by factors such as erosion and frequency of inundation. Triggers can also be developed to reflect societal pressures such as a decrease in a level of public service for a community.

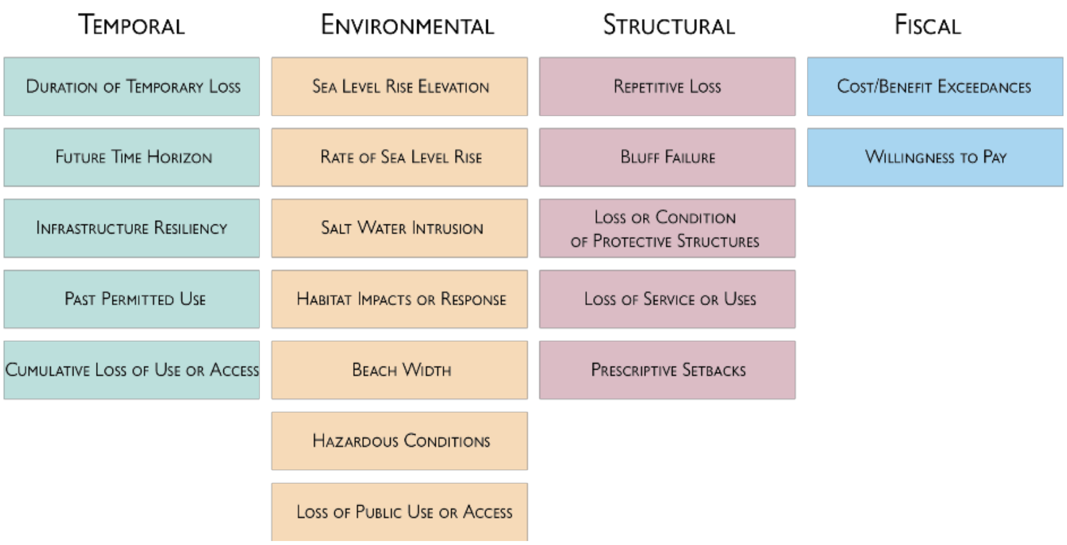


Figure 11-1. Example Triggers

Other examples of triggers may be an observed annual sea level rise above a certain elevation, erosion beyond a certain point, a higher than usual frequency of storms and inundation or costs beyond a certain amount. Triggers focused on repetitive loss or repair frequencies can help drive changes in adaptation strategies toward rolling erosion easements, increased elevation, or retreat strategies. Triggers can also be set by policy, limiting the use of one coastal protective measure (if that measure conflicts with adopted goals) longer than desired by the community.

Triggers should be related to easily observable and measurable changes, which must be monitored. Some monitoring actions can be easily and relatively inexpensively monitored or measured to minimize City costs and avoid high long term monitoring costs. Others may require sustained commitment in funding and partnership with local research institutes. Funding can come from grants, local crowd sourcing, in-lieu fees, or other financial instruments. There are several types of triggers and potential monitoring examples that may be useful to consider, such as:

- **By sea level rise elevation (or rate of sea level rise)**—The City is already vulnerable to hazards that may occur from an El Niño event or individual storms; however, sea level rise could increase the severity and impacts of these storms. Monitoring sea level from either the nearest NOAA tide gauge in Monterey (# 9413450) or by installing a local gauge, triggers could be tied to an elevation change from present conditions over a 6-month period (to avoid seasonal/El Niño signals) or a rate of sea level rise increase that would allow the City to implement further actions in advance of projected sea level rise impacts.

