Council Agenda Report

To: Mayor Silverstein and the Honorable Members of the City Council

Prepared by: Farah Stack, Environmental Sustainability Analyst

Reviewed by: Yolanda Bundy, Community Development Director

Approved by: Rob DuBoux, Interim City Manager

Date prepared: February 4, 2026 Meeting date: February 23, 2026

Subject: Completion of the Coastal Vulnerability Assessment with Final List of Possible Adaptation Strategies Chapter

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RECOMMENDED ACTION: Receive and file the final Coastal Vulnerability Assessment prepared by Environmental Science Associates, including the final chapter outlining a range of potential adaptation recommendations to address sea level rise impacts.

FISCAL IMPACT: Funding for these services in the amount of $31,000, are included in the Adopted Budget for FY 2025-26 in Account No. 101-2004-5100 (Building Safety and Sustainability Professional Services).

STRATEGIC PRIORITY: This item supports the City's 2025 Strategic Plan Goal 3: Advance Infrastructure Resilience.

DISCUSSION: The Coastal Vulnerability Assessment ('Assessment") evaluates the impacts of projected sea level rise on the City's built and natural coastal resources. The Assessment was developed through a combination of: (1) analyzing scenarios (2) identifying vulnerable community assets (3) educating the community through GIS webpages depicting different sea level rise scenarios and (4) receiving feedback from the community. The final Assessment evaluates how the potential adverse effects of climate change (sea level rise, tidal inundation, storm flooding, and coastal erosion) will impact Malibu's assets along the coastline such as coastal residences, commercial development, public infrastructure, public beach access, coastal habitats, and water quality. The final report also includes coastal hazard maps for each sea level rise scenario evaluated.[1]

The report identifies vulnerabilities and consequences that the City can use to prioritize planning efforts to account for the urgency (time horizon) of individual impacts and the importance of each impact on the community and its resources. The final report contains coastal hazard maps for each sea level rise scenario and adaptation strategies. Further, these assessment measures will align with the California Coastal Commission's Sea Level Rise Policy Guidance.

The final chapter of the Assessment outlines a menu of potential adaptation strategies that may be suitable for addressing sea level rise impacts within Malibu. The strategies span a range of approaches, including natural and nature-based solutions, traditional structural measures, and non-structural measures such as policy, regulatory, and financial tools. These strategies, however, are not regulatory, adopted or funded actions, but rather are intended to help inform City planning efforts by identifying thresholds at which significant planning areas, assets, and coastal resources could be impacted by sea level rise.

At this time, there is no funding identified to support implementation or next steps related to the adaptation strategies. As such, staff is not requesting policy direction or action beyond approval of the final report. Staff recommend that the City Council receive and file the Assessment, including the final chapter describing potential adaptation recommendations, to formally complete the Assessment and document the City's coastal vulnerability analysis for future reference.

In the future, the Assessment and the included adaptation strategies will be used to inform amendments to the City's General Plan, Local Coastal Program, Municipal Code, and additional policies to ensure the City is implementing strategies and guiding development to protect and preserve Malibu's coastlines.

ATTACHMENTS:
1. Appendix F Potential Adaptation Measures Summary Matrix prepared by ESA
2. Final Coastal Vulnerability Assessment Report

[1] For background information on the Coastal Vulnerability Assessment, view October 13, 2025 City Council Agenda Report. (https://www.malibucity.org/AgendaCenter/ViewFile/Item/7639?fileID=84044)

Adaptation Measure	Applicability (Yes or No)	Engineering Feasibility	Environmental Benefit	Regulatory Feasibility	Social Benefit	Economic Cost
Beach Nourishment	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Beach nourishment increases beach width and can reduce coastal hazard impacts to backshore property and infrastructure and reduce bluff erosion.	**Medium** Frequently done in U.S. Primary challenge is identifying and authorizing compatible sand sources. Nourishment too close to lagoon mouth may impact tidal circulation.	**Medium** Short-term (construction-related) impacts to species and potential impacts to creek mouth conditions. Increases beach persistence and improves habitat function and ecosystem processes.	**Medium** Requires extensive review of sediment quality and construction/maintenance related impacts. Requires permits from multiple agencies.	**Medium-High** Can provide favorable beach access and recreation for general public. May result in temporary disturbance and loss of public access during placement.	**Medium** A typical beach nourishment can benefit multiple properties.
Temporary Sand Berms	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Beach sand is temporarily pushed into berms in front of exposed beachfront facilities (parking lots, public structures, lifeguard facilities, etc).	**High** Frequently done on LA County beaches, including Zuma Beach. Accomplished with a single piece of equipment.	**Medium** Short-term (construction-related) impacts to species. May protect habitats behind berm.	**Medium** If sand is imported, requires extensive review of sediment quality and construction/maintenance related impacts. Requires permits from multiple agencies.	**Medium** May result in temporary disturbance and loss of public access during construction and disturbance during implementation. Can also temporarily impact coastal views.	**Medium Low** The cost is relatively low to shape temporary sand berms on the beach compared to importing sand.
Vegetated Dunes	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Where sufficient space is available, dunes can be expanded and/or built along the back beach to reduce coastal hazard impacts.	**Medium-High** Have been constructed in Malibu and elsewhere, require sufficient beach space. Reconstruction will likely be needed after extreme events and after years of exposure. Pedestrian access must be coordinated to maintain vegetation which helps stabilize the dunes.	**High** Short-term (construction-related) loss of species abundance & richness. Enhances ecosystem processes leading to improved habitat function and greater overall biodiversity.	**Medium** Importing sediment requires extensive review of sediment quality and construction/maintenance related impacts. Requires permits from multiple agencies.	**Medium-High** Can improve, diversify, and maintain beach access and recreation for the public. May result in temporary disturbance and loss of public access during construction.	**Medium** Cost depends on size of dunes. May require more frequent maintenance with sea level rise and increased storms.
Cobble-Gravel Berms	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Cobble berms function as natural dynamic revetments and can be used with or without landward dunes to reduce coastal hazard impacts to backshore development and bluffs.	**Medium** Have been constructed elsewhere, important consideration is source of the cobble material needed. Will require reconstruction over time without natural cobble source.	**Medium** Short-term (construction-related) and potential long-term loss of species abundance & richness. Provides potential long-term increase in intertidal, supratidal, and foredune habitat & species diversity.	**Medium** Similar considerations to "Vegetated Dunes", but includes cobble in addition to sand, which would require additional review.	**High** Can maintain beach access and recreation for the public. Exposed cobble during winter/storms can affect access to water, however sand/ beach anticipated to rebuild during summer. May result in temporary disturbance and loss of public access during construction.	**Medium** Depending on alongshore length, cobble-gravel berms (CGB) could benefit many properties.
Artificial Headlands and Outcrops	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Artificial headlands function similar to groins and could be used to stabilize the beach on either side of the feature.	**Medium-High** Traditional coastal engineering structure with well-developed design guidance. Effectiveness depends on spacing and length and number of groins. Can increase downcoast erosion and flood exposure.	**Medium** Short-term (construction-related) impacts to shoreline. Maintains beach fillets on either side that benefit sandy shoreline habitats.	**Medium** Artificial headlands are a newer adaptation concept that has not yet gone through the regulatory process in California. See Oceanside REBEACH for pilot project example.	**Medium** Can maintain fillet beach on upcoast side of headland, but may also result in downcoast beach width effects.	**Medium-High** Cost information is limited for these new shoreline concepts, and may be comparable to or greater than groin construction, depending on the size of structures.
Artificial Reefs	**Tidal Inundation Coastal erosion Groundwater Fluvial Flooding Coastal Flooding Wave run-up** Artificial reefs (nearshore) can reduce wave impacts to the shoreline and increase retention of sandy beach behind the reef.	**Medium** Long term stability is dependent on hard substrate (scour/settling likely at sandy bottom applications). Likely requires maintenance over time for storm impacts and sea level rise.	**Medium-High** Short-term (construction-related) loss of habitat. Potential long-term increase in intertidal, supratidal, and foredune habitat & species diversity .	**Medium** Artificial reefs are not permitted frequently but there is a new wave of interest. Requires permits from multiple agencies.	**Medium-High** Benefits public by maintaining salient beach behind reef. Multi-purpose reefs may provide surfing and diving resources.	**High** Complex construction and high volume of materials needed depending on depth/size of structure.

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Color Key – Red performs worse, green performs better:

Worse Better

Adaptation Measure Category:	Natural and Nature-based Measures	Traditional Structural Measures	Regulatory and Financial Measures

Attachment 1

Adaptation Measure	Applicability (Yes or No)	Engineering Feasibility	Environmental Benefit	Regulatory Feasibility	Social Benefit	Economic Cost
Submerged Aquatic Vegetation (SAV) Restoration	**Tidal Inundation Coastal erosion** **Groundwater Fluvial Flooding** **Coastal Flooding Wave run-up** Kelp, eelgrass and surfgrass restoration can benefit coastal ecosystem functions but in most cases does not appreciably reduce coastal flooding or erosion impacts.	**High** Kelp and eelgrass restoration feasibility demonstrated in Santa Monica Bay. However, kelp restoration does not significantly reduce coastal flooding or erosion impacts.	**High** Benefits marine ecosystem functions.	**Medium** Requires permits from multiple agencies.	**High** Can enhance marine recreational activities including snorkeling, free diving, and SCUBA.	**Medium** Cost depends on restoration approach/methods and extent. Kelp restoration does not significantly reduce coastal flooding or erosion.
Ecotone Levees	**Tidal Inundation Coastal erosion** **Groundwater Fluvial Flooding** **Coastal Flooding Wave run-up** Ecotone levees may be applicable for limited low lying areas around Malibu Lagoon where space allows.	**High** Demonstrated feasibility in San Francisco Bay if sufficient upland space for implementation. Flat slopes attenuate wave energy and reduce erosion.	**Medium** Short-term (construction-related) and permanent loss/conversion of existing habitat, depends on how much existing wetland is impacted. Provides a fringe of marsh and ecotone with space to migrate with sea level rise.	**Medium** Can require extensive impact analysis and engineering if habitat is impacted. Requires permits from multiple agencies. Requires Monitoring and Adaptive Management Program.	**Medium-High** More gradual transition slopes associated with ecotone levees can support public access and hiking trails for recreation/access along wetland areas.	**Medium-High** Ecotone levees can provide benefits along multiple properties. Cost to implement is greatly affected by viable space: relocating/modifying development and infrastructure to make room for ecotone levees can be costly.
Coastal and Riparian Wetland Restoration and Sediment Management	**Tidal Inundation Coastal erosion** **Groundwater Fluvial Flooding** **Coastal Flooding Wave run-up** Restoring wetlands around lagoons and creeks can improve flood resilience and water quality while supporting biodiversity. Sediment augmentation is used to maintain wetland habitat elevations with sea level rise.	**Medium-High** Feasibility depends on the level of existing development and infrastructure that would need to be relocated/removed to restore wetland areas. Restoration is otherwise relatively straightforward and can help to reduce flood and erosion hazards to nearby development.	**High** Short-term (construction-related) loss of habitat. Provides improved water quality, protects anadromous fish habitat, reduces debris from property damage, potentially increases freshwater aquifer recharge.	**Medium** Requires review and approval by multiple local and federal agencies. Requires extensive impact analysis and engineering.	**Medium** Benefits public by maintaining long-term access. Can temporarily impact public access and facilities during flood event.	**Medium** Cost depends on various factors including existing fill and development/infrastructure to be removed for restoration. Sediment management costs vary depending on sediment source and method of delivery/placement.
Living Coastal Armoring	**Tidal Inundation Coastal erosion** **Groundwater Fluvial Flooding** **Coastal Flooding Wave run-up** Living coastal armoring can provide the same protective measures as sea walls or revetments while also providing additional design features that provide ecological benefits.	**Medium** Relatively new concept, feasibility may be limited by product availability. Effective until exceeded by increasing water levels and wave heights with sea level rise. Can increase erosion and flood exposure in adjacent areas locations without additional measures.	**Medium** Short-term (construction-related) and permanent loss/conversion of existing habitat. Protects open space behind structure, provides habitat along structure.	**Low** Similar to coastal armoring, requires extensive impact analysis and demonstration that other less impactful alternatives are not feasible. Requires permits from multiple agencies.	**Low** Can increase erosion and flood exposure in other locations where no measures exist and can lead to loss of fronting beach and limit alongshore access. Exposed revetments are dangerous to cross to access the shore without additional access facilities. May result in temporary disturbance and loss of public access during construction.	**High** Living coastal armoring can protect individual properties/structures or extend along multiple properties. Cost may be high depending on type of structure used (e.g. revetment or seawall type).
Breakwaters	**Tidal Inundation Coastal erosion** **Groundwater Fluvial Flooding** **Coastal Flooding Wave run-up** Breakwaters are constructed parallel to shore to block or dampen wave energy from reaching the shoreline.	**Medium** Traditional coastal engineering structure with well-developed design guidance. Effective until exceeded by increasing water levels and wave heights with sea level rise. Can lead to increased erosion and flood exposure in other locations.	**Medium** Short-term (construction-related) and permanent loss/conversion of existing subtidal habitat, depends on what habitats are impacted. Potential benefits to beach ecology along the shoreline protected in the breakwater shadow	**Low** Requires extensive impact analysis and demonstration that other less impactful alternatives are not feasible. Requires permits from multiple agencies, more complicated for work in water.	**Medium-High** Benefits public by maintaining salient beach behind breakwater. Multi-purpose breakwaters may provide surfing and diving resources. May lead to adverse downcoast effects on beaches without management.	**High** May benefit longer stretches of shoreline and multiple properties depending on distance offshore and length. Breakwaters require a large volume of material.

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Adaptation Measure Category:	Natural and Nature-based Measures	Traditional Structural Measures	Regulatory and Financial Measures

Adaptation Measure	Applicability (Yes or No)	Engineering Feasibility	Environmental Benefit	Regulatory Feasibility	Social Benefit	Economic Cost
Groins	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Groins are perpendicular structures typically built in series to create cells alongshore to slow sediment transport and create small cells that ideally retain sandy beach.	**Medium-High** Traditional coastal engineering structure with well-developed design guidance. Effectiveness depends on spacing and length and number of groins. Can increase downcoast erosion and flood exposure if the groin cells are not nourished as part of initial construction.	**Medium** Requires review and approval by multiple local and federal agencies. Requires extensive impact analysis and engineering.	**Low** Requires extensive impact analysis and demonstration that other less impactful alternatives are not feasible. Requires permits from multiple agencies.	**Medium** Benefits public by maintaining beach fillets and/or cells between groins, however groins may impact alongshore access depending on beach width conditions and groin geometry.	**Medium-High** Groin fields may benefit longer stretches of shoreline and multiple properties. Cost can be relatively high depending on size/geometry requirements and number of groins.
Rock revetments	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Rock revetments can be used to protect oceanfront structures and property from coastal flood and erosion hazards.	**Medium-High** Traditional coastal engineering structure with well-developed design guidance. Effective until exceeded by increasing water levels and wave heights with sea level rise. Can increase erosion and flood exposure in adjacent areas locations without additional measures.	**Low** Short-term (construction-related) and long-term loss of species and habitat diversity. Provides limited low-quality habitat for select bird species. Impacts to threatened snowy plover overwintering along armored shorelines.	**Low** Requires extensive impact analysis and demonstration that other less impactful alternatives are not feasible. Requires permits from multiple agencies.	**Low** Can increase erosion and flood exposure in other locations where no measures exist and can lead to loss of beach seaward of the structure and limit alongshore access. Exposed revetments are dangerous to cross to access the shore if access facilities are not built. May result in temporary disturbance and loss of public access during construction.	**Medium-High** Rock revetments can protect individual properties/structures or extend along multiple properties.
Seawalls (new or upgrade existing)	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Seawalls can be used to protect oceanfront structures and Pacific Coast Highway from coastal hazard impacts.	**Medium-High** Well-developed traditional coastal engineering structure with design guidance. Effective until exceeded by increasing water levels and wave heights with sea level rise. Less resilient than rock revetments due to renovation requirements. Can increase erosion and flood exposure in other locations without measures.	**Low** Short-term (construction-related) and long-term loss of species and habitat diversity. Potentially protects habitat behind seawall from storm surge but can lead to loss of beach seaward of the structure and impact threatened snowy plover overwintering along armored shorelines	**Low** Requires extensive impact analysis and engineering. Requires permits from multiple agencies.	**Low** Can lead to loss of beach seaward of the structure and limit alongshore access. Exposed seawalls are difficult/ dangerous to cross to access the shore if access facilities are not built. May result in temporary disturbance and loss of public access during construction.	**High** Seawalls can protect individual properties/structures or extend along multiple properties.
Floodwalls and Levees	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Traditional levees, berms and floodwalls can be used to reduce flooding impacts to low lying properties near creeks and lagoons in Malibu.	**Medium** Traditional coastal engineering structure with design criteria. Primary challenge is stability of subgrade. Resilience limited to the extent that adaptive capacity built into design.	**Low** Causes permanent loss of existing habitat, increases flow and erosion, reduces in-channel and floodplain habitat diversity. Protects open space behind levee, provides potential limited habitat along levee if native plants are used.	**Low** Requires extensive impact analysis and engineering. Requires permits from multiple agencies.	**Low** Steeper levees/berms are more difficult to traverse, and may also require armoring that further hinders access. Can affect visual coastal access by blocking public views of the creek/lagoon.	**Medium- High** A levee/berm can protect individual properties/structures or extend along multiple properties.
Structural Elevation	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Elevating low lying structures above the floodplain can reduce impacts during lagoon, creek and/or coastal wave run-up flooding events. Low roadways can be reconstructed at higher elevations with either imported fill or vertical support such as piles.	**Medium** Frequently implemented in the U.S., effective up to design flood levels and wave conditions. Additional considerations regarding wind loads and vehicular and utility access. Drainage would need to be carefully designed, and adjacent roads and other infrastructure may need modifications to maintain connectivity.	**Medium-High** Elevating on piles increases sediment deposition, reduces debris from property destruction, provides limited habitat under and around structures. Raising on fill increases building or roadway footprint. Can be environmental impacts if there is fill of sensitive habitats.	**Medium-High** Buildings would be implemented by private property owners on a parcel-by-parcel basis. Requires County building permit, CDP, and others. May require changes to municipal code requirements. Requires extensive coordination, planning, and permitting. Roads in Malibu include both public and private.	**Medium** Elevating buildings may be cost burden to low-income homes and buildings. Can result in increased flood exposure and risk for nearby homes and assets that are unable to elevate.	**Medium- High** Elevating structures is accomplished on an individual building basis at cost to the owner. Elevating roads benefits multiple properties.

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Adaptation Measure	Applicability (Yes or No)	Engineering Feasibility	Environmental Benefit	Regulatory Feasibility	Social Benefit	Economic Cost
Floodproof structures and infrastructure	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Non-residential buildings can be floodproofed (e.g. sealed) in place to reduce flooding impacts. FEMA floodplain insurance regulations do not allow residential buildings to be floodproofed.	**Medium** The technology exists and can be applied in some cases for non-residential structures. Effective up to a maximum water level that can be accommodated, however floodproofing is not allowed for residences or areas with wave runup.	**Medium** Can reduce need for flood control structures, allowing more space for natural ecosystem and processes.	**Medium** Would be implemented by property owners on a parcel-by-parcel basis. Requires County building permit, CDP, and others. May require changes to municipal code requirements. Not allowed for residential buildings in FEMA Zone A flood zone, not allowed in wave runup Zone V.	**Medium-High** May be cost burden to low-income homes and buildings. Redirecting water can result in increased flood exposure and risk for nearby homes and assets that are unable to elevate or waterproof.	**Medium Low** Waterproofing structures is accomplished on an individual building basis at cost to the owner.
Raise grades	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Low lying properties can be elevated above flooding elevations with imported fill material.	**Medium** Standard engineering and construction. Effectiveness depends on existing development, space for fill slopes, drainage and slope stability and subsidence potential.	**Medium-Low** Can increase flooding of adjacent habitats, potentially causing displacement of wildlife. Improves wave attenuation and increases transition zone habitat if hybrid approach with horizontal levee.	**Medium** Changes to drainage and impacts from construction, maintenance and conversion of habitat would require thorough analysis. Local permits required include: County grading permit	**Medium** Raising parking/public park grades preserves public access and recreation. Can increase flood exposure and risk to surrounding homes and assets that are unable to elevate or waterproof.	**Medium** Raising grades can be accomplished on an individual property basis or for public areas. Cost may be higher for constrained areas that require earth retention structures.
Stormwater management systems	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Stormwater management systems can be used in conjunction with coastal or riverine barriers to convey stormwater that becomes trapped behind a flood barrier.	**Medium** Frequently used with predictable performance. Often require maintenance for sediment removal and may have water quality implications. Typically requires substantive modification with sea level rise. Primary concerns are location and operation/ maintenance costs. Must be designed to accommodate sea level rise.	**Medium** Maintains connection between stormwater drainage and receiving waterbody. Pumping can cause erosion and water quality effects in outflow areas.	**Medium-High** Requires extensive impact analysis and engineering. May require long and complex permitting process involving multiple agencies.	**Medium-High** Removing trapped stormwater can prevent or lessen flooding of public infrastructure. May cause noise disturbance.	**Medium** Implementation can benefit individual or multiple properties, depending on the associated barrier.
Groundwater management systems	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Dewatering wells and other groundwater management can be used to manage rising groundwater in low lying areas to limit impacts to homes, utilities, septic treatment, etc.	**Medium** Feasibility assessed on a site specific basis. Concerns include consolidation of soil and subsidence, and pump capacity. Operations and maintenance costs are also considerations.	**Medium** Potential habitat impacts due to discharge of any polluted groundwater to the marine environment. Dewatering could impact habitat near creeks. Maintains function and treatment effectiveness of septic systems, decreases pollution of surrounding environment.	**Medium-Low** Groundwater pumping effluent discharge would require thorough analysis of environmental and water quality impacts.	**Medium-High** Limited impact to social equity and public access. Dewatering to maintain adequate wastewater treatment would reduce potential discharge of undertreated wastewater via groundwater seepage to wetlands/beach.	**Medium** Dewatering wells can benefit individual or multiple properties. Cost to implement ranges depending on substrate conditions and the number of wells needed to manage groundwater levels for an area.
Onsite wastewater treatment systems (OWTS) modification	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Aging and/or low-lying OWTS will require update or replacement to continue providing adequate treatment.	**Medium-Low** Technology and capabilities to implement exist. Limited by depth to groundwater and other factors. OWTS are less feasible with sea level rise without other measures to manage flooding/groundwater.	**Medium** Reduces groundwater pollution from septic failures or overflows into nearshore marine ecosystem.	**Medium** Work typically done by individual property owners. Requires permits from multiple agencies.	**High** Compared to no action, maintaining effective wastewater treatment reduces pollution related impacts to public health. May be cost burden to low-income homes and buildings.	**Medium** OWTS upgrades are accomplished on an individual property basis.
Community wastewater treatment system	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** A community system can replace individual septic systems to provide more dependable and effective wastewater treatment.	**Medium-High** Technology and capabilities to implement exist. Requires participation by multiple property owners and collection infrastructure (pipes and pump stations). Malibu recently implemented Phase 1 of its Civic Center Water Treatment Facility.	**High** Reduces groundwater pollution from septic failures or overflows into nearshore marine ecosystem, increases groundwater filtration, soil permeability, and water quality.	**Medium** Would involve extensive design, planning, and coordination. Requires permits from multiple agencies.	**High** Compared to no action, maintaining effective wastewater treatment reduces pollution related impacts to public health.	**Medium-High** Implementation of a community wastewater treatment system benefits multiple properties while eliminating OWTS repair/service costs.

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Modify utilities and stormwater infrastructure	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Buried, on ground, or other low lying utilities and stormwater infrastructure may need to be upgraded/ replaced to reduce impacts from regular inundation and storm flooding.	**Medium** Largely dependent on the conditions of existing utilities and cost to modify, as well as the cooperation of residents and utility agencies.	**High** Reduces debris and/or releases caused by coastal infrastructure destruction.	**Medium** Could be implemented by owners and/or agencies at multi-properties scale. Requires permits/review from utility companies/agencies. Local permits required include CDP.	**Medium** Applied to public park facilities, maintaining public amenities preserves recreation services. May be cost burden to low-income homes and buildings.	**Medium** Utility modifications can be accomplished at the individual property level or occur at a multi-properties scale.
Managed removal and realignment	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Managed removal/realignment moves structures and infrastructure out of coastal hazard areas.	**Medium** Can be very effective depending on available adjacent space to realign landward/upward or relocating elsewhere.	**High** Reduces need for protective structures, enhances/restores natural processes, habitats, and wildlife.	**Medium** Requires extensive planning, coordination, and legal review. May require land acquisition and/or changes to local zoning, ordinances, or policies. Requires permits from multiple agencies.	**Medium-High** Removal or relocation of exposed development or other infrastructure away from the beach or wetland interface restores natural morphology of the beach or wetland and the access and recreational amenities it provides. Requires close coordination with infrastructure managers and home owners.	**Medium-High** The cost to realign public infrastructure depends on the infrastructure type and available space/design requirements based on conditions at the new location. Includes demolition and reconstruction/relocation as well as modifications to utilities as needed.
Zoning and Overlay Zones	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Overlay zones may add restrictions onto existing zoned areas related to flood or erosion preparedness.	**High** Would primarily apply to new structures and redevelopment of existing structures.	**High** Depending on the nature of the zoning district, could reduce need for protective structures, enhance/restore natural processes, habitats, and wildlife.	**High** Extensive legal review would be required.	**High** Could prevent damage by restricting new development in high-risk areas.	**Varies** There could be significant administrative costs to developing, approving and implementing/enforcing zoning and avoiding takings claims.
Building Codes and Retrofits	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Building codes regulate new construction to help development withstand flooding. For the existing built environment, building retrofits may be imposed by ordinance, through an overlay zone, or may be implemented by incentives instead of regulation.	**High** Depends on implications to existing structures and the need to modify or retrofit structures.	**High** Depending on the nature of the building code, could reduce need for protective structures, enhance/restore natural processes, habitats, and wildlife.	**Medium** Extensive legal review could be required.	**High** Could prevent damage by restricting new development and/or retrofitting existing development in high-risk areas.	**Varies** There could be significant administrative costs to developing, approving and implementing/enforcing building codes.
Setbacks and Buffers	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Setbacks and buffers require development is located a certain distance from hazardous areas (i.e. the shoreline or bluff edge).	**High** Depends on implications to existing structures and the need to modify or relocate structures to maintain setback/buffer.	**High** Reduces need for protective structures, enhances/restores natural processes, habitats, and wildlife.	**Medium** Extensive legal review required. May require local zoning, ordinances or policy changes.	**Medium-High** Maintaining natural beach or wetland interface would allow natural morphology of the beach or wetland and the access and recreational amenities it provides. Requires close coordination with infrastructure managers and homeowners.	**Varies** Cost relatively minor compared to some of the other land use planning tools. The largest cost is likely analysis to determine the setback distance. Also, there may be significant administrative costs to implementing/enforcing setbacks and avoid takings claims.
Buyouts	Tidal Inundation, Coastal erosion Groundwater, Fluvial Flooding Coastal Flooding, Wave run-up Purchasing vulnerable properties like high-risk beachfront parcels.	**High** Depends on implications to existing structures and the need to relocate or remove development following buyout.	**High** Reduces need for protective structures, enhances/restores natural processes, habitats, and wildlife.	**Medium** Extensive legal review required. May require local zoning, ordinances or policy changes. Relocation or rebuilding may require many local permits and applications.	**High** Maintaining natural beach or wetland interface would allow natural morphology of the beach or wetland and the access and recreational amenities it provides.	**Varies** Cost depends on property value and any additional action required (demo, relocation, etc). Also, there may be significant administrative costs to implement buyouts and avoid takings claims.

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Adaptation Measure Category:	Natural and Nature-based Measures	Traditional Structural Measures	Regulatory and Financial Measures

Adaptation Measure	Applicability (Yes or No)	Engineering Feasibility	Environmental Benefit	Regulatory Feasibility	Social Benefit	Economic Cost
Tax Incentives and Special Assessments	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Tax policy could be used to create incentives and disincentives for various land uses and the location of development. Special assessments are fees added to property taxes to pay for benefits that serve the whole area or district that pays these fees.	**Not Applicable**	**High** Depending on the nature of the tax incentive / special assessment, could provide funding for protective structures, enhance/restore natural processes, habitats, and wildlife.	**Medium** Extensive legal review could be required.	**Medium-High** Could provide financing for neighborhood scale adaptation, including habitat restoration.	**Varies** Cost depends on property value and any additional action required. Also, there may be significant administrative costs to implement.
Geologic Hazard Abatement Districts	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Geologic Hazard Abatement Districts (GHAD) are independent governmental districts that can assess properties within a defined area and dedicate the revenue to abating or controlling hazards such as landslides, earthquakes, and erosion. GHADs have been used in parts of Malibu including Broad Beach.	**Not Applicable**	**High** Depending on the nature of the GHAD, could provide funding for protective structures, enhance/restore natural processes, habitats, and wildlife.	**Medium** Extensive legal review could be required.	**Medium-High** Could provide financing for neighborhood scale adaptation, including habitat restoration.	**Varies** Cost depends on property value and any additional action required. Also, there may be significant administrative costs to implement.
Conservation and Rolling Easements	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Legal agreements to preserve public access and allow landward migration of beaches.	**Not Applicable** Depends on implications to existing structures and the need to modify or relocate structures to maintain easement.	**High** Reduces need for protective structures, enhances/restores natural processes, habitats, and wildlife.	**Medium** Extensive legal review required. May require local zoning, ordinances or policy changes. Relocation or rebuilding may require many local permits and applications.	**High** Maintaining natural beach or wetland interface would allow natural morphology of the beach or wetland and the access and recreational amenities it provides.	**Varies** Cost depends on property value and any additional action required (demolition, relocation, etc). Also, there may be significant administrative costs to implement setbacks and avoid takings claims.
Transfer of Development Rights	**Tidal Inundation** **Coastal erosion** **Groundwater** **Fluvial Flooding** **Coastal Flooding** **Wave run-up** Zoning incentives to redirect development from hazard-prone areas to safer zones.	**Not Applicable** Depends on implications to existing structures and the need to modify or relocate existing structures following TDR implementation.	**High** Reduces need for protective structures, enhances/restores natural processes, habitats, and wildlife.	**Medium** Extensive legal review required. May require local zoning, ordinances or policy changes. Relocation or rebuilding may require many local permits and applications.	**High** Maintaining natural beach or wetland interface would allow natural morphology of the beach or wetland and the access and recreational amenities it provides.	**TBD** Costs are uncertain.

Criteria Rating Key (low to high): A high rating under engineering, environmental, regulatory and social criteria means the adaptation measure performs better, while high rating under economic cost means the measure performs worse.
Color Key – Red performs worse, green performs better:

Worse Better

Adaptation Measure Category:	Natural and Nature-based Measures	Traditional Structural Measures	Regulatory and Financial Measures

Final

1BCoastal Hazard Vulnerability Assessment, City of Malibu

Prepared for
City of Malibu

February 2026

Attachment 2

Final

0B1BCoastal Hazard Vulnerability Assessment, City of Malibu

Prepared for
City of Malibu

February 2026

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EXECUTIVE SUMMARY

Introduction

Climate change and sea level rise are projected to impact communities across the globe. Many communities are working to understand and prepare for potential impacts to their homes, businesses, built infrastructure and the natural environment. In California to date, nearly four dozen coastal jurisdictions from Del Norte County to San Diego County have completed vulnerability assessments to understand the potential effects of sea level rise and related hazards.

This Coastal Vulnerability Assessment was undertaken to begin to plan for measures to reduce the potential future vulnerability of the City's built and natural coastal resources to projected sea level rise. The assessment analyzes coastal hazards including tidal inundation, shoreline and bluff erosion, and extreme coastal storm flooding. The study evaluates the potential impacts and vulnerabilities in Malibu under the following sea level rise (SLR) scenarios that include recommended timeframes for planning purposes based on best available science and guidance (see Data Collection below and Section 2.1):

- Existing Conditions
- 2.5 feet sea level rise (projected 2070-2075)
- 6.6 feet sea level rise (projected 2100-2130)

This Coastal Vulnerability Assessment is intended to inform public and private stakeholders and decision-makers of the potential impacts of sea level rise and support the identification and analysis of adaptation measures that avoid or reduce impacts from coastal hazards.

Study Area

The study area includes Malibu's shoreline that stretches approximately 22.6-miles from Nicholas Canyon County Beach to Topanga Beach and includes the lower Trancas and Zuma canyons and low-lying areas around Malibu Lagoon. The Malibu coastline consists of a series of bluffs backed by the Santa Monica Mountains that are interspersed with stream and river canyons that transition to coastal floodplain areas and sandy beaches, including the lower Trancas and Zuma canyons and low-lying areas around Malibu Lagoon.

Beaches in Malibu are mostly narrow and exist around the mouths of streams and local bluff alcoves except for the widest stretch of beach along Zuma Beach. Malibu's coastline was filled with approximately 1.3 million cubic yards of soil for the construction of Highway 1 in the 1920s (Noble 2010), which covered much of the narrow beaches and dunes that existed along the coast. Today, Malibu's coastline is largely developed by residential and commercial properties that occupy much of the historic beach and dune areas and extend up the bluff face and top in many areas.

Several LA County beaches are located within Malibu and include Nicholas Canyon, El Sol, Zuma, Latigo Shores, Dan Blocker, Las Tunas, and Topanga Beaches. State beaches within Malibu include the Robert H. Meyer State Beaches (El Pescador, La Piedra, El Matador Beaches), Point Dume, Malibu Lagoon, Malibu Surfrider (a World Surfing Reserve) and Las Tunas Beaches. These beaches are supported by infrastructure including parking, restrooms and other amenities, lifeguard towers, and maintenance yards.

Historic Flooding Events and Existing Conditions in Malibu

Malibu has experienced impacts from numerous coastal storm events over the past few decades that included flooding and erosion damages. The Malibu coastline is most vulnerable to swells coming from southern hemisphere storms that typically arrive outside of the winter storm season. These swells can be very damaging because they typically are long crested and powerful, and the south facing coastline has direct exposure. Typical winter storm swells that come from the northwest are blocked by the Channel Islands. Past years of the biggest swells (southern swells in bold) include: **August 19, 1969**, December 1969, **May 1975**, January 1993, April 2004, March 2005, **July 2009**, **September 2011, September 2014, August 2020, August 2021, July 2022**, January 2023 (L. Doyel, pers. com. February 2023). In the late fall and winter of 1982/83, California experienced an El Niño that produced significant precipitation, strong winds, and high surf along the southern California coast. The storms damaged a Paradise Cove Pier, eroded beaches and coastal cliffs, destroyed homes above the beach, and caused flooding in creek and river systems. Other notable El Niño seasons occurred in 1988, 1998, and 2010. Most recently, the Adamson House property was damaged in 2019. Malibu oceanfront properties are also subject to tidal inundation during high tides that occur monthly (spring tides) to yearly (king tides).

Due to the coastal flooding and erosion impacts that have occurred in Malibu, several adaptation measures have been implemented to reduce vulnerabilities to coastal hazards along the City's shoreline. Numerous beach nourishment projects have been completed in Malibu including Las Tunas Beach (1960-1974) and Zuma Beach (1979). Coastal armoring structures such as seawalls and rock revetments cover approximately 31% of the coastline in Malibu. Los Angeles County Department of Beaches and Harbors regularly constructs temporary beach sand berms to reduce winter flooding of the lifeguard facilities, restrooms, and maintenance yard in the Zuma Beach parking lots.

Data Collection

Sea level rise scenarios for the vulnerability assessment are defined based on California State guidance (OPC 2024) and evaluated using available hazard mapping data with some adjustments as needed. The sea level rise scenarios are listed in Table ES-1 below. Coastal vulnerabilities in the City were analyzed for existing sea level, 2.5 feet (0.75 m) of sea level rise, and 6.6 feet (2 m) of sea level rise. The timing of potential impacts for these sea level rise scenarios was determined from using projections that are recommended for community planning studies. The first date is generally consistent with the High sea level rise scenario (recommended for evaluating the most risk averse projects such as major transportation infrastructure), while the later date is consistent with the Intermediate sea level rise scenario (recommended for residential projects and community planning efforts such as this study). Data collection is discussed further in Section 2 of this report.

Table ES-1. Malibu Sea Level Rise Scenarios Evaluated

Scenario	Sea level Rise (feet)	Sea level Rise (meters)	Date Range
Existing conditions	0	0	Now
Mid Century	2.5	0.75	2070 - 2075
Late Century	6.6	2	2100 - 2130

NOTE: Date range presents timing of sea level rise based on the latest projections for High sea level rise (sooner date) and Intermediate-high sea level rise (later date) from OPC 2024., see Table 2-1.

Available spatial data were collected for the built and natural assets in the City of Malibu. Many of these assets are currently or may potentially become exposed to tidal inundation, storm flooding and wave run-up, and erosion due to sea level rise. Spatial data for assets in Malibu were processed and overlaid in GIS with sea level rise hazard layers to assess vulnerability. The data sources for each asset class are listed in **Appendix A.** Maps showing built and natural assets in Malibu are provided in **Appendix B**. Spatial datasets were obtained for the following asset categories:

Communication - Communication Towers

Critical Facilities and Services - Fire, Public Offices, Lifeguards

Development: Buildings, armoring structures

Ecology - Environmentally Sensitive Habitat Areas (ESHA), Wetlands, Beaches

Energy - Electrical Meters

Recreation and Visitor-Serving - Parks and Open Space, Piers, Hiking Trails, Beaches, Coastal Access Points

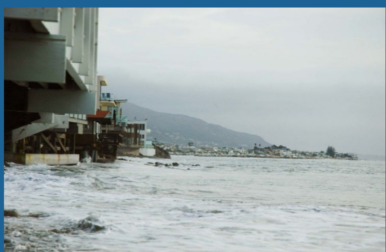
Transportation – Bridges, Fueling Stations, Roads and Highways, Parking Lots

Water – Sewers/Sewer Treatment, Stormwater

Not all assets within Malibu are represented by existing spatial datasets. Data gaps include natural gas and communications infrastructure (internet, phone utilities) as well as drinking water and local wastewater infrastructure. Septic systems are used for all beachfront properties and a large percentage of development in Malibu in general, but information on septic systems was not readily available for this study.

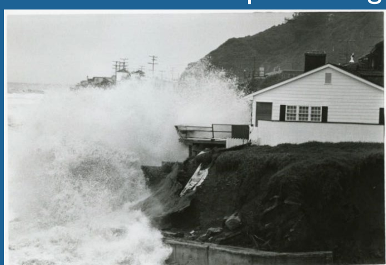
COASTAL HAZARDS AND VULNERABILITY METHODS

Tidal Inundation



Source: LA Waterkeeper

Storm Wave Runup/Flooding



Source: Pepperdine University

Erosion

Source: KBUU News

The following coastal hazard zones were mapped for the vulnerability assessment:

> **Tidal inundation (non-storm) and groundwater levels**

- Extent of monthly spring high tides with existing topography in Malibu. Low lying areas that are adjacent to but disconnected from tidal areas by high ground are considered in this study as surrogates for areas that may experience potential groundwater issues due to high tides. Some portions of the City around Malibu Lagoon are below the tidal inundation and storm flooding elevations, but are not directly connected to the ocean or areas inundated by high tides. These disconnected low-lying areas may be subject to groundwater issues or storm flooding

> **Storm flooding from a 100-year coastal storm event**

- The storm flooding hazard zone represents areas flooded during a 100-year coastal storm event. This zone includes low areas flooded by wave overtopping and Trancas, Zuma and Malibu Creek flows (i.e., modest creek flooding occurring during a 100-year coastal storm event). USGS CoSMoS mapped 100-year coastal storm flooding in Malibu considering a large southern swell (deepwater wave height of 20 to 22 feet).
- The storm waves hazard zone represents the landward limit of wave run-up during the 100-year coastal storm.