- **By physical distance**— routinely measure distance especially following storm or erosion events, such as when the distance between the ocean side of the Recreational Trail is within 8 feet of the cliff edge.
- **By planning year**—specify that by a future planning year (e.g., 2025), a long-range study identifying appropriate strategies must be complete (e.g., wastewater upgrade or transportation planning). The drawback of monitoring mechanisms based on planning year is that modeled projections of coastal hazards could occur sooner or later than a given year. This is better applied to review of policies when permits expire. But the regulatory agencies appreciate knowing when the City will reevaluate its adaptation approach and thus require periodic check-in.
- **By storm exposure and frequency**—monitor the frequency of exposure to wave action (e.g. how frequently does West Cliff Drive at Woodrow get exposed to wave action and require cleaning? To monitor the frequency of flooding, the City should track and record coastal flooding at Woodrow Avenue/Bethany Curve, including the date, location, type, and severity.
- **By damages**—identify structural damage levels that may require a reevaluation of adaptation approaches such as the damage to coastal armoring structures, erosion of the Recreational Trail.
- **By cost**—once the City spends $XX in total or $XX annually in maintenance, then additional steps need to be taken.
- **By net benefits**—the point identified in a detailed cost/benefit analysis where benefits for one adaptation approach exceed the cost of a previous approach. A monitoring example could be maintenance costs over time versus one-time relocation costs.
- **By number of incidences**—given the various bike/pedestrian/auto conflicts**,** perhaps the City could document injury incidences, and work toward creating more multi-modal space, for example when there are three injuries reported per month for 3 months between bikes and pedestrians.

Adaptation plans that utilize triggers selected in a robust manner are important to facilitating planning, which incorporates the inherent uncertainty (risk) surrounding the effects of climate change on coastal areas. Figure 11-2 below shows an example of a dynamic adaptation pathway framework developed using trigger points to initiate the development and implementation of plans and actions.

11.3 Trigger Preferences Based on the TAC and City Leadership Workshops

Various trigger preferences were discussed during workshops conducted with the Technical Advisory Committee and City leadership in February 2020 (Section 10.4). The survey provided to the TAC and DH, following the February workshops, asked respondents to recommend triggers to use as an indicator to move from preferred short term strategies to long term strategies. The following triggers were recommended for each West Cliff Drive Zone and will help inform potential triggers in the development of the Adaptation Pathways in future tasks. If the trigger was recommended by more than person, this is noted in parentheses. Triggers were introduced as a concept to the public during summer 2019 focus groups, at 2019-2020 one on one meetings with historically under-represented groups and to the general public at the March 5, 2020 public workshop. The TAC, City leadership and public will have another opportunity to weigh in on triggers as they are further developed.

Zone 1 (Natural Bridges to Almar Avenue)

- Repetitive loss (4)
- Loss of public use or access (3)
- Loss or condition of protective structures (2)
- Bluff failure (2)
- Structural (2)
- Cost/benefit exceedances (2)
- Cumulative loss of use or access (1)
- Ocean levels
- Structural failure of the revetment
- Cliff failure affecting the bike path or road
- Hazardous Conditions
- Beach width

Zone 2 (Almar Avenue to It's Beach)

- Cost/benefit exceedances (3)
- Loss or condition of protective structures (2)
- Cumulative loss of use or access (2)
- Infrastructure resiliency
- Repetitive loss
- Bluff failure
- Loss of use combined with duration of temporary loss
- Hazardous conditions
- Repetitive, serious damage to infrastructure
- Sea cave erosion that significantly undermines road
- Environmental
- Loss of public use or access
- Flood elevations
- Structural
- Prior to structural failure of existing bridge

Zone 3 (It's Beach to Pelton Avenue)

- Bluff failure (6)
- Loss of public use or access (4)
- Repetitive loss (2)
- Structural (2)
- Hazardous conditions
- Duration of temporary loss of use or access
- Erosion reaches a threshold point closer to the present lighthouse location
- Erosion of sea caves

Zone 4 (Pelton Avenue to Bay Avenue)

- Loss of public access or use (4)
- Bluff failure (3)
- Ocean levels (2)
- Structural (2)
- Financial feasibility
- Cumulative loss of use or access
- Loss of service or use
- Repetitive loss
- Stability of the bluff face & the surface below, near sea level
- Cliff or cave erosion event impacting road
- Loss or condition of cave fill
- Hazardous conditions

11.4 Changing Adaptation Paths

In an ideal world, a shift between adaptation paths would be guided based on a cross over point at which benefits for one adaptation approach exceed the cost of a previous adaptation approach. In the example shown in Figure 11-2, the decision to shift from maintaining revetments to a soil nail wall could be informed by triggers such as the beach width, or cost of maintenance to the revetments. A detailed cost/benefit analysis of the fiscal impacts of each approach provides an economic estimate for when that shift should be made. Identification of the adaptation pathways will then be used to further the development of the West Cliff Drive Adaptation and Management Plan.