> **Coastal erosion**

- Shoreline and beach erosion due to ongoing coastal processes and future sea level rise. These projections of shoreline erosion are also used to compute beach width changes due to sea level rise.
- Bluff erosion from sea level rise and terrestrial processes

Available data from the U.S. Geological Survey's (USGS) Coastal Storm Modeling System (CoSMoS) show that Malibu's beaches and many oceanfront properties behind them are exposed to extreme coastal storm flooding and wave run-up at today's current sea level. CoSMoS results show that various facilities and structures along Zuma Beach (e.g. Lifeguard station, helipad, other buildings and parking lots) are exposed to extreme coastal wave run-up. Around Malibu Creek and Lagoon, most of the Malibu Colony properties, the golf course, and a section of Highway 1 are also shown to be exposed to coastal storm wave run-up hazards, while properties adjacent to Malibu Creek are exposed to storm flooding. Several areas west of Malibu Creek are also shown to be low lying and potentially flooded (areas are at elevations below the adjacent projected storm flooding water levels in the creek, while some smaller areas are identified as below tidal elevations).

The sea level rise **vulnerability** of each asset category to a given hazard was analyzed based on the asset **exposure** (i.e. whether and when it is impacted by coastal hazards), the asset **sensitivity** (i.e. whether hazard damages the asset or caused other consequences), and **adaptive capacity** (i.e. can the asset be easily modified, relocated or removed to reduce hazard impacts).

Sea level rise Vulnerability Summaries

With projected sea level rise, Malibu's vulnerabilities to coastal flooding and erosion are projected to increase. There are many assets shown as currently exposed to flooding and erosion hazards in the coastal zone that are protected to experience greater hazard impacts without action. There are also many assets that are shown as not being currently subject to coastal hazards, but may become exposed under projected future conditions. The sections that follow summarize key vulnerabilities in Malibu.

Critical Facilities and Infrastructure

Critical infrastructure in Malibu includes Lifeguard Towers and the Station at Zuma Beach, which may need modification/relocation to avoid erosion and flooding impacts with sea level rise. Several stretches of Highway 1 are vulnerable to late century hazards including bluff erosion or coastal storm flooding and wave run-up (along Zuma Beach, Dan Blocker County Beach, Puerco Beach and Carbon Beach). Several fire hydrants may be exposed to coastal flooding and erosion with sea level rise. Other important infrastructure includes a sewer pump station at the east end of Subarea A that may be exposed to coastal erosion with sea level rise. In addition, beachfront parcels may also experience issues with onsite septic systems due to rising groundwater levels with sea level rise. Failure of septic systems may result in discharge of untreated wastewater, poor local water quality and adverse impacts to human health and the environment.

Development

Vulnerable development in Malibu includes beachfront and blufftop homes and businesses, much of which are currently armored and/or elevated. With sea level rise, development on the beaches or lower bluffs may be subjected to coastal erosion and flooding more frequently, leading to property damages and degradation of existing coastal armoring structures. Some oceanfront property and buildings may become impacted by tidal inundation depending on floor elevation and configuration of utilities beneath structures. Shore and bluff erosion may impact upland property and structures. By late century, much of the commercial area west of Malibu Creek and lagoon is vulnerable to coastal storm flooding and regular inundation by spring tides.

Access roads to beachfront development may become exposed to erosion with sea level rise, while Malibu Colony Road may also be subject to tidal inundation and coastal storm flooding.

Beaches

Many of the narrow beaches along the Malibu coast may disappear with sea level rise, impacting shore ecology and recreation. Beaches in Malibu mostly exist as narrow stretches along beachfront homes, coastal bluffs and Hwy 1, with wider beaches exist at Zuma/Westward Beach, Point Dume State Beach, and Malibu Surfrider Beach. Today, approximately one quarter of beaches in Malibu may disappear annually from seasonal fluctuations alone; nearly two thirds may disappear annually by mid century. Beaches may cease to recover along coastal armoring and other hardened shorelines without action; beaches will disappear as sea levels rise if development is protected in place and beaches are not allowed to migrate inland. The disappearance of beaches in Malibu would adversely impact ecological functions along the coastline as well as recreation opportunities for Malibu residents and visitors.

Toolbox of Potential Adaptation Measures

There exist many adaptation measures (tools) that can be used to address the sea level rise vulnerabilities identified in this study. In fact, many adaptation measures are employed today to deal with existing coastal hazards along the coast of Malibu (see Section 1.2.3). Specific strategies for adaptation may vary depending on the area and assets in question and range from protect (fortify assets as is), accommodate (modify assets in current location to maintain resilience), and retreat (move assets away from hazards). Several agencies and groups are engaged in sea level rise planning activities that affect the Malibu coastline; notable agencies and efforts are summarized for context. A toolbox of potential adaptation measures was compiled and includes a range of individual measures from traditional engineering approaches such as shoreline armoring and structural elevation to nature-based measures such as dune restoration and other living shoreline concepts like artificial reefs and headlands. General next steps for adaptation planning in Malibu include progressing ongoing studies and efforts such as beach nourishment and living shorelines as well as other activities. Ultimately, Malibu City Council will provide direction to City staff on next steps regarding sea level rise adaptation.

Section 1

INTRODUCTION

Future sea level rise is expected to create a permanent rise in ocean water levels that will shift the water's edge landward. If no action is taken, higher water levels would increase erosion of the beach and bluff, cause a loss of sand, and result in a narrower beach. Additionally, the combination of higher ocean water levels and beach and bluff erosion would result in greater flooding and damage during coastal storms.

Climate change and sea level rise are projected to impact communities across the globe. Many communities are working to understand and prepare for potential impacts to their homes, businesses, built infrastructure and the natural environment. In California to date, nearly four dozen coastal jurisdictions from Del Norte County to San Diego County have completed vulnerability assessments to understand the potential effects of sea level rise and related hazards.

This Coastal Vulnerability Assessment was undertaken to begin to plan for measures to reduce the potential future vulnerability of the City's built and natural coastal resources to projected sea level rise. The assessment analyzes coastal hazards including tidal inundation, shoreline and bluff erosion, and extreme coastal storm flooding. The assessment projects the potential impacts and vulnerabilities in the City of Malibu due to potential sea level rise (SLR) by mid-century (2070-2075) and late century (2100-2130). This Coastal Vulnerability Assessment is intended to inform public and private stakeholders and decision-makers of the potential impacts and support the identification and analysis of SLR adaptation measures to avoid or reduce the impacts.

1.1 Study Area

The shoreline in the City of Malibu stretches approximately 22.6-miles from Nicholas Canyon County Beach at the west to Topanga Beach at the east. The geography in Malibu consists of coastal bluffs backed by the Santa Monica Mountains that are interspersed with stream and river canyons with low-lying sandy beaches and backshores, including the lower Trancas and Zuma canyons and low-lying areas around Malibu Lagoon. Backshores are areas of a beach that extend inland from the limit of high water to the extreme inland limits of the beach, including bluffs and dunes that are in the coastal floodplain now or may be in the coastal floodplain in the future with projected erosion and sea level rise. Backshore areas are typically only affected by waves during exceptional high tides or severe coastal storms and southern swell events.

Beaches in Malibu are mostly narrow and exist around the mouths of streams and local bluff alcoves except for the widest stretch of beach along Zuma Beach. Malibu's coastline was filled with approximately 1.3 million cubic yards of soil for the construction of Highway 1 in the 1920s (Noble 2010), which covered much of the narrow beaches and dunes that existed along the coast. Today, Malibu's coastline is largely developed by residential and commercial properties that occupy much of the historic beach and dune areas.

Several LA County beaches are located within Malibu and include Nicholas Canyon, El Sol, Zuma, Latigo Shores, Dan Blocker, Las Tunas, and Topanga Beaches. State beaches within Malibu include the Robert H. Meyer State Beaches (El Pescador, La Piedra, El Matador Beaches), Point Dume, Malibu Lagoon, Malibu Surfrider (a World Surfing Reserve) and Las Tunas Beaches. These beaches are supported by infrastructure including parking, restrooms and other amenities, lifeguard towers, and maintenance yards.

Sub-areas were defined for the Coastal Vulnerability Assessment (**Figure 1-1**). It is useful to define sub-areas in Malibu to properly characterize the range of shoreline typology (e.g. low beach, tall bluff, lagoon), wave exposure, geomorphic processes, and level/type of development. These factors together determine what sea level rise adaptation measures are appropriate for a given area. Potential adaptation measures for these areas will be discussed in the next phase of this project. **Table 1-1** lists the five sub-areas that define Malibu's coastline including the extents of each, type(s) of development, shore morphology type, and existing assets.

Table 1-1. City of Malibu Sub-areas

Sub-area	Extents	Shore Development Types	Shore Morphology Types	Assets
A	Nicholas Canyon County Beach to Point Lechuza *3.9 mi shoreline, 0.4 mi armored*	Mixed developed and natural blufftop	• Bluff-backed beach	• Residential development • Nicholas Canyon County Beach, Robert H. Meyer State Beaches (El Pescador La Piedra, El Matador), Lechuza Beach
B	Point Lechuza to Point Dume *3.9 mi shoreline, 0.8 mi armored*	Developed beachfront and blufftop Recreational beach backshore	• Beaches and coastal lagoon • Bluff-backed beach • Bluff headland	• Residential development • Pacific Coast Highway, Zuma Parking (Emergency Shelter Location) • Broad Beach, Trancas Creek, Zuma Beach and Lagoon, Westward Beach/Point Dume State Beach
C	Point Dume to Escondido Beach *3.2 mi shoreline, 0.2 mi armored*	Natural and developed blufftop – Developed beachfront	• Bluff headland • Bluff-backed beach	• Residential development • Paradise Cove • Point Dume State Beach and Nature Preserve, Big Dume State Beach
D	Escondido Beach to Malibu Lagoon State Beach *6.1 mi shoreline, 2.8 mi armored*	Developed blufftop and beachfront Developed floodplain around Malibu Lagoon Public road	• Beach • Bluff-backed beach • Coastal lagoon, adjacent and upstream wetlands	• Residential development • Malibu Village Commercial Center • Pacific Coast Highway • Adamson House and Malibu Lagoon Museum, Malibu Pier • Malibu Lagoon State Beach, Malibu Point, Malibu Surfrider Beach, Dan Blocker Beach, Corral Canyon Beach
E	Malibu Surfrider Beach to Topanga Beach *5.4 mi shoreline, 2.9 mi armored*	Developed beachfront Public road	• Sandy beach • Rocky and armored shores • Developed backshore	• Commercial and residential development, • Pacific Coast Highway • Carbon, La Costa, Las Flores, Big Rock, and Las Tunas Beaches, Topanga State Beach

Figure 1-1. City of Malibu Sub-areas

[11” by 17” figure to be inserted in final PDF]

1.2 Historic Flooding Events and Existing Conditions

Malibu is currently vulnerable to tidal inundation, storm flooding, wave overtopping and direct wave impacts, and shoreline and bluff erosion. In the past, extreme coastal flood events have caused significant damage along the coastline. This section describes significant extreme coastal flood events that have occurred since the 1970s, as well as recent king tides and erosion events. Events are characterized based on news and technical reports. In the future, coastal impacts from these types of events will increase in intensity and frequency due to sea level rise and climate change, as discussed in Section 3.

1.2.1 Coastal Storms

Malibu has experienced impacts from numerous coastal storm events over the past few decades that included flooding and erosion damages. The Malibu coastline is most vulnerable to swells coming from southern hemisphere storms that typically arrive outside of the winter storm season. These swells can be very damaging because they typically are long crested and powerful, and the south facing coastline has direct exposure to wave impacts and wave overtopping. Typical winter storm swells that come from the northwest are screened out by the Channel Islands. Past years of the biggest swells (southern swells in bold) include: **August 19, 1969**, December 1969, **May 1975**, January 1993, April 2004, March 2005, **July 2009**, **September 2011, September 2014, August 2020, August 2021, July 2022**, January 2023 (L. Doyel, pers. com. February 2023). The January 2023 swell did not cause very much damage because it came from the west northwest, even though it was notably one of the largest swells in the last 7 years. In the late fall and winter of 1982/83, California experienced an El Niño that produced significant precipitation, strong winds, and high surf along the southern California coast. The storms damaged coastal structures, eroded beaches and coastal cliffs, and caused flooding in creek and river systems. Waves damaged the Paradise Cove Pier and caused shoreline and cliff erosion that damaged buildings along the Malibu coastline (**Figure 1-2**). Some homes constructed on pier foundations above the beach were destroyed. Erosion from large surf stripped the sand away from beaches and exposed the underlying rock in many locations. Other notable El Niño seasons occurred in 1988, 1998, and 2010. Most recently, the Adamson House property was damaged in 2019 as high water levels and wave run-up caused erosion and loss of a 100-year old palm tree (**Figures 1-3** and **1-4**).

Source: Pepperdine University Digital Archives

Figure 1-2. Photos from the 1983 El Niño showing the damaged Paradise Cove Pier (left) and wave overtopping along the shore (right)

Source: KBUU News

Figure 1-3. Photos taken after Spring 2019 show a fallen 100-year old palm tree and property damage from erosion at the Adamson House (left) and beach erosion in front of the Lifeguard Station at Surfrider Beach (right)

Source: ESA

Figure 1-4. Photos taken in July 2019 show fallen palm tree (left) partially buried by the recovered beach and remaining erosion damage (right) at the Adamson House.

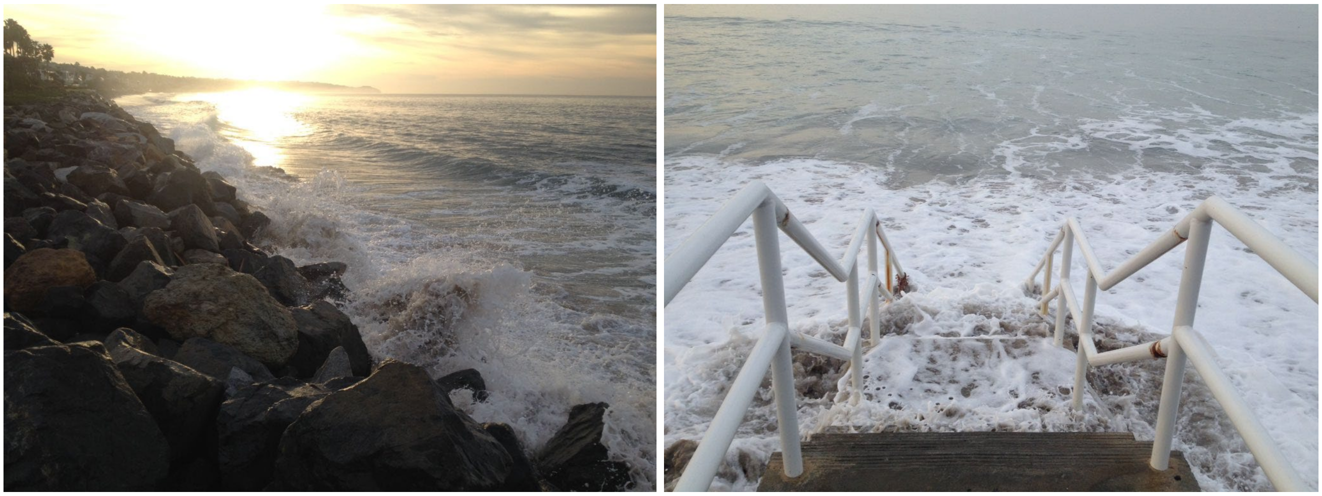
1.2.2 King Tides

King tides refer to the highest tides of the year, which occur naturally and predictably when the gravitational pull of the sun and moon align. King tides provide an example of future conditions with sea level rise, since they are higher than typical tides. The California King Tides Project[1] is an initiative that has documented recent king tides around the country, including Malibu. **Figures 1-5** and **1-6** below show king tide conditions in 2012 and 2016, respectively, which appear on the King Tides Project website.

Source: LA Waterkeeper via https://www.coastal.ca.gov/kingtides/gallery.html

Figure 1-5. King tide inundation beneath homes along Malibu Road in 2012

[1] Learn about the CA King Tides Project at www.coastal.ca.gov/kingtides/learn



Source: LA Waterkeeper via https://www.coastal.ca.gov/kingtides/gallery.html

Figure 1-6. King tide conditions at Broad Beach along the revetment (left) and at a beach access point (right) on January 22, 2016

1.2.3 Existing Adaptation Measures

Due to coastal flooding and erosion impacts that have occurred along the Malibu coastline, adaptation measures have been implemented to reduce vulnerabilities to coastal hazards along the City's shoreline. Future adaptation planning studies can evaluate the impacts that adaptation measures themselves may have to beaches/sand supply, public access and recreation, habitats, and the City's tourism economy.

<u>Beach Nourishment:</u> Historically, sediments from various sources have been used to nourish beaches. Las Tunas Beach was nourished with 50,000 cubic yards of suitable fill from 1960-74 and Zuma Beach received 22,000 cubic yards in 1979. In 2010, an emergency permit was granted to build a rock revetment wall to protect homes along Broad Beach. The permit is no longer valid and the property owners have proposed the Broad Beach Restoration Project that proposes importing 300,000-600,000 cubic yards of sediment to widen the beach.

<u>Coastal Armoring:</u> Shoreline protection through seawalls or other armoring can reduce flooding and erosion impacts behind them. Today, approximately 31% of the Malibu coastline is protected by coastal armoring structures such as rock revetments and sea walls of various materials including concrete, timber, rock and combinations thereof. While sea walls and revetments provide protection to existing shoreline development, these structures can contribute to erosion and accelerate beach loss. An inventory of shoreline protective devices was developed in 2005 by NOAA for the entire California coastline, including a GIS database of structures. ESA updated the shoreline armoring extents along Malibu for this study by interpreting recent aerial imagery and

oblique shoreline photography from the California Coastal Records project[2]. Existing shoreline protection devices in Malibu range from timber walls and old cemented rubble to engineered rock revetments and concrete seawalls, as shown in **Figure 1-7** below. **Figure 1-8** shows the extents of existing shoreline protective devices along the Malibu coastline.

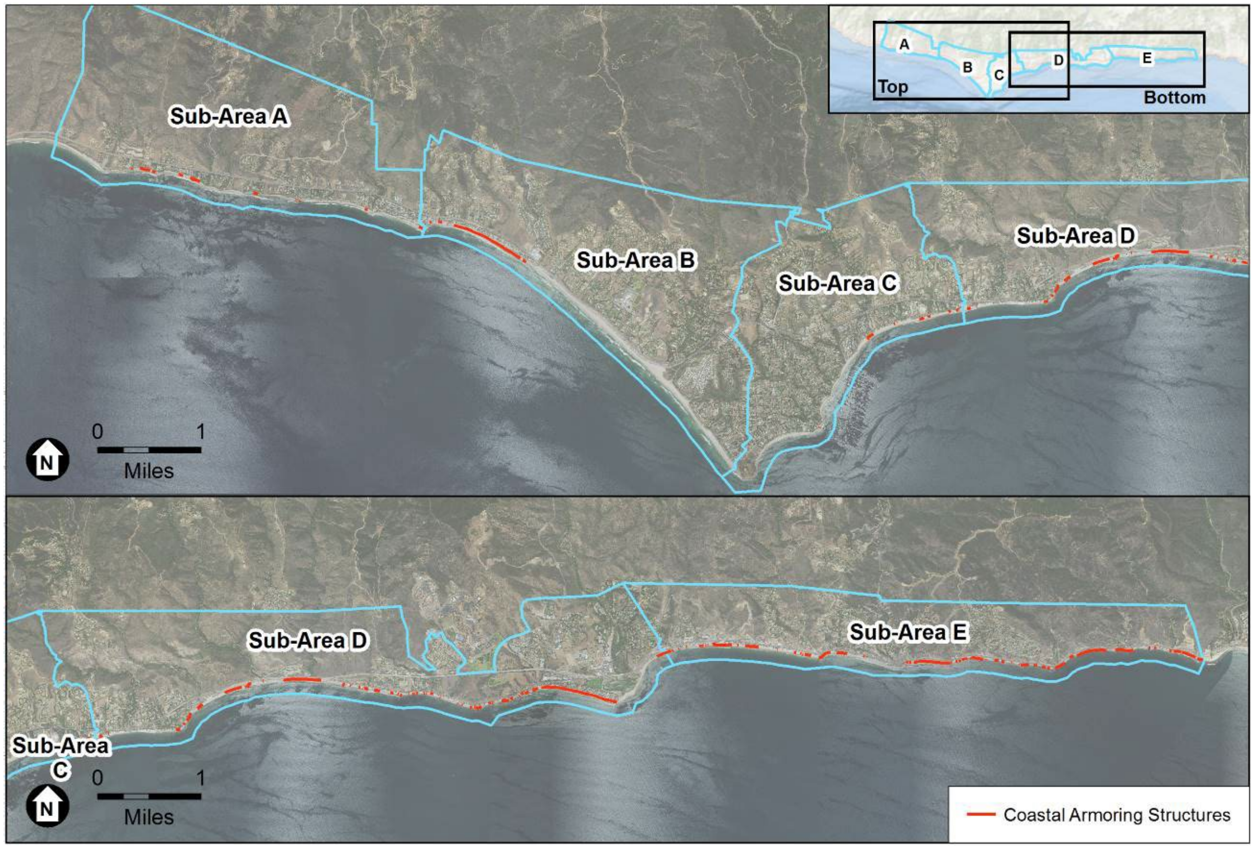
Structural Elevation: Many beachfront buildings are elevated today using support structures such as timber pile and reinforced concrete pile foundation systems.

Temporary Sand Berms: Los Angeles County Department of Beaches and Harbors regularly constructs temporary beach sand berms to reduce winter flooding of the lifeguard facilities, restrooms, and maintenance yard in the Zuma Beach parking lots, as shown in **Figure 1-9** below.

Source: ESA

Figure 1-7. Existing shoreline protection in Malibu: Rock revetment at Broad Beach (left) and timber seawalls at Malibu Colony (right)

[2] Access the CA Coastal Records project at https://www.californiacoastline.org/



Source: ESA, City of Malibu, NAIP, NOAA

Figure 1-8. Existing Coastal Armoring Structures in Malibu

Source: Noble 2016

Figure 1-9. Temporary Winter Sand Berm Locations at Zuma County Beach

Section 2

DATA COLLECTION AND PROCESSING

ESA collected publicly available data of Malibu coastal hazards and assets (i.e., built and natural resources). The data included in the following sections relate specifically to the vulnerability assessment. Additional details on input data and processing for this vulnerability assessment are included in **Appendix A**.

2.1 Sea level Rise Scenarios

Sea level rise scenarios[3] were initially determined for this vulnerability assessment based on California State guidance from 2018. This study applies future sea level rise of 2.5 feet for mid-century and 6.6 feet for end of century. The OPC has since released and adopted a science and policy update (OPC 2024), this study includes the new projected timing of these selected sea level rise amounts. Information on the latest science and state guidance on sea level rise is discussed in the following sections. The planning horizons and sea level rise scenarios selected for this study are discussed in Section 2.1.4.

2.1.1 Regional Sea level Rise Projections

The California Ocean Protection Council (OPC) adopted the latest State of California Sea Level Rise Guidance: 2024 Science and Policy Update (OPC, 2024), which provides projections for sea level rise at various locations along the coast of California through 2150. OPC produced this guidance in partnership with the California Ocean Science Trust (OST) and a scientific Task Force. The updated guidance is based on the National Oceanic and Atmospheric Administration (NOAA) 2022 Global and Regional Sea Level Rise Scenarios for the United States (Sweet, et al., 2022), which provides updated sea level rise scenarios for the United States based on global projections from the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report. The updated draft 2024 guidance presents five sea level rise scenarios

[3] A sea level rise scenario is a potential amount of sea level rise occurring by a certain date. Typically, multiple scenarios are chosen to represent the range of possible outcomes, since the exact amount of sea level rise is uncertain and depends on future greenhouse gas emissions and other factors.

and values that incorporate: (1) sea level rise observations, estimated and modeled projections, and uncertainties, and (2) a range of global greenhouse gas emissions scenarios, which rely on shared socioeconomic pathways (SSPs).[4] The following summaries of each sea level rise scenario are provided in the State of California Sea Level Rise Guidance (2024):

Low Scenario: Aggressive emissions reductions leading to very low future emissions; the scenario is on the lower bounding edge of plausibility given current warming and sea level trajectories, and current societal and policy momentum.

Intermediate-Low Scenario: A range of future emissions pathways; a reasonable estimate of the lower bound of most likely sea level rise in 2100 based on support from sea level observations and current estimates of future warming.

Intermediate Scenario: A range of future emissions pathways; could include contribution from low confidence processes. Based on sea level observations and current estimates of future warming, a reasonable estimate of the upper bound of most likely sea level rise in 2100.

Intermediate-High Scenario: Intermediate-to-high future emissions and high warming; this scenario is heavily reflective of a world where rapid ice sheet loss processes are contributing to sea level rise.

High Scenario: High future emissions and high warming with large potential contributions from rapid ice-sheet loss processes; given the reliance on sea level contributions for processes in which there is currently low confidence in their understanding, a statement on the likelihood of reaching this scenario is not possible.

Several changes were made from the previous State of California Sea Level Rise Guidance (OPC, 2018). The updated 2024 Guidance removes the extreme sea level rise scenario (H++) that was included in the previous guidance. The H++ scenario assumed rapid ice sheet loss on Antarctica, which could drive rates of sea level rise 30-40 times faster than the sea level rise experienced over the last century. This scenario is not included in the 2024 update, as the rates and amounts of sea level rise are not supported by best available science. Additionally, the 2024 guidance provides a greater certainty of sea level rise through 2050, with a California statewide average of 0.8 feet. By 2100, the expected range of sea level rise is between 1.6 and 3.1 feet,

[4] SSP background from OPC 2024 guidance: *Developed more recently, the SSPs are a collection of narrative descriptions of alternative futures of socio-economic development in the absence of climate policy intervention. Five SSPs describe five different pathways that the world could take, drawing on data including population, economic growth, education, urbanization, and the rate of technological development. The SSPs are important inputs into the IPCC sixth assessment and are used to explore how societal choices will affect greenhouse gas emissions. Pathways 5-85 (SSP 585) assumes heavy fossil-fueled development with high percentage of coal and energy-intensive lifestyles worldwide and assumes a radiative forcing of 8.5 W/ m2.*

although higher amounts cannot be ruled out. Beyond 2100, sea level rise uncertainty increases, with the potential for average sea levels in CA to rise from 2.6 to 11.9 feet or greater by 2150.

The updated guidance recommends evaluation of the Intermediate, Intermediate-High, and High Scenarios in sea level rise planning and projects. The High Scenario is precautionary for risk averse applications. The High Scenario assumes high future greenhouse gas emissions. Note that future emissions are inherently uncertain because emissions depend on societal choices; therefore, it is not possible to estimate the probability that future emissions will be high. Assuming high emissions and considering the range of model projections for a high emissions scenario, the High Scenario's sea level rise estimates have less than a 1% chance of exceedance in 2100.[5] Each of the three recommended scenarios corresponds with the low, medium-high, and extreme risk aversion categories that were introduced in OPC 2018 guidance:

- *Low risk aversion* is appropriate for adaptive, lower consequence projects (e.g., unpaved coastal trails). The ***Intermediate Scenario*** is recommended for consideration in low risk aversion applications.
- *Medium-high risk aversion* is appropriate as a precautionary projection that can be used for less adaptive, more vulnerable projects or populations that will experience medium to high consequences as a result of underestimating sea level rise (e.g., coastal housing development). The ***Intermediate-High Scenario*** is recommended for consideration in medium-high risk aversion applications.
- *Extreme risk aversion* is appropriate for high consequence projects with little to no adaptive capacity and which could have considerable public health, public safety, or environmental impacts (e.g., airport, coastal power plant, wastewater treatment plant, etc.). The ***High Scenario*** is recommended for consideration in extreme risk aversion applications.

Table 2-1 below presents State-recommended projections for the Santa Monica area in terms of Low, Intermediate-Low, Intermediate, Intermediate-High, and High Scenarios. The scenarios recommended for evaluation in sea level rise planning and projects (Intermediate, Intermediate-High, and High) are outlined by the blue box. See Section 2.1.4 for a summary of sea level rise scenarios selected for this study.

[5] As stated in OPC (2024): "It is important to note that probabilistic projections do not provide actual probabilities of occurrence of sea level rise but provide probabilities that the ensemble of climate models used to estimate contributions of sea level rise (from processes such as thermal expansion, glacier and ice sheet mass balance, and oceanographic conditions, among others) will predict a certain amount of sea level rise."

Table 2-1. Sea level Rise Projections for Santa Monica

YEAR	LOW	INT-LOW	INTERMEDIATE	INT-HIGH	HIGH
2020	0.2	0.2	0.2	0.2	0.2
2030	0.3	0.3	0.4	0.4	0.4
2040	0.3	0.4	0.5	0.6	0.7
2050	0.4	0.6	0.7	0.9	1.2
2060	0.5	0.7	1.0	1.5	1.9
2070	0.6	0.9	1.3	2.1	2.8
2080	0.6	1.0	1.7	2.9	3.9
2090	0.7	1.2	2.3	3.7	5.2
2100	0.8	1.4	2.9	4.6	6.4
2110	0.8	1.6	3.6	5.5	7.7
2120	0.9	1.8	4.2	6.2	8.8
2130	0.9	1.9	4.7	6.8	9.7
2140	1.0	2.1	5.2	7.3	10.6
2150	1.1	2.3	5.7	7.9	11.5

NOTE: *Median values of Sea Level Scenarios, in feet, for each decade from 2020 to 2150, with a baseline of 2000. All median scenario values incorporate the local estimate of vertical land motion.*
SOURCE: OPC 2024

While the 2024 State guidance provides projections through 2150, it is important to note that sea level rise is expected to continue for centuries, because the earth's climate will require time to respond to the emissions that have already been released to the atmosphere. Although sea level rise is typically presented as a range in the amount of sea level rise that will occur by a certain date (e.g., 1-2 feet of sea level rise by 2050), it can also be presented as a range of time during which a certain amount of sea level rise is projected to occur (e.g., 1.5 feet of sea level rise between 2040 and 2070). It is important to note that even if emissions are reduced to levels consistent with the low-emissions-based projections, sea levels will rise to higher levels, just at a later date.

2.1.2 CA Coastal Commission Guidance

The California Coastal Commission (CCC) last updated their *Sea level Rise Policy Guidance* in 2024 (CCC 2024). The guidance recommends using the OPC sea level rise projections at various planning horizons to assess vulnerability and conduct adaptation planning. The CCC guidance provides a step-by-step process for addressing sea level rise and adaptation planning, specifically for updating LCPs (CCC 2024). State planning guidance calls for considering a range of scenarios (OPC 2024; CCC 2024) in order to bracket the range of likely impacts. Scenario-based analysis promotes the understanding of impacts from a range of potential outcomes and identifies the amounts of sea level rise that would cause these impacts. Section 2.1.4 presents the scenarios considered for this vulnerability assessment.

The CCC guidance recommends that long-term, community-wide planning efforts evaluate, at a minimum, the "medium-high risk aversion" projection. The extreme risk aversion projection is to be used to evaluate critical facilities.

2.1.3 CoSMoS Modeling Scenarios

The Coastal Storm Modeling System (CoSMoS)[6] was developed by the United States Geologic Survey (USGS) with state funding for use in sea level rise planning (Barnard and others 2014). The modeling effort focused on evaluating flood hazards associated with sea level rise, as well as shoreline and bluff erosion. Coastal hazards were last mapped for the Malibu coastline with CoSMoS 3.0 in 2016. A total of 40 scenarios were run combining sea level rise and storm type: ten sea level rise amounts (0 to 6.6 feet at 0.8 foot increments and 16.4 feet) were modeled with four coastal storm conditions (100-year, 20-year, and 1-year events and no storm). Hazard modeling outputs include the extent of inundation, wave run-up, and long-term erosion. GIS data for these outputs were downloaded[7] for Malibu and processed for use in the vulnerability assessment. Details on the CoSMoS hazard data and required processing for this assessment are provided in **Appendix A**.

[6] Details on the USGS CoSMoS model are accessible online at: https://www.usgs.gov/centers/pcmsc/science/coastal-storm-modeling-system-cosmos

[7] CoSMoS hazard maps are accessible online at: https://www.sciencebase.gov/catalog/item/5633fea2e4b048076347f1cf

2.1.4 Malibu Sea level Rise Scenarios

To assess vulnerabilities for the City of Malibu (City), two future sea level rise scenarios were selected in addition to existing sea level (noted as "zero sea level rise") to represent the range of potential impacts that the City may experience from coastal hazards. The scenarios selection was informed by the State guidance and considers the timing of sea level rise scenarios presented in updated CA Sea Level Rise Guidance (OPC 2024) as well as the sea level rise modeling scenarios available from CoSMoS 3.0. **Table 2-2** presents the sea level rise scenarios used for this vulnerability assessment. Coastal vulnerabilities in the City were analyzed for existing sea level, 2.5 feet (0.75 m) of sea level rise, and 6.6 feet (2 m) of sea level rise. The timing of impacts for these scenarios was determined from risk aversion discussed in 2.1.1: the earlier date is consistent with the extreme risk aversion scenario (High SLR in Table 2-1), while the later date is consistent with the medium-high risk aversion scenario (Intermediate-High SLR in Table 2-1).

Table 2-2. Malibu Sea level Rise Scenarios

Scenario	Sea level Rise (feet)	Sea level Rise (meters)	Date Range
Existing conditions	0	0	Now
Mid Century	2.5	0.75	2070 - 2075
Late Century	6.6	2	2100 - 2130

NOTE: Date range presents timing of sea level rise based on the latest projections for High sea level rise (sooner date) and Intermediate-high sea level rise (later date) scenarios from OPC 2024.

The updated California Sea Level Rise Guidance (OPC 2024) includes discussion of exceedance probability for each sea level rise scenario based on a range of future global warming levels. The probability that any sea level rise scenario is met/exceeded depends on multiple factors that include low confidence (high scientific uncertainty) processes associated with Antarctica and Greenland ice-sheet loss. Accounting for low confidence processes, the Intermediate-High scenario (6.6 feet SLR by 2130), has a 1% chance of exceedance with low global warming, while it has a 20% chance of being exceeded assuming very high global warming. Similarly, the High Scenario (6.6 feet SLR by 2100) has less than 0.1% chance of exceedance with low warming and an 8% chance of exceedance with high global warming. Note that these probabilistic projections do not provide actual probabilities that an amount of sea level rise will occur but rather provide probabilities that the climate models used to estimate contributions of sea level rise (from processes such as thermal expansion, glacier and ice sheet mass balance, and oceanographic conditions, among others) will predict a certain amount of sea level rise (OPC 2024). See Table 2.2 in the 2024 State Guidance for more information on probabilities associated with each sea level rise scenario.

2.2 Asset Inventory

Available spatial data were collected for the built and natural assets in the City of Malibu. Many of these assets are currently or may potentially become exposed to tidal inundation, storm flooding and wave run-up, and erosion due to sea level rise. Spatial data for assets in Malibu were processed and overlaid in GIS with sea level rise hazard layers to assess the exposure of each asset class listed below (hazard exposure results are presented in Section 4). The data sources for each asset class are listed in **Appendix A.** Maps showing built and natural assets in Malibu are provided in **Appendix B**.

Communication

Communication Towers

Critical Facilities

Fire Stations
Fire Hydrants
Lifeguard Towers
Public Defenders' Offices

Development

Coastal Armoring Structures
Commercial Buildings
Other Buildings
Recreational Buildings
Residential Buildings
Government Buildings
Institutional Buildings
Industrial Buildings

Ecology

Environmentally Sensitive Habitat Areas (ESHA)
Wetlands
Beaches

Energy

Electrical Meters

Recreation and Visitor-Serving

Parks and Open Space
Hiking Trails
Beaches
Paradise Cove and Malibu Piers
Coastal Access Points

Transportation

Bridges
Roads and Highways
Fueling Stations
Parking Lots

Water

Sewer Mains
Sewer Pump Stations
Storm Drain Inlets/Junctions
Sewer Pipes
Sewer Treatment
Storm Drain Lines

2.2.1 Asset Data Gaps

Not all assets within Malibu are represented by existing spatial datasets. Data gaps include natural gas and communications infrastructure (internet, phone utilities) as well as drinking water infrastructure. Septic systems are used for all beachfront properties and a large percentage of development in Malibu in general, but information on site-septic systems was not readily available for this study.

Section 3

FUTURE TIDAL INUNDATION, STORM FLOODING, WAVES, AND EROSION

A small storm today may cause limited damage, but the same storm event could have a much larger impact with higher sea levels in the future.

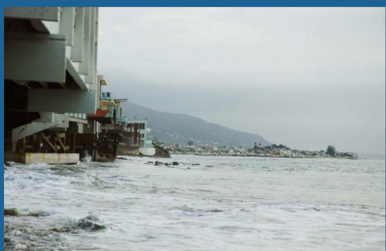
Future sea level rise is expected to create a permanent rise in ocean water levels that would shift the water's edge landward. Higher water levels would increase erosion of beaches and cliffs, and result in a narrower beach, if no action is taken. Additionally, the combination of higher ocean water levels and beach erosion would mean that coastal storms will potentially cause greater flooding and damage alongshore, because reduced beach width is less effective at reducing wave energy, and waves that break in deeper water and/or closer to shore will result in greater wave run-up. For example, a small storm event under today's sea levels may not cause much damage, but with higher sea levels, the same event could potentially have a much larger impact. This section identifies future hazard zones including permanent tidal inundation, beach, and bluff erosion and temporary storm flooding and wave run-up, as well as low lying areas associated with the permanent and temporary coastal water levels. This section also discusses the underlying data sets and assumptions and methods used to map each hazard zone.

3.1 Potential Future Hazard Zones

The first step in understanding Malibu's vulnerabilities to sea level rise is identifying potential hazard areas. Existing and potential future tidal inundation, storm flooding and wave run-up, and beach and bluff erosion were determined using publicly available hazard maps from the USGS CoSMoS model with some refinements made by ESA for use in geospatial analysis software (GIS).

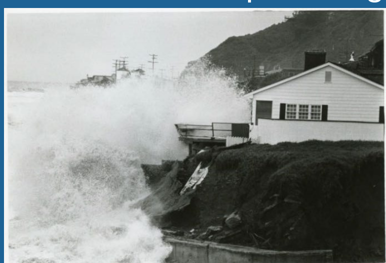
The following coastal hazard zones were mapped for the vulnerability assessment:

Inundation



Source: LA Waterkeeper

Storm Wave Runup/Flooding



Source: Pepperdine University

Erosion

Source: KBUU News

- **Tidal inundation (non-storm) and groundwater levels**
  - Extent of regular high tides with existing topography in Malibu. Low lying areas that are adjacent to but disconnected from tidal areas by high ground are considered in this study as surrogates for areas that may experience potential groundwater issues due to high tides. Some portions of the City around Malibu Lagoon are below the tidal inundation and storm flooding elevations, but are not directly connected to the ocean or areas inundated by high tides. These disconnected low-lying areas may be subject to groundwater issues or storm flooding and are further described in Section 3.2.4.
- **Storm flooding from a 100-year coastal storm event**
  - The storm flooding hazard zone represents areas flooded (for more than 2 minutes) during a coastal storm event. This zone includes low areas flooded by wave overtopping and Trancas, Zuma and Malibu Creek flows (i.e., creek flooding occurring during a 100-year coastal storm event). USGS CoSMoS mapped 100-year storm flooding in Malibu considering a large southern swell (deepwater wave height of 20 to 22 feet).
  - The storm waves hazard zone represents the landward limit of wave run-up during a coastal storm.
- **Coastal erosion**
  - Shoreline and beach erosion due to ongoing coastal processes and future sea level rise. These projections of shoreline erosion are also used to compute beach width changes due to sea level rise.
  - Bluff erosion from sea level rise and terrestrial processes

Table 3-1 presents a summary of the hazard types and their impact class (i.e., permanent or temporary impact to land areas). This study assumes that permanent impacts occur to land areas exposed to long-term erosion of beaches, long-term erosion of bluffs, and tidal inundation, while temporary impacts occur to land areas exposed to storm flooding and storm wave impacts. Note that the hazard impact on any particular asset depends on multiple factors (see Vulnerability Assessment in Section 4).