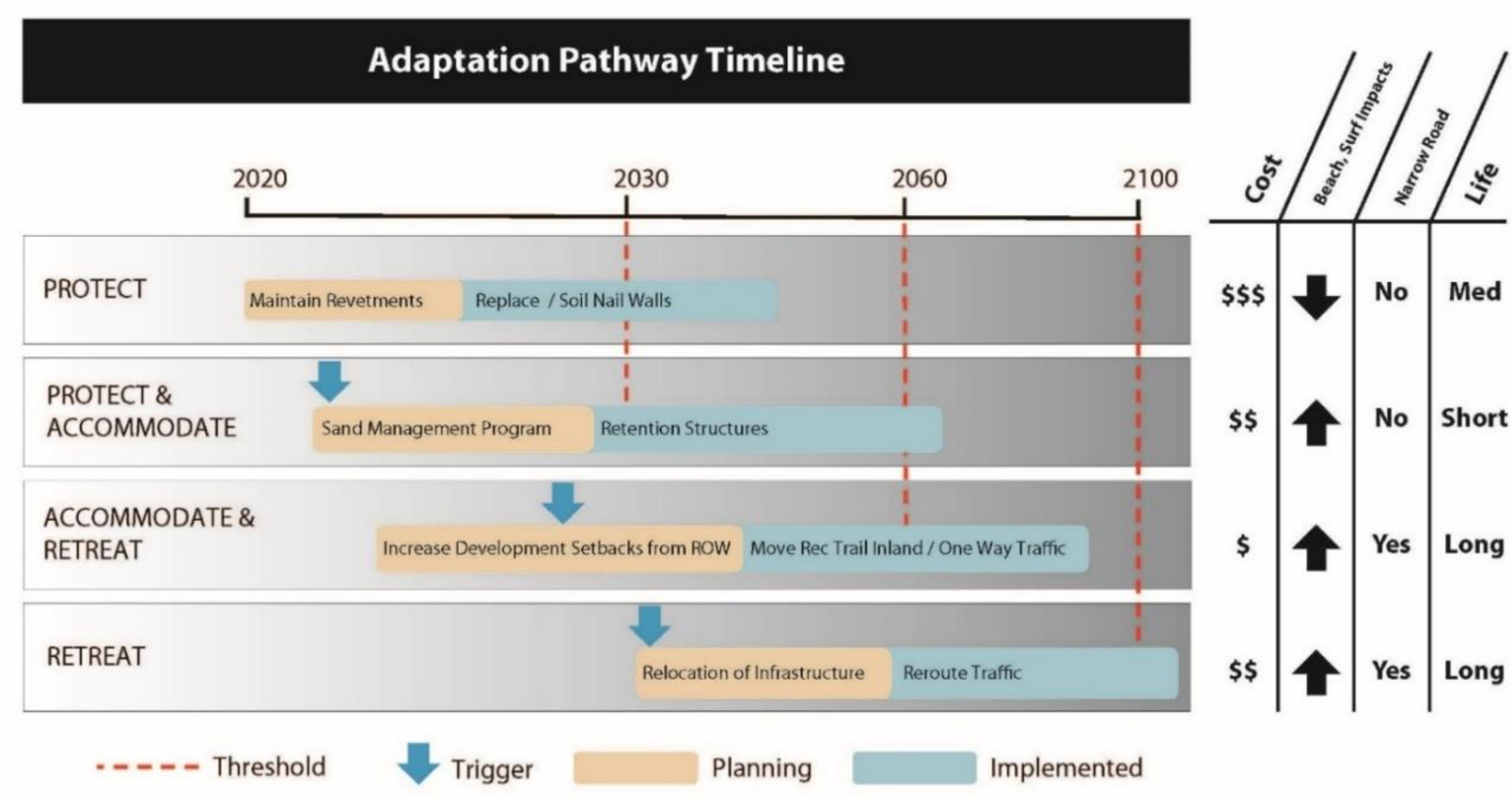


Figure 11-2. Hypothetical example of an Adaptation Pathway for West Cliff Drive