Table 3-1 Summary of Hazard Type and Impact Class

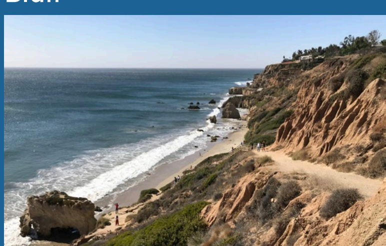
Hazard Type	Impact Class	Mapping Data Source
Tidal Inundation / Low Lying Areas	Permanent	CoSMoS 3.0[a]
Long-Term Erosion – Sandy Beach and Dune	Permanent	CoSMoS 3.0 [a]
Long-Term Erosion – Bluff	Permanent	CoSMoS 3.0 [a]
Storm Flooding	Temporary	CoSMoS 3.0 [a] /AdaptLA[b]
Storm Waves	Temporary	CoSMoS 3.0 [a]

NOTES:
[a] *Coastal Hazards from CoSMoS 3.0: Erikson et al. 2017*
[b] *Lagoon berm flooding added per AdaptLA: ESA 2016*

Sandy Beach

Dunes

Bluff



Shoreline Armoring

Photos Source: ESA

A hierarchy of the coastal hazard zones was used to map the most long-term impact to land area for each sea level rise scenario: if an area is exposed to shoreline or bluff erosion (permanent), it is not also shown as exposed to storm flooding (temporary). This is because eroded areas are considered permanently lost; whereas storm flooding areas are considered temporarily impacted. Using mutually exclusive hazard zones simplifies the hazard maps for interpretation, however areas shown to have permanent impacts (e.g. tidal inundation, shoreline erosion) are likely to also experience temporary storm impacts. Hazard zones are evaluated in the order listed in Table 3-1, starting with tidal inundation and ending with storm flooding waves. Note that the figures below include disconnected low-lying areas in addition to the hazards in Table 3-1, which are used to indicate potential flood-prone areas and locations where future groundwater elevations could become a nuisance or impact buried utilities and/or septic systems. Figures presenting coastal hazard zones in Malibu for existing conditions and future sea level rise are provided in **Appendix C**. See Section 5 for discussion of existing and future vulnerabilities with sea level rise and Section 6 for focused discussions of each study sub-area.

3.2 Coastal Processes

The following sections describe the data used to understand different coastal processes in Malibu for the purpose of this vulnerability assessment.

3.2.1 Beach and Bluff Erosion with Sea level Rise

Beach and bluff erosion results from the USGS CoSMoS model were used to develop the potential future hazard zones for coastal erosion. The USGS modeled beach and bluff erosion for four management scenarios in CoSMoS:

- Hold the line, no beach nourishment
- Hold the line, beach nourishment
- Let it go, no beach nourishment
- Let it go, beach nourishment

The "hold the line" scenarios assume that management actions are taken to repair and replace damaged structures and construct new armoring to protect all existing development. The "let it go" scenarios assume that no management actions are taken, and erosion can continue unabated into coastal development. Neither scenario reflects any policy determination on the part of the City. Specific policies regarding how to address sea level rise impacts will be developed in future phases of work.

The CoSMoS model does not directly account for beach nourishment. The model uses past shoreline position data to estimate the historic "background" rate of shoreline change (e.g., if a shoreline moves inland, the beach has eroded). This background (i.e. long term) erosion rate is then included in the projections of future erosion with sea level rise (i.e., results include long term erosion rate plus increased rate of erosion due to sea level rise). ; If the model results show a shoreline position farther seaward than past shoreline position data, then the model estimates the amount of beach nourishment needed to match this shoreline condition. For the beach nourishment model scenarios, the model includes these estimates of past beach nourishment as part of the shoreline erosion projections. For the "no beach nourishment" model scenarios, the model does not include this adjustment.

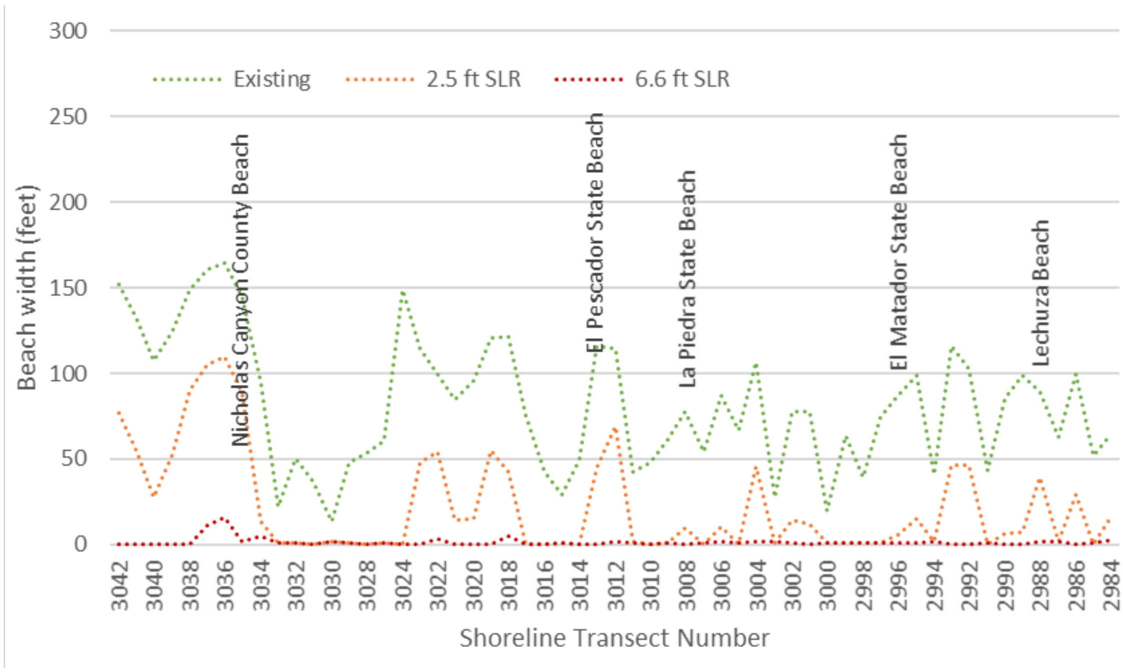
This Coastal Vulnerability Assessment applies erosion hazard zones from the "Let it go, no nourishment" management scenario in order to characterize the full extent of potential impacts to Malibu assets. It is important to understand the full scope of potential impacts and consequences of sea level rise so that impacts can be evaluated and later compared to adaptation strategies and the benefits they provide.

Future Beach Widths with Sea level Rise

Beaches will shift upwards and landwards with sea level rise depending on a number of factors that include wave climate, sediment supply, as well as what is behind the beach (e.g. natural dune/bluff or built assets/coastal armoring). Long term erosion of the shoreline and beach is commonly calculated from the combination of the historic change rate (erosion or accretion/growth) of the shoreline and the additional erosion of the shoreline profile resulting from sea level rise. The shoreline retreat from sea level rise is typically calculated by multiplying the increase in sea level by the overall profile slope (between the beach berm and the offshore limit of the active beach profile). Malibu beach profile slopes are approximately 0.03 on average, or 1 foot vertical for every 30 feet horizontal, meaning that the shoreline may erode by 30 feet for every foot of sea level rise (ESA 2016).

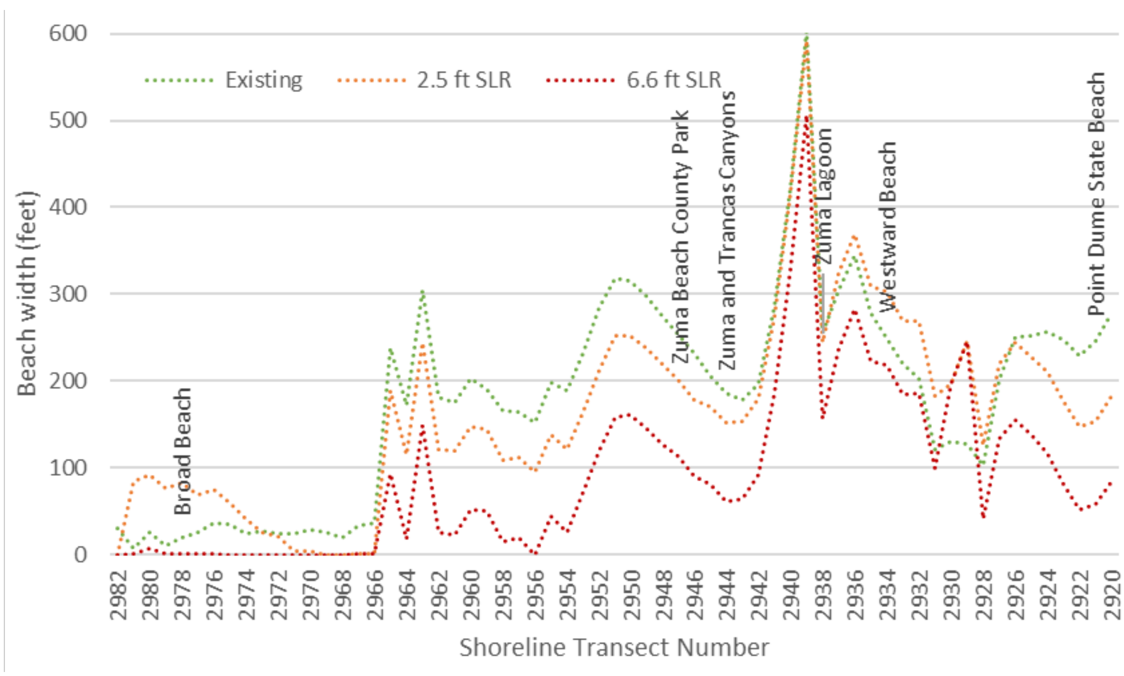
Existing beach widths in Malibu were defined as the distance of sandy beach from the mean high water shoreline to the back of beach (dune or bluff toe, or edge of development/armoring structure). To characterize the full potential vulnerability of Malibu beaches, future beach widths were determined from CoSMoS eroded shorelines for 2.5 and 6.6 feet sea level rise and the backshore boundary line (backshore development or bluff toe). This essentially represents a "hold the line" scenario which has the greatest implications for beaches, indicating the maximum potential vulnerability of beaches to sea level rise impacts (compared to a scenario in which bluffs or development retreat to allow increased beach width). As sea level rises and/or as coastal erosion continues over time, holding the line (with armoring) behind the beach will result in the squeezing and ultimate disappearance of beaches seaward of the armoring. Beach widths for existing conditions at Malibu were determined from CoSMoS data using the 2010 fall mean high water shoreline extracted from the digital elevation model used for CoSMoS and the backshore boundary/development line from CoSMoS. ESA shifted the CoSMoS backshore boundary/development line seaward along Zuma Beach and Point Dume State Beach to account for existing parking lots and roads.

Beaches along the CA coast fluctuate seasonally due to changes in the wave climate (stormy seas in winter erode beaches, long period swell in summer rebuilds beaches); widest conditions typically occur in summer/fall and narrowest in winter/spring. Beach widths along the Malibu coastline fluctuate seasonally by about 30 feet on average from summer/fall to winter/spring (Noble/GEC 2016). In 2010 (recent fall shoreline), 23% of fall beach widths were below 31 feet, meaning they could disappear almost completely during an average winter. By mid-century, 62% of beach widths along Malibu are projected to be below the seasonal fluctuation width. By late century, 86% of beach widths are projected to be below this threshold. Coastal storm erosion causes many beaches to temporarily disappear under current conditions. Coastal storm erosion is projected to have greater potential impacts to beaches with future sea level rise. Existing (fall 2010) and future beach widths with sea level rise for Malibu sub-areas A through K are shown in Figures 3-1 to 3-5. The horizontal axes in the figures indicate the CoSMoS modeling transect numbers on which future shorelines were projected; these increase in value from east to west. Labels for landmarks are added to each plot for reference. Note that CoSMoS erosion projections show a wider beach with 2.5 feet sea level rise compared to existing beach width in some locations; this is because the historic data used in CoSMoS analysis showed an accreting shoreline (widening beach) at such locations including the west end of Broad Beach and Westward Beach. Note that existing beach widths along the Malibu Lagoon mouth (Figure 3-4) are assumed to persist with future sea level rise since there is room within the lower lagoon for the beach to shift inland. Beach vulnerability is further discussed in Section 4.



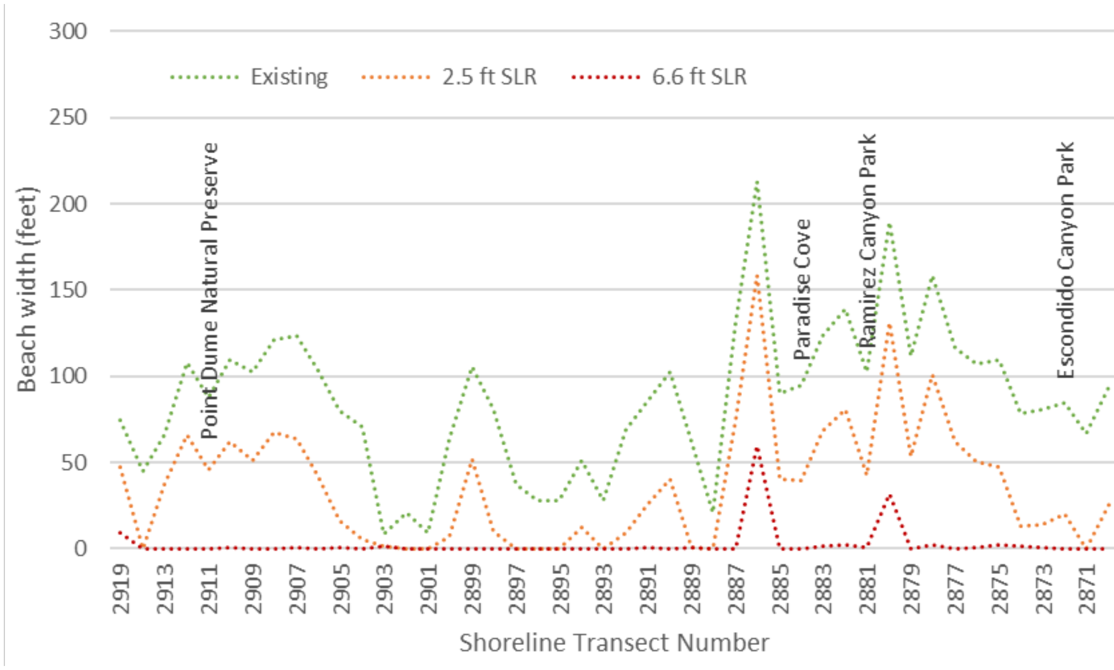
Source: ESA, USGS CoSMoS

Figure 3-1. Existing and Future Beach Widths in Sub-area A: Nicholas Canyon County Beach to Point Lechuza



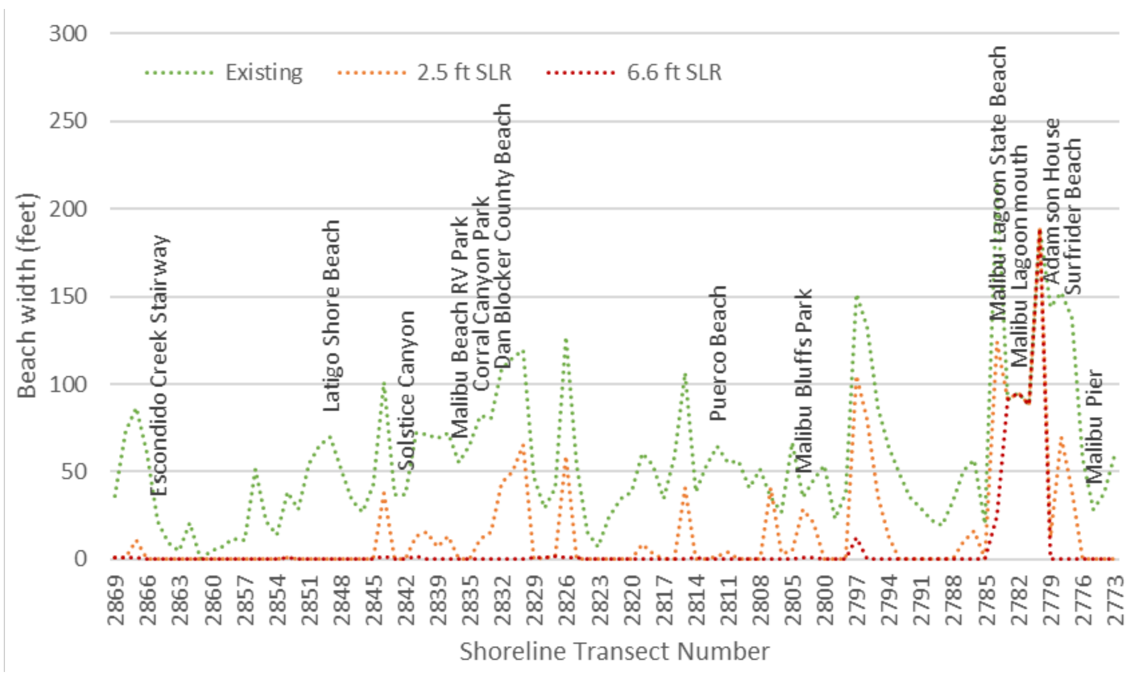
Source: ESA, USGS CoSMoS

Figure 3-2. Existing and Future Beach Widths in Sub-area B: Point Lechuza to Point Dume



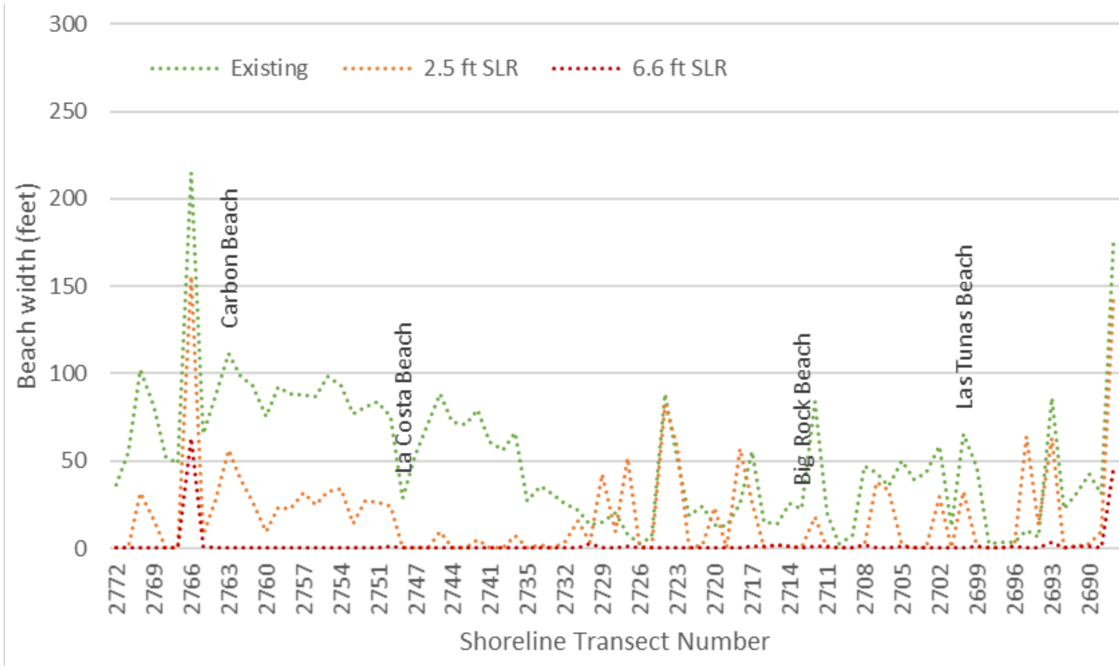
Source: ESA, USGS CoSMoS

Figure 3-3. Existing and Future Beach Widths in Sub-area C: Point Dume to Escondido Beach



Source: ESA, USGS CoSMoS

Figure 3-4. Existing and Future Beach Widths in Sub-area D: Escondido Beach to Malibu Lagoon State Beach



Source: ESA, USGS CoSMoS

Figure 3-5. Existing and Future Beach Widths in Sub-area E: Malibu Surfrider Beach to Topanga Beach

3.2.2 Tidal Inundation and Storm Flooding Levels with Sea level Rise

Storm flooding refers to potential impacts from a coastal storm that happens infrequently, whereas tidal inundation refers to the extents of regular tides that occur day-to-day. Storm flooding and tidal inundation results from the USGS CoSMoS model were used to determine potential impacts of sea level rise in Malibu for average high tide conditions and extreme storm conditions. The USGS modeled and mapped storm flood and tidal inundation extents, flood depth, and wave run-up for four storm scenarios:

- No flood (regular tidal inundation from the average high tide)
- 1-year coastal storm flood event (100% chance of occurring each year)
- 20-year coastal storm flood event (5% chance of occurring each year)
- 100-year coastal storm flood event (1% chance of occurring each year)

These four storm scenarios were analyzed under ten sea level rise scenarios:

- 0 feet (existing sea level)
- 0.8 feet
- 1.6 feet
- 2.5 feet
- 3.3 feet
- 4.1 feet
- 4.9 feet
- 5.7 feet
- 6.6 feet
- 16.4 feet

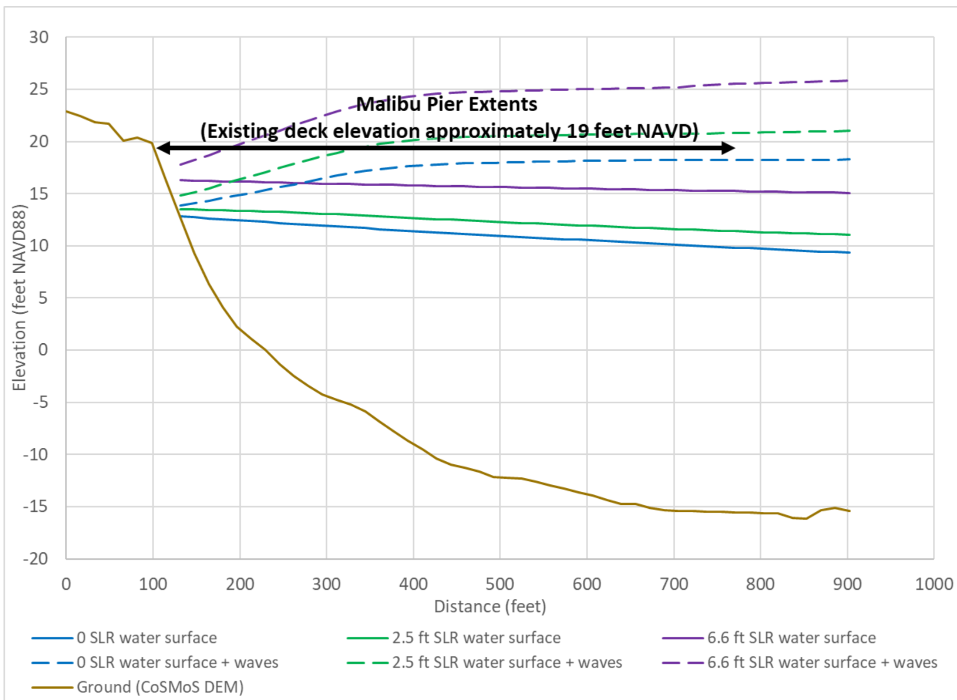
As discussed in Section 2.1.4, three sea level scenarios were selected for this Coastal Vulnerability Assessment corresponding to zero feet (existing conditions), 2.5 feet , and 6.6 feet sea level rise. These sea level scenarios were evaluated considering two ocean conditions for this assessment: regular tidal inundation (no flood event, typical monthly spring high tide conditions) and 100-year coastal storm flooding. These two scenarios were chosen to efficiently bracket the potential impacts that Malibu could experience with sea level rise; annual and 20-year storm impacts were not evaluated. The tidal inundation scenario depicts areas where inundation is a regular event, which shows how daily inundation could potentially change in the future with sea level rise. The 100-year coastal storm flood event represents the potential temporary impacts that could occur during an extreme coastal storm event. For context, FEMA flood mapping through the National Flood Insurance Program also provides river and coastal storm flooding extent and floodwater elevations for a 100-year coastal storm event under current conditions. FEMA does not model or map coastal storm events with sea level rise, so this planning-level Coastal Vulnerability Assessment does not use FEMA flood hazard data. See **Appendix A** for discussion on processing storm flooding hazard maps for this study.

In addition to the coastal flooding results from CoSMoS, ESA applied a simplified lagoon flooding analysis, which ESA previously developed and implemented for the AdaptLA project (ESA 2016). This approach accounts for lagoon flooding as an additional flooding mechanism that is not analyzed in CoSMoS. The method considers a potential condition in which (1) the beach berm at a lagoon mouth is built up to an exceptionally high elevation over an active summer of waves and (2) an early wet season storm fills the lagoon behind the elevated berm at the mouth and causes increased flood exposure to low areas surrounding the lagoon. Such analysis was performed for Trancas, Zuma and Malibu Creek Canyons. The lagoon flood potential hazard zones were combined with the CoSMoS coastal storm flooding hazard zones for vulnerability mapping and analysis in these three lagoons.

3.2.3 Maximum Wave Run-up with Sea level Rise

Coastal wave run-up results from the USGS CoSMoS model were used to develop the potential coastal storm flooding and waves hazard zone. The USGS modeled wave run-up at discrete transects along the coast, with a point output used to represent the inland extent of wave run-up along each transect. ESA connected these points using GIS to form a potential wave run-up exposure zone (a polygon showing spatial extent, instead of individual points). However, it is important to note that a linear interpolation between points is not accurate in many situations. The USGS did not model all of the sea level rise scenarios discussed in Section 3.2.2 for wave run-up. The CoSMoS results only include wave run-up hazards at each 0.8-foot increment, so the more conservative 1-meter sea level rise scenario was used for the mid-term (2.6 feet) wave hazard zone in this assessment. Further details on the processing and modifications made by ESA are described in **Appendix A**. Note that the wave run-up extents mapped by CoSMoS show the landward-most limit of wave action. CoSMoS does not distinguish the zone of high momentum wave action that may cause damage to life and property, such as the VE wave hazard zone shown on FEMA maps.

Coastal storm flooding model outputs from CoSMoS were used to evaluate the exposure of Malibu Pier to coastal storms with sea level rise. The water surface elevation and wave height maps from CoSMoS were extracted along the length of Malibu Pier and combined to illustrate the storm swells that can impact the pier. **Figure 3-6** shows water surface plus wave height (dashed lines) at 0, 2.5 and 6.6 feet sea level rise computed from the 100-year storm model outputs from CoSMoS (solid line shows water surface without waves added). The figure provides an indication of existing and future wave exposure to Malibu Pier for extreme storm conditions. Actual wave run-up height may be greater than shown in **Figure 3-6** due to interactions between the waves and pier structure.



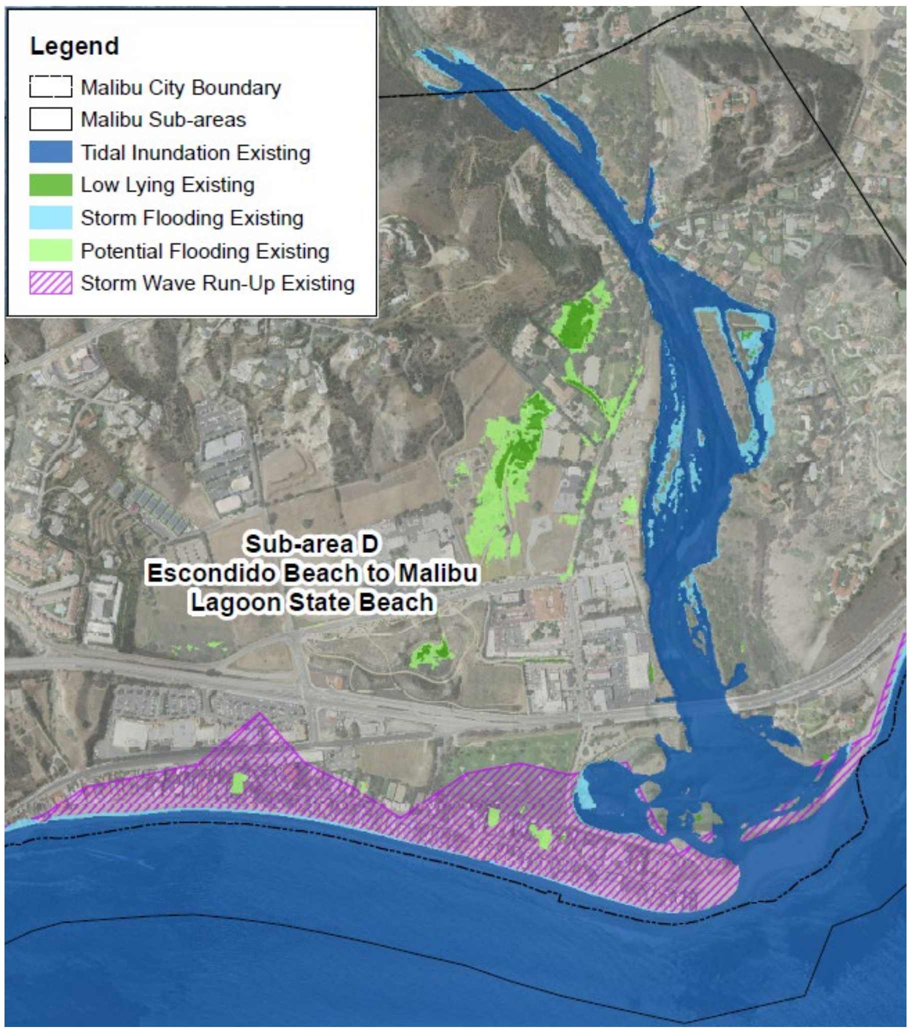
Source: ESA, USGS CoSMoS

Figure 3-6. Malibu Pier Coastal Storm Wave Exposure with Sea level Rise

3.2.4 Disconnected Low-Lying and Flood-Prone Areas

There are a few low-lying areas in Malibu that are below existing spring tide inundation elevation (called "low-lying areas"); see dark green areas in Figure 3-7 below, which is excerpted from Appendix C Figure C1-6. These low areas are mostly around Malibu Lagoon and may experience issues due to a rising groundwater table with sea level rise even if they remain disconnected from the ocean tides. These areas are included as potential areas of permanent impact.

Additional portions of the City are below the water surface elevations identified for 100-year coastal storm conditions but are not directly connected to the ocean. These areas consist of lower stream canyons, Zuma Lagoon and areas around Malibu Lagoon (Figure 3-7). While these low areas may be protected from direct exposure by high ground or structures, they may still be susceptible to flooding. These areas are called "potential flooding areas" and may experience flooding from precipitation or wave over wash that is unable to drain to the ocean because water levels are too high during a storm. Flood-prone areas are considered to have potential temporary impacts for this study.



Source: ESA, City of Malibu, USGS CoSMoS

Figure 3-7. Malibu Creek and Lagoon Existing Coastal Storm Exposure

Higher sea levels will likely increase riverine flooding, because higher ocean water levels will limit river drainage to the ocean and water will back up into the river or creek. Additionally, the sand berm at the mouth of the river or creek will likely increase in height as waves push sand up, which will also limit drainage and increase flooding upstream.

3.2.5 Riverine Flooding

The effects of climate change and sea level rise on extreme river and creek flooding is not explicitly examined in this Coastal Vulnerability Assessment because data on the increase in river and creek flooding with sea level rise and climate change is not readily available. In general, climate change will lead to flashier (i.e. fast-peaking), more extreme floods and more intense droughts. Higher sea levels will also increase riverine flooding in downstream reaches closest to the coast. Higher ocean water levels cause water levels to back up in coastal rivers and can limit river drainage to the ocean. During flood events, this can cause flood waters to inundate greater areas in river and creek floodplains near the ocean. CoSMoS 3.0 coastal storm flooding extents used for this study do include flooding due to river and creek flows that occur coincident with extreme coastal storms, but these coincident river and creek flows are less severe than flooding due to extreme (i.e., 100-year) precipitation and extreme river and creek flows.

Section 4

VULNERABILITY ASSESSMENT

This section uses the coastal hazard zones described in Section 3 and mapped in **Appendix C** to identify the assets potentially at risk from sea level rise (e.g. homes, roads, utilities). These assets (described in Section 2.2) are categorized into the following asset categories: communication, critical facilities, development, ecology, energy, recreation, transportation, and water.

Understanding the risk of not taking action is an important first step in planning for sea level rise.

In order to develop an effective adaptation plan and policies to address sea level rise vulnerability, the risk of not taking action must be understood first. For this reason, this Vulnerability Assessment considers a "no action" scenario in which the City or other asset managers do not respond to or prepare for sea level rise. This scenario assumes the existing armoring would not be maintained, per the "let it go" scenario modeled with CoSMoS. By considering this scenario, decision makers are able to understand the full potential impacts of sea level rise and identify areas with the greatest vulnerabilities (areas with high asset density that are subject to flooding and or erosion). In reality, the City, its residents, and businesses will likely take action (many already have, see Section 1.2.4). This assessment of vulnerability is the first step in taking a proactive approach to sea level rise adaptation planning in Malibu.

4.1 Methodology

Each asset category was analyzed to determine the potential exposure to the different hazard areas and consequences, and the sensitivity of the assets to the potential hazard and adaptive capacity of the assets. The results of these analyses are summarized in tables provided in Section 5.2 for each asset category. Each table summarizes the types of assets in a particular category and provides details relevant to Malibu along with vulnerability assessment categories and overall vulnerability summary. The following sections describe in further detail the assessment categories within each of these tables.

4.1.1 Hazard Exposure

*The **hazard exposure** of an asset is based on the type of hazard an asset is subjected to under future conditions and the timing at which the hazard occurs.*

To assess exposure to hazards, the assets in different categories were intersected in GIS with each potential future hazard zone. In general, point assets (like fire stations, lifeguard towers, pump stations) in each potential future hazard zone are counted, linear assets (like roads and pipelines) are measured by mile, and planar assets (like wetland areas) are measured by acre. The resulting **hazard exposure** for each asset class is summarized in the second row of each result table in the following sections. Hazard Exposure maps showing assets and hazards are provided in **Appendix D**. A full tabular summary of hazard exposure results for each asset class is provided in **Appendix E**.

To characterize an asset's exposure to hazards for this vulnerability assessment, a *hazard exposure* grade of low, medium, or high was assigned based on the potential consequences of exposure and the timeframe in which the asset is exposed. For example, if Asset A is flooded in the near-term it has a higher hazard exposure grade than Asset B that only floods in the long-term since Asset A may be impacted sooner. The hazard zones described in Section 3 represent different levels of severity and consequences as further described below. The different mapped hazard zones correspond to either permanent or temporary impacts to built and natural assets. Thus, consequences of asset exposure can vary depending on what hazard zone(s) the assets are exposed to and when, as well as the asset type and elevation relative to flooding (for example a beachfront home elevated on engineered piles will likely sustain less erosion or flooding damages compared to a home at beach level in the same location.

Generally, permanent impacts (erosion and tidal inundation) have greater consequences than temporary impacts (storm flooding and wave run-up). Areas subject to the potential future beach and bluff erosion hazard zones could be lost entirely (permanent impacts, greatest consequences). Areas in the potential future tidal inundation flooding zone could also be lost entirely (permanent impacts, greatest consequences). Areas in the potential future coastal storm flooding hazard zone could likely be heavily damaged by ocean storm surge and waves (temporary impacts, significant consequences). Areas in the potential future coastal storm wave run-up hazard zone may be damaged or disrupted from flowing or ponded water depending on proximity to the ocean (higher velocity/momentum run-up closest to ocean waves or lower water velocities and inland extent of the run-up zone). Thus, assets may be recoverable depending on location and elevation relative to wave run-up, and could return to service when waves and floodwaters recede (temporary impacts, low to moderate consequences). Note that the wave run-up hazard zone depicted by CoSMoS data represents the landward most limit of potential wave run-up, which extends beyond the high wave momentum zone depicted in FEMA maps as Zone VE. Note that FEMA hazard mapping data does not account for sea level rise.

The following list describes the exposure grades for different timing and types of coastal hazards considered in this study.

- Mid century erosion and tidal inundation (permanent impacts) equate to **high** exposure
- Mid century storm flooding (temporary impacts) equate to **medium** exposure
- Mid century wave run-up flooding equates to **low** exposure, given how this data is provided by CoSMoS relative to storm flooding
- Late century erosion and tidal inundation (permanent impacts) equate to **medium** exposure
- Late century storm and wave run-up flooding (temporary impacts) equate to **low** exposure

The hazard exposure grading scheme is summarized in **Table 4-1**. The purpose of this hazard exposure grading rationale is to enable a simplified summary of asset exposures and thus vulnerabilities in the City and is not intended to downplay the risks of infrequent storm flooding and wave run-up that may have significant and increasing impacts to development over time/with sea level rise.

Table 4-1. Hazard Exposure Grading Scheme

Timeframe	Beach and Bluff Erosion	Tidal Inundation	Coastal Storm Flooding	Wave Run-up Flooding
Mid-century	High	High	Medium	Low
Late-century	Medium	Medium	Low	Low

4.1.2 Sensitivity to Hazards

*An asset's **sensitivity** to a given hazard is defined as the asset's level of impairment if impacted (e.g. flooded temporarily, inundated permanently, or if impacted by erosion or waves).*

For an exposed asset, the overall vulnerability of the asset depends in part on the **sensitivity** of the asset to the hazard. In general, assets that are highly sensitive can lose their primary function if exposed to any flooding or erosion whatsoever. If assets can maintain their primary function(s) during hazard impacts, they have low sensitivity. For example, one of the sensitivities of impacts to wave run-up on transportation corridors is the disruption of vehicular access critical for the provision of emergency services (e.g. Highway 1), which would mean the asset has a high sensitivity. In contrast, a lifeguard tower that sits high above the beach has a lower sensitivity to wave run-up.

Similar to the hazard exposure grades, grades for an asset's *sensitivity to hazards* are based on the specific asset and exposure(s) considered. **Table 4-2** presents the grading scheme for hazard sensitivity ranging from low to high. Low sensitivity means an asset is lightly impacted and continues to function or can recover quickly after impacted by a hazard. High sensitivity means an asset would be damaged and disabled by the hazard and would not recover quickly. Another aspect of asset sensitivity is what impact an asset's failure has on the environment or public safety. For example, failure of septic systems along a stretch of oceanfront residential homes can result in untreated wastewater leaching through the beach, affecting water quality, the environment and public safety.

Table 4-2. Asset Sensitivity Grading Scheme

Considerations	Grade
The given hazard would have no or a low impact on the asset function. The asset would be able to rebound from the impact quickly.	Low
The given hazard would cause minor damage or temporary operational interruption.	Medium
The given hazard would cause major damage or long-term operational interruption (direct or indirect) including impacts to public safety. The asset would require significant effort to rebound from the impact.	High

4.1.3 Adaptive Capacity

*The **adaptive capacity** of an asset is the ability of that asset to change over time and respond to a hazard.*

In the fourth row of each Asset Vulnerability table in Section 4.2, an asset's adaptive capacity is discussed. Adaptive capacity refers to the ability of an asset to change in response to hazard exposure with rising sea levels. For example, a lifeguard tower may be exposed to flooding or erosion today (high exposure), but the tower can be moved easily (high adaptive capacity).

Grades for an asset's *adaptive capacity* is assigned based on the type of asset and its relative function in relation to development or infrastructure system. **Table 4-3** presents the grading scheme for adaptive capacity, which ranges from High to Low. High adaptive capacity means an asset can be easily adapted to accommodate higher sea levels, while low adaptive capacity means an asset requires a significant effort to adapt or adaptation has significant implications to surrounding assets or the infrastructure system that the asset is part of.

Table 4-3. Adaptive Capacity Grading Scheme

Considerations	Grade
The asset could easily adapt to higher sea levels.	High
The asset requires moderate effort to adapt to higher sea levels.	Medium
The asset requires significant effort to adapt to higher sea levels or adaptation would cause ripple effects to the wider system (e.g. sewer system or other infrastructure)	Low

4.1.4 Vulnerability Summary

*An asset's **vulnerability** depends on*

*the degree and type of **hazard** the asset is **exposed** to,*

*the **sensitivity** of the asset to the hazard, and*

*the **capacity** of the asset to **adapt** to mitigate the hazard exposure.*

The overall **vulnerability** of the assets to potential future hazards is based on analysis of the above grading categories. The overall vulnerability score for each asset was determined based on the combination of an asset's vulnerability components (exposure to hazard(s), sensitivity to hazard(s), and adaptive capacity) by assigning point scores to each vulnerability component. Hazard exposure and sensitivity scores range from 1 point for low grade exposure/sensitivity to 3 points for high grade exposure/sensitivity (i.e. higher hazard exposure and higher asset sensitivity to lead to higher asset vulnerability). The adaptive capacity grade is inversely related to score; the point scale ranges from 1 point for high adaptive capacity to 3 points for low adaptive capacity (i.e. an asset with higher adaptive capacity has a lower potential vulnerability). All component scores are summed to calculate the total vulnerability score for each asset category. **Table 4-4** presents the vulnerability score calculation determined from each component. The vulnerability summaries are indications of the degree of potential vulnerability, not rankings or priorities.

Table 4-4. Vulnerability Summary Grading Scheme

Component	Grade	Score
Hazard Exposure	Low to High	1 to 3
Asset Sensitivity	Low to High	1 to 3
Adaptive Capacity	High to Low	1 to 3
Vulnerability	**Grade**	**Total**
Sum of component scores	**High**	**9**
	Medium-High	**7 to 8**
	Medium	**5 to 6**
	Medium-Low	**4**
	Low	**3**

4.2 Malibu Asset Vulnerabilities

Vulnerability of each asset type in Malibu is summarized in the following tables. Vulnerability of some Categories are presented as separate tables (e.g. Critical assets, Development, Water). A City-wide Malibu Vulnerability summary, **Table 4-5,** is provided in **Section 4.3** that presents average vulnerability grades for each asset class based on average hazard exposure across each class. Hazard exposure is summarized for permanent and temporary impacts for existing conditions and potential sea level rise projected in mid century (2.5 feet at 2070-2075) and late century (6.6 feet at 2100-2120). Vulnerability Maps shown in **Appendix D** overlay the assets and coastal hazards for each sea level rise scenario. The asset and hazard mapping data used for the exposure analysis are also shown in the Malibu Sea level Rise WebMap that is linked on the City's Website.

4.2.1 Communication

Table 4-5. Communication Asset Vulnerability	
Assets	Communication assets within Malibu include cellular and other communication towers.
Hazard Exposure	The GIS analysis shows that 19 communication towers could be impacted by sea level rise this century. Exposure of Communication Towers: ▪ Permanent: 1 mid century, 11 late century ▪ Temporary: 9 mid century, 8 late century
	Hazard Exposure grade: ▪ Communication Towers: 3 Low, 15 Medium, 1 High
Asset Sensitivity	▪ Increased frequency of flooding of towers leading to water damage and other flood related damages. ▪ Long-term operational interruption if mechanical/electrical systems are subject to damage. ▪ Increased risk of erosion or storm damage which could damage or down the tower and cause delays in communications.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Communications towers may require significant effort to modify or relocate given the size and implications to ongoing communications during modifications.
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Communication towers: 3 Med-Low, 16 Medium

4.2.2 Critical Facilities

Emergency Facilities, Fire Stations, Fire Hydrants

Table 4-6. Emergency Facilities Vulnerability	
Assets	Emergency facilities in Malibu include a designated emergency shelter location at Zuma Beach parking lot. Four LA County fire stations and numerous fire hydrants exist in Malibu. Pacific Coast Highway (a critical access route) is summarized in Transportation.
Hazard Exposure	Part of the Zuma Beach parking lot is a designated emergency shelter location with a helipad. The area is currently exposed to coastal storm flooding wave run-up; flooding exposure increases with sea level rise. LA County Fire Station #88 on Malibu Road is at risk of storm flooding today and mid century. The other fire stations in Malibu are not at risk within the sea level rise scenarios analyzed. The GIS analysis shows that 155 fire hydrants could be impacted by sea level rise this century. Exposure of Fire Hydrants: ▪ Permanent: 18 mid century, 96 late century ▪ Temporary: 34 mid century, 59 late century
	Hazard exposure grade: ▪ Zuma Beach emergency shelter location: Medium ▪ LA County Fire Station #88: Medium ▪ Fire Hydrants: 42 Low, 95 Medium, 18 High
Asset Sensitivity	▪ Flooding of Fire Station 88 may impact fire response capabilities and response time. Erosion of many fire hydrants could impact response capabilities and disrupt the hydrant network. ▪ Increased frequency of flooding may lead to water damage and other flood related damages. ▪ Flooding of Zuma parking lots would impact emergency shelter operations.
	Sensitivity grade: High
Adaptive Capacity	▪ Adaptation modifications to Fire Station 88 may require a temporary station to be established to provide continued emergency response coverage. ▪ Fire Hydrants may be difficult to relocate because they are part of a greater pipe network. ▪ Emergency Shelter location parking lot could be elevated above flood elevations, protected by other means with sea level rise or relocated to another area.
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Zuma Beach emergency shelter location: Medium ▪ Fire Station 88: Medium ▪ Fire Hydrants: 137 Med-High, 18 High

Lifeguard Facilities

Table 4-7. Lifeguard Facilities Vulnerability	
Asset	There are many LA County lifeguard towers along Malibu's beaches.
Hazard Exposure	Many of the lifeguard towers are already at risk of flooding during a 100-year storm or through wave run-up. Future sea level rise will expose many lifeguard facilities to flooding and erosion this century. Exposure of Lifeguard Facilities: ▪ Permanent: 6 mid century, 24 late century ▪ Temporary: 24 mid century, 7 late century Lifeguard Towers #1, #2, and #3 at Dan Blocker/Corral State Beach are exposed to beach erosion by mid century, as are Surfrider Beach Lifeguard Tower #1 and the tower at Nicholas Canyon Beach. Zuma Beach Lifeguard Tower #13 is expected to be inundated daily by mid century. Most of the remaining lifeguard stations (19 stations) are expected to experience erosion or tidal inundation by late century, including the Zuma Beach Lifeguard Headquarters
	Hazard exposure grade: ▪ Lifeguard Towers and Stations: 1 Low, 21 Medium, 6 High ▪ Westward Beach Lifeguard Substation: Low ▪ Zuma Beach Lifeguard Headquarters: Medium
Asset Sensitivity	▪ Lifeguard Stations: Flooding and erosion of headquarters buildings may impact emergency response capabilities and response time. Increased frequency of flooding may lead to water damage and other flood related damages. ▪ Lifeguard towers on beaches have greater adaptive capacity; they can be moved landward from flooding and erosion hazards as needed
	Sensitivity grade: ▪ Lifeguard Towers: Low ▪ Lifeguard Headquarters and Sub Stations: High
Adaptive Capacity	▪ Extensive modifications to lifeguard headquarters and stations may require temporary stations to be established for continued first responder service. ▪ Lifeguard headquarters and stations could be reconfigured to improve flood resilience by locating important components and utilities higher in the building, elevate structures entirely, or move structures landward. ▪ Lifeguard towers in Malibu are mobile by design and can be relocated as needed to avoid/reduce erosion and flooding impacts as long as there is available space (on beach or bluff top).

Table 4-7. Lifeguard Facilities Vulnerability	
	Adaptive Capacity grade: ▪ Lifeguard Towers: High ▪ Lifeguard Headquarters and Substation: Medium
Vulnerability Summary	▪ Lifeguard Towers: 1 Low, 21 Medium-Low, 6 Medium ▪ Topanga Beach Lifeguard Station: Medium-High ▪ Westward Beach Lifeguard Sub Station: Medium ▪ Zuma Beach Lifeguard Headquarters: Medium-High

Other Public Safety Facilities

Table 4-8. Legal Facilities Vulnerability	
Assets	Public Defenders' offices are in the City of Malibu.
Hazard Exposure	The Los Angeles County Superior Courthouses, Public Defenders' offices, and District Attorney's offices are all at risk of daily tidal inundation by late century.
	Hazard exposure grade: ▪ Legal Facilities: 3 Medium
Asset Sensitivity	▪ Flooding disruptions may impact operations of the legal system. ▪ Increased frequency of flooding may lead to water damage and other flood related damages.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Large buildings may be difficult to elevate or relocate away from hazards without serious effort and disruptions to the legal system.
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Legal Facilities: 3 Medium-High

4.2.3 Development

Coastal Armoring

Table 4-9. Coastal Armoring Vulnerability	
Assets	Several coastal armoring structure types exist in Malibu, including: ▪ Timber walls ▪ Seawalls (concrete, sheet pile) ▪ Rock revetments ▪ Other rubble
Hazard Exposure	Coastal armoring is specifically designed and intentionally located to be in the hazard zones. However, over time, the exposure of the structures will likely increase, so that a revetment that experiences occasional flooding today could experience deeper floodwaters and stronger wave action in the future. Failure of a coastal armoring structure can have high consequences for landward development that it protects depending on the offset between armoring and development. The GIS analysis shows that 7 miles of coastal armor could be impacted this century Exposure of Coastal Armoring Structures: ▪ Permanent: 5.9 miles mid century,7.0 miles late century ▪ Temporary: 0.7 miles mid century, 0.0 miles late century
	Hazard exposure grade: ▪ Coastal Armoring Structures: 0.0 miles Low, 1.1 miles Medium, 5.9 miles High
Asset Sensitivity	Coastal structures are designed to be in hazard zones, however: ▪ Increased water levels and wave run-up during storms can cause damage to the armoring structures; and ▪ Increased erosion in front of and around the ends of armoring structures can lead to incremental reduction in the level of flood protection and/or increased maintenance costs.
	Sensitivity grade: Medium with adequate maintenance (note sensitivity would be high with little to no maintenance)
Adaptive Capacity	▪ Some armoring structures may be easily modifiable, while others may require full reconstruction in order to provide increased protective services.
	Adaptive Capacity grade: Medium
Vulnerability Summary	▪ Coastal Armoring Structures: 1.1 miles Medium, 5.9 miles High

Commercial

Table 4-10. Commercial Buildings Vulnerability	
Assets	A total of 248 commercial buildings exist within Malibu, including: ▪ Commercial retail stores; ▪ Office buildings; ▪ Service stations; ▪ General industrial; ▪ Restaurants and bars; and ▪ Hotels and motels.
Hazard Exposure	The GIS analysis shows that 126 commercial building assets could be potentially impacted this century. Exposure of Commercial Buildings: ▪ Permanent: 22 mid century, 75 late century ▪ Temporary: 41 mid century, 51 late century
	Hazard exposure grade: ▪ Commercial Buildings: 45 Low, 59 Medium, 22 High
Asset Sensitivity	▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages. ▪ Long-term operational interruption if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. ▪ Disrupted access to and from buildings.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Large buildings may be difficult to elevate or relocate away from hazards.
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Commercial Buildings: 45 Medium-Low, 81 Medium

Government and Institutional

Table 4-11. Government and Institutional Buildings Vulnerability	
Assets	A total of 195 Government and Institutional buildings exist within the coastal zone in Malibu, including: ▪ State buildings ▪ County buildings ▪ Libraries ▪ Churches ▪ Colleges and schools
Hazard Exposure	The GIS analysis shows that 33 government buildings could be potentially impacted this century. Exposure of Government Buildings: ▪ Permanent 5 mid century, 14 late century ▪ Temporary 19 mid century, 19 late century No Institutional buildings are exposed for the sea level rise scenarios considered in this study.
	Hazard exposure grade: ▪ Government Buildings: 6 Low, 22 Medium, 5 High
Asset Sensitivity	▪ Disrupted access to and from the buildings. ▪ Affected ability to provide emergency services. ▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Large buildings may be difficult to elevate or relocate away from hazards
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Government Buildings: 6 Medium, 27 Medium-High

Industrial

Table 4-12. Industrial Buildings Vulnerability	
Assets	A total of 68 Industrial buildings exist within Malibu, including: ▪ Manufacturing ▪ Warehousing/Storage ▪ Distribution ▪ Mineral Processing
Hazard Exposure	The GIS analysis shows that 6 industrial buildings could be potentially impacted this century. Exposure of Industrial Buildings: ▪ Permanent: 1 mid century, 5 late century ▪ Temporary: 0 mid century, 1 late century
	Hazard exposure grade: ▪ Industrial Buildings: 1 Low, 4 Medium, 1 High
Asset Sensitivity	▪ Disrupted access to and from the buildings. ▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Large buildings may be difficult to elevate or relocate away from hazards
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Industrial Buildings: 1 Medium, 5 Medium-High

Recreational

Table 4-13. Recreational Building Vulnerability	
Assets	A total of 35 Recreational buildings exist within Malibu, including: ▪ Athletic and Amusement ▪ Camps ▪ Clubs and Lodge Halls
Hazard Exposure	The GIS analysis shows that 4 recreational buildings could be potentially impacted this century. Exposure of Recreational Buildings: ▪ Permanent 2 mid century, 3 late century ▪ Temporary 2 mid century, 1 late century
	Hazard exposure grade: ▪ Recreational Buildings: 2 Medium, 2 High
Asset Sensitivity	▪ Disrupted access to and from the buildings. ▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Large buildings may be difficult to elevate or relocate away from hazards
	Adaptive Capacity grade: Low
Vulnerability Summary	▪ Recreational Buildings: 4 Medium-High

Residential

Table 4-14. Residential Building Vulnerability	
Assets	A total of 6966 residential buildings exist in Malibu, including: ▪ Single-family homes ▪ Single-family homes ▪ Mobile homes ▪ Mobile homes
Hazard Exposure	The GIS analysis shows that 1410 residential buildings could be potentially impacted this century. Exposure of Single Family Homes: ▪ Permanent: 613 mid century, 1146 late century ▪ Temporary: 446 mid century, 126 late century Exposure of Multi-Family Buildings: ▪ Permanent: 104 mid century, 129 late century ▪ Temporary: 18 mid century, 4 late century Exposure of Mobile Homes: ▪ Permanent: 1 mid century, 5 late century ▪ Temporary: 1 mid century, 0 late century
	Hazard exposure grade: ▪ Single Family Homes: 56 Low, 603 Medium, 613 High ▪ Multi-Family Buildings: 1 Low, 29 Medium, 103 High ▪ Mobile homes: 3 Medium, 2 High
Asset Sensitivity	▪ Disrupted access to and from the buildings. ▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages. ▪ Many building footprints are shown to be exposed to existing tidal inundation, though they may be elevated (e.g. on piles) above tidal elevations and potentially also above flooding elevations. Additional study would be needed to refine the sensitivity and vulnerability of oceanfront buildings based on finished floor elevations and their foundations.
	Sensitivity grade: ▪ Single Family Homes: 56 Low, 603 Medium, 613 High ▪ Multi-Family Buildings: 1 Low, 29 Medium, 103 High ▪ Mobile homes: 3 Medium, 2 High

Table 4-14. Residential Building Vulnerability	
Adaptive Capacity	▪ Some residential buildings could be further elevated or relocated to reduce inundation and/or flooding exposure. Relocation options are limited for buildings on smaller parcels. ▪ Larger residential buildings and homes may require significant effort to adapt to erosion and flooding hazards. ▪ Mobile homes may be relatively easier to relocate or elevate than other building types.
	Adaptive Capacity grade: ▪ Single family homes: Medium ▪ Multi-family buildings: Low ▪ Mobile homes: High
Vulnerability Summary	▪ Single Family Homes: 659 Medium, 613 Medium-High ▪ Multi-Family Buildings: 1 Medium, 132 Medium-High ▪ Mobile homes: 5 Medium

Other Development

Table 4-15. Other Building Vulnerability	
Assets	A total of 79 uncharacterized buildings exist within the coastal zone in Malibu that are included for completeness.
Hazard Exposure	The GIS analysis shows that 12 uncharacterized buildings could be potentially impacted (mid to late century): Exposure of Other Buildings: ▪ Permanent: 6 mid century, 12 late century ▪ Temporary: 3 mid century, 0 late century
	Hazard exposure grade: ▪ Other Buildings: 6 Medium, 6 High
Asset Sensitivity	▪ Disrupted access to and from the buildings. ▪ Increased frequency of flooding of buildings leading to water damage and other flood related damages.
	Sensitivity grade: ▪ Medium
Adaptive Capacity	▪ Some buildings could be elevated or relocated to reduce inundation and or flooding exposure. Relocation options are limited for buildings on smaller parcels. ▪ Larger buildings may require significant effort to adapt to erosion and flooding hazards.
	Adaptive Capacity grade: ▪ Medium
Vulnerability Summary	▪ Other Buildings: 6 Medium, 6 Medium-High

4.2.4 Ecology

Vulnerability for ecological resources in Malibu is based on exposure determined in GIS similar to other built assets as well as specific evaluations for Malibu Lagoon and beaches along the Malibu coastline.

Table 4-16. Ecology Vulnerability	
Assets	Natural assets within the coastal zone include beaches, wetlands and environmentally sensitive habitat areas (ESHA). Wetland types considered include estuarine, marine wetland (e.g. beaches), freshwater emergent wetland, freshwater forested wetland, freshwater pond, and riverine. ESHAs in Malibu include lagoons, rivers, creeks, canyons, bluff top and upland foothills of the Santa Monica Mountains. For context, the following ecological assets are exposed to tidal inundation under existing conditions: ▪ Beaches: 54.3 acres ▪ ESHAs: 67.9 acres ▪ Wetlands: 243.8 acres
Hazard Exposure	Natural assets can be resilient to storm events (e.g., by only sustaining mild impacts and/or recovering) but can be impacted by erosion and increased inundation with sea level rise. The GIS analysis shows that many ecological assets could be potentially impacted this century. Exposure of Beaches: ▪ Permanent: 152.3 acres mid century, 191.6 acres late century ▪ Temporary: 71.9 acres mid century, 35.4 acres late century ▪ Includes 100 to 176 acres of beach lost to shoreline erosion by mid to late century respectively, or 40 feet (mid century) to 68 feet (late century) reduction in average beach width. ▪ Beaches along 43% to 78% of the shore may be lost by mid and late century, respectively Exposure of ESHAs: ▪ Permanent: 144.3 acres mid century, 169.9 acres late century ▪ Temporary: 36.3 acres mid century, 37.0 acres late century ▪ Includes 68 to 82 acres lost to erosion and 8 to 19 acres of increased tidal influence compared to existing conditions (by mid to late century, respectively). Exposure of Wetlands: ▪ Permanent: 324.8 acres mid century, 357.8 acres late century ▪ Temporary: 76.2 acres mid century, 47.8 acres late century; ▪ Includes 44 to 63 acres of wetlands lost to erosion (e.g. beaches, lagoons and freshwater streams) and 37 to 51 acres of increased tidal inundation compared to existing conditions (by mid to late century, respectively)
	Hazard exposure grade: ▪ Beaches: 1.0 acres Low, 73.6 acres Medium, 152.3 acres High ▪ Wetlands: 3 acres Low, 90 acres Medium, 335 acres High ▪ ESHAs: 11.3 acres Low, 51.8 acres Medium, 144.3 acres High

Table 4-16. Ecology Vulnerability	
Asset Sensitivity	Beaches: While some beaches in Malibu are wide and can accommodate erosion from year to year (seasonal fluctuations), many beaches in Malibu are already narrow, are lost to erosion in winter, and are thus sensitive to small amounts of sea level rise and coastal storm erosion. ESHA: Environmentally sensitive habitat areas are sensitive to fragmentation and encroachment. Erosion will encroach on bluff top areas and riparian corridors that drain to the ocean, converting habitat in the process. Tidal inundation will encroach upon wetlands and may lead to expansion. Habitats subject to flooding near the coast are only temporarily affected. Wetlands: While wetland habitats by definition experience some amount of inundation or flooding, erosion and increased inundation may change habitats and the species that can establish in those areas (e.g., salt marsh vegetation species tend to establish at elevations dependent on inundation frequency. With sea level rise, if certain plant species are inundated too frequently, they will drown out, and other plant species that are adapted to more frequent inundation can establish).
	Sensitivity grade: ▪ Beaches: High ▪ Wetlands: Medium ▪ ESHA: Medium
Adaptive Capacity	▪ Beaches have some adaptive capacity in the few areas that are currently wide (Zuma, Westward Beach) and/or have lowland transgression space at lagoon mouths (Zuma and Malibu). Beaches in front of unarmored bluffs may have some adaptive capacity for sea level rise but may become unable to persist with higher rates of sea level rise. Beaches have little to no adaptive capacity in front of armoring structures. ▪ ESHAs subject to permanent erosion impacts have limited ability to adapt other than wildlife to migrate upland/inland as certain ESHAs are eroded. On the other hand, wetland ESHAs have adaptive capacity depending on local topography and sediment supply (see wetlands description below). ▪ Adaptive capacity of wetland habitats depends in part on space for habitats to migrate (transgress) with sea level rise. Wetlands in Malibu (lagoons) appear to have some adaptive capacity for habitat transgression with sea level rise. As higher sea levels cause higher lagoons water levels, wetland vegetation will establish further upstream higher onto floodplains and upland slopes. Analysis of CoSMoS tidal inundation extents in Malibu Lagoon suggests that there is space to accommodate wetland transgression in lower Malibu Canyon; existing tidal inundation increases from 54.1 acres to 57.7 acres by mid century and up to 67.7 acres by late century. This suggests that the lagoon itself is not constrained topographically (i.e. there is some lateral space for habitats to migrate). However, these acreages include areas that become subtidal and are not able to sustain marsh habitats. Detailed habitat evolution modeling is needed to better

Table 4-16. Ecology Vulnerability	
	understand the vulnerability of Malibu Lagoon to sea level rise. Other factors influencing wetland adaptive capacity includes changes in salinity, sedimentation and nutrient supply.
	Adaptive Capacity grade: ▪ Beaches: Low ▪ ESHA: Medium ▪ Wetlands: Medium
Vulnerability Summary	**Vulnerability grade:** ▪ Beaches: High ▪ ESHA: Medium-High ▪ Wetlands: Medium

4.2.5 Energy

Table 4-17. Energy Vulnerability	
Assets	Energy assets within Malibu include electrical meters that represent the power distribution infrastructure throughout Malibu.
Hazard Exposure	The GIS analysis shows that 130 electrical meters could be potentially impacted this century. Exposure of Electrical Meters: ▪ Permanent: 10 mid century, 60 late century ▪ Temporary: 10 mid century, 70 late century
	Hazard exposure grade: ▪ Electrical Meters: 70 Low, 50 Medium, 10 High
Asset Sensitivity	▪ Increased erosion or storm flooding damages could shut down the electric meters and cause service disruptions.
	Sensitivity grade: ▪ Electrical meters: Medium
Adaptive Capacity	▪ Electrical infrastructure could be difficult to reconfigure for increased inundation, flooding or erosion in some areas. Underground lines may already be waterproofed and overhead lines are already protected from flooding and inundation. Electrical meters and connection points could be relocated or elevated above flooding elevations where applicable.
	Adaptive Capacity grade: Electrical meters: Medium
Vulnerability Summary	▪ Electrical meters: 120 Medium, 10 Medium-High

4.2.6 Recreation

Table 4-18. Recreation Vulnerability	
Assets	Public recreation and visitor-serving assets in Malibu's coastal zone include: ▪ Beaches (see ecology) ▪ Parks and Open Space ▪ Hiking Trails ▪ Paradise Cove and Malibu Piers ▪ Coastal Access Points
Hazard Exposure	The GIS analysis shows that the following assets would potentially be impacted (mid to late century): Exposure of Parks and Open Space: ▪ Permanent: 141.4 acres mid century, 186.6 acres late century ▪ Temporary: 101.0 acres mid century, 81.0 acres late century ▪ Includes 50 to 80 acres lost to erosion; 16 to 32 acres more tidal inundation than under existing conditions Exposure of Hiking Trails: ▪ Permanent: 0.61 miles mid century, 0.74 miles late century ▪ Temporary: 0.24 miles mid century, 0.26 miles late century Exposure of Coastal Access Points: ▪ Permanent: 20 mid century, 32 late century ▪ Temporary: 9 mid century, 3 late century Exposure of Piers: ▪ Paradise Cove Pier is exposed to storm flooding under existing conditions (designated as high exposure) ▪ Malibu Pier is exposed to storm flooding impacts under existing conditions and erosion by mid century.
	Hazard exposure grade: ▪ Parks: 13.8 acres Low, 112.9 acres Medium, 141.4 acres High ▪ Hiking Trails: 0.2 miles Low, 0.3 miles Medium, 0.6 miles High ▪ Coastal Access Points: 0 Low, 15 Medium, 20 High ▪ Malibu Pier and Paradise Cove Pier: High
Asset Sensitivity	▪ Increased frequency of flooding and erosion leading to water damage and other flood related damages. ▪ Loss of coastal access due to inundation of and storm impacts to coastal access points. ▪ Loss of access to recreational amenities due to inundation of parks and other facilities. ▪ Loss of mobility for pedestrian and bicyclists within the coastal zone due to inundation of segments of existing trails. ▪ Access to the piers would be disrupted during flood events, which would halt operations of facilities on Malibu Pier.

Table 4-18. Recreation Vulnerability	
	Sensitivity grade: ▪ Parks: Low ▪ Hiking trails: Medium ▪ Coastal access points: Medium ▪ Malibu and Paradise Cove piers: Medium (assuming some level of maintenance)
Adaptive Capacity	▪ Parks and Open Space can accommodate more impacts due to limited built assets. ▪ Hiking trails are easily relocated to avoid inundation or erosion impacts in most cases. ▪ Coastal access points may need to be reconstructed or reconfigured to accommodate permanent and temporary impacts. ▪ Malibu and Paradise Cove Piers may be raised on existing piers or may potentially need new taller piers.
	Adaptive Capacity grade: ▪ Parks: High ▪ Hiking trails: High ▪ Coastal access points: Medium ▪ Malibu and Paradise Cove piers: Medium
Vulnerability Summary	▪ Parks: 13.8 acres Low, 112.9 acres Medium-Low, 141.4 acres Medium ▪ Hiking Trails: 0.2 miles Medium-Low, 0.9 miles Medium ▪ Coastal Access Points: 15 Medium, 20 Medium-High ▪ Malibu Pier and Paradise Cove Pier: Medium-High

The Malibu and Paradise Cove Piers are designed to avoid flooding and wave impacts. However, over time, the exposure of the structure to waves and large storm events will increase. Additionally, the assets on top of the Malibu pier (e.g., restaurant, restrooms) will experience more frequent flooding and wave exposure with sea level rise. Given the damages sustained at each pier during previous El Niño events and hazard exposures above, both are categorized as high exposure.

4.2.7 Transportation

Pacific Coast Highway is a critical local and regional access corridor through Malibu. Some neighborhoods are at risk of isolation if major impacts to the highway or other local roads occur.

Table 4-19. Transportation Vulnerability	
Assets	The transportation assets in Malibu include: ▪ Pacific Coast Highway (PCH), a critical access route in the region ▪ Many local roads that provide access to businesses, residences, and the coast ▪ Fueling Stations (County fueling, propane, electricity) ▪ Bridges (Pacific Coast Highway) ▪ Parking Lots
Hazard Exposure	The GIS analysis shows that the following transportation assets may be impacted by sea level rise this century: Exposure of Local Roads: ▪ Permanent: 1.16 miles mid century, 5.52 miles late century ▪ Temporary: 2.31 miles mid century, 2.18 miles late century Exposure of Pacific Coast Highway: ▪ Permanent: 0.55 miles mid century, 2.71 miles late century ▪ Temporary: 0.32 miles mid century, 1.91 miles late century Exposure of Fueling Stations: ▪ Permanent: 0 mid century, 1 late century ▪ Temporary: 0 mid century, 2 late century Exposure of Bridges: ▪ Permanent: 1 mid century, 3 late century ▪ Temporary: 2 mid century, 3 late century Exposure of Parking Lots: ▪ Permanent: 3 mid century, 27 late century ▪ Temporary: 31 mid century, 25 late century
	Hazard exposure grade: ▪ Local Roads: 1.2 miles Low, 5.4 miles Medium, 1.2 miles High ▪ PCH: 1.6 miles Low, 2.5 miles Medium, 0.5 miles High ▪ Fueling Stations: 2 Low, 1 Medium ▪ Bridges: 1 Low, 4 Medium, 1 High ▪ Parking Lots: 12 Low, 37 Medium, 3 High
Asset Sensitivity	▪ Disrupt access pathways critical for emergency services. ▪ Disrupt transportation links to local businesses, residences, and municipal infrastructure. ▪ Damage to existing roadways and related infrastructure due to scour and erosion of embankments, footings and other structural/ geotechnical elements. ▪ Fueling stations may be relied upon by emergency vehicles, and may be damaged by saltwater flooding. ▪ Bridges are designed for some level of creek flooding.

Table 4-19. Transportation Vulnerability	
	Sensitivity grade: ▪ Local Roads: Medium ▪ Pacific Coast Highway: High ▪ Fueling Stations: High ▪ Bridges: Low ▪ Parking Lots: Medium
Adaptive Capacity	▪ Local Roads may be elevated in place, but may have implications to property access during construction and may require modifications to property access connections. ▪ Pacific Coast Highway is a critical transportation corridor that would require more significant efforts to elevate or realign. ▪ Bridges for PCH would require significant efforts to elevate or realign, however erosion protection measures could be implemented at exposed locations.
	Adaptive Capacity grade: ▪ Local roads: Medium ▪ Pacific Coast Highway: Low ▪ Fueling Stations: Low ▪ Bridges: Low ▪ Parking Lots: Medium
Vulnerability Summary	▪ Local roads: 6.6 miles Medium, 1.2 miles Medium-High ▪ Pacific Coast Highway: 4.1 miles Medium-High, 0.5 miles High ▪ Bridges: 5 Medium, 1 Medium-High ▪ Fueling Stations: 3 Medium-High ▪ Parking Lots: 49 Medium, 3 Medium-High

Pacific Coast Highway is exposed by mid century to erosion and coastal flooding near Corral Canyon and coastal flooding near Zuma Beach. In the long term it is exposed to erosion at Nicholas Canyon Beach. The following local roads may be permanently impacted by erosion or inundation resulting from sea level rise:

- Bayshore Dr
- Big Rock Dr
- Birdview Av
- Budwood Mtwy
- Civic Center Wy
- Cross Creek Rd
- Escondido Beach Rd
- Fines Rd
- Fines Rd
- Guernsey Av
- La Paz Ln
- Latigo Shore Dr
- Latigo Shore Pl
- Malibu Colony Dr
- Malibu Colony Rd
- Malibu Cove Colony Dr
- Malibu Rd
- Mariposa De Oro
- Nicholas Beach Rd
- Point Lechuza Dr
- Puerco Canyon Rd
- Rambla Vista
- Sea Daisy Dr
- Sea Level Dr
- Seafield Dr
- Shearwater Ln
- Stuart Ranch Rd
- Topanga Beach Rd
- Tuna Canyon Rd
- Via Escondido
- Victoria Point Rd
- Webb Wy
- Zuma Bay Wy
- Zuma Beach Access Rd

4.2.8 Water Infrastructure

Stormwater

Table 4-20. Stormwater Infrastructure Vulnerability	
Assets	The municipal storm drain system serves coastal communities in Malibu. The asset data for the stormwater system includes: ▪ Storm Drain Lines (pipes and culverts) ▪ Storm Drain Blocks (inlets, junctions)
Hazard Exposure	The analysis shows that the following stormwater assets could potentially be impacted (mid to late century): ▪ Storm Drain Lines: 2.5 to 6.9 miles Permanent, 1.5 to 1.7 miles Temporary ▪ Storm Drain Blocks: 9 to 76 Permanent, 20 to 45 Temporary
	Hazard exposure grade: ▪ Storm Drain Lines: 1.6 miles Low, 5.4 miles Medium, 2.5 miles High ▪ Storm Drain Blocks: 36 Low, 76 Medium, 9 High
Asset Sensitivity	▪ Potential blockage of stormwater drains by beach sediment or damage of drains from waves. ▪ Backwater effects in drainage lines due to downstream flow blockage or constrictions. ▪ Insufficient capacity for conveying increased rainfall runoff. ▪ Failure of storm drainage systems may cause flooding in low areas away from the coast and associated property damage. ▪ Failure of storm drainage system may cause impacts to water quality.
	Sensitivity grade: Medium
Adaptive Capacity	▪ Storm drains typically extend beneath roads or other developed areas and may be difficult to reconfigure without impacting other assets.
	Adaptive Capacity grade: Medium
Vulnerability Summary	▪ Storm Drain Lines: 7.0 miles Medium, 2.5 miles High ▪ Storm Drain Blocks: 36 Low, 76 Medium, 9 High

Wastewater

Table 4-21. Wastewater Infrastructure Vulnerability	
Assets	Sanitary sewer pipes, pumping stations, and treatment plants are essential to the function of the sewer system for some areas. The wastewater infrastructure includes sewer lines and mains, pump stations and treatment facilities. Beachfront properties and most others in Malibu rely on septic systems that may be susceptible to impacts from rising groundwater levels.
Hazard Exposure	The GIS analysis shows that the following wastewater assets could potentially be impacted this century. Sewer mains, treatment plants and pump stations: none exposed by late century Exposure of Sewer Pipes: ▪ Permanent: 0.00 miles mid century, 0.09 miles late century ▪ Temporary: 0.00 miles mid century, 0.04 miles late century
	Hazard exposure grade: ▪ Sewer Pipes: 0.04 miles Low, 0.09 miles Medium
Asset Sensitivity	▪ Increased flooding exposure of critical infrastructure (pumps, utilities), may disrupt operations and potentially damage equipment. ▪ Rising surface waters may limit access to facilities and pipelines for maintenance and operations. ▪ Rising ground water levels may place unanticipated buoyancy forces on buried pipelines, potentially leading to leaks and/or other pipe-related issues. ▪ Erosion may damage the wastewater system and cause impacts to water quality
	Sensitivity grade: ▪ Sewer infrastructure: High
Adaptive Capacity	▪ Sewer pipes flow via gravity and typically extend beneath roads or other developed areas and may be difficult to reconfigure conveyance lines without impacting other assets. ▪ Sewer mains may have more flexibility in location and elevation because they are pressurized, although are more resource intensive and may require additional pump stations
	Adaptive Capacity grade: ▪ Sewer infrastructure: Low
Vulnerability Summary	▪ Sewer Pipes: 0.04 miles Medium, 0.09 miles Medium-High

NOTE: Most properties in Malibu are on septic wastewater systems. Septic systems are used at most beachfront parcels and most parcels near the coastline in Malibu. Septic systems typically rely on a buried tank and a groundwater infiltration system that slowly drains into the groundwater. Septic systems are most vulnerable to sea level rise on parcels at beach elevations with a shallow groundwater table. Rising groundwater levels may intercept buried tanks and cause buoyancy issues (i.e. force tanks upwards) or limit the efficacy of infiltration systems. Because site-specific data on Malibu septic system configurations are not available, vulnerability could not be quantified. For the purpose of this study, septic system vulnerability to sea level rise is rated Medium-High given the large number of beachfront properties. Further study is needed to determine septic system vulnerabilities on a parcel level.

GIS data for stormwater and sewer manholes were not available at the time of this study. Manholes for stormwater and sewer infrastructure may intercept saltwater when exposed to storm flooding and/or tidal inundation, which may impact transmission and/or treatment infrastructure.

4.3 Malibu Vulnerability Summary

With projected sea level rise, Malibu's current vulnerabilities to coastal flooding and erosion are projected to increase. There are many assets currently exposed to flooding and erosion hazards in the coastal zone that will experience greater hazard impacts without action. There are also many assets that are not currently subject to coastal hazards but may become exposed under projected future conditions. **Table 4-22** summarizes the grades for each asset category's exposure to hazard, sensitivity to hazard, and overall vulnerability.

Table 4-22. Malibu Sea level Rise Vulnerability Summary

Asset Category	Asset	Hazard Exposure	Asset Sensitivity	Adaptive Capacity	Vulnerability
Communication	Communication Towers	Med	Med	Low	**Med-High**
Critical Facilities	Fire Stations	Med	High	Low	**High**
	Fire Hydrants	Med	High	Low	**High**
	Emergency Shelter	Med	High	Low	**High**
	Legal Facilities	Med	Med	Low	**Med-High**
	Lifeguard Towers	Med-High	Low	High	**Med**
	Lifeguard Stations and Headquarters	Med	High	Med	**Med-High**
Development	Coastal Armoring Structures	High	Med	Low	**Med-High**
	Commercial Buildings	Med	Med	Low	**Med-High**
	Government Buildings	Med	Med	Low	**Med-High**
	Industrial Buildings	Med	Med	Low	**Med-High**
	Recreational Buildings	Med-High	Med	Low	**Med-High**
	Single Family Homes	Med-High	Med	Med	**Med-High**
	Multi-Family Buildings	High	Med	Low	**Med-High**
	Mobile Homes	Med-High	Med	High	**Med**
	Parking Lots	Med	Med	Med	**Med**
	Other Buildings	Med-High	Med	Med	**Med-High**
	Malibu Parcels	Med-High	Med	Med	**Med-High**
Ecology	Wetlands	High	Med	Med	**Med-High**
	Beaches	Med-High	High	Low	**High**
	Environmentally Sensitive Habitat Areas (ESHA)	Med-High	Med	Med	**Med-High**
Energy	Electrical Meters	Med-Low	Med	Med	**Med**

Table 4-22. Malibu Sea level Rise Vulnerability Summary

Asset Category	Asset	Hazard Exposure	Asset Sensitivity	Adaptive Capacity	Vulnerability
Recreation	Parks and Open Space	Med-High	Low	High	**Med**
	Hiking Trails	Med-High	Med	High	**Med**
	Coastal Access Points	Med-High	Med	Med	**Med-High**
	Paradise Cove and Malibu Piers	Med	Med	Med	**Med**
Transportation	Bridges	Med	Low	Low	**Med**
	Local Roads	Med	Med	Med	**Med**
	Pacific Coast Highway	Med	High	Low	**Med**
	Fueling Stations	Med-Low	High	Low	**Med-High**
Water	Sewer Mains	n/a*	High	Med	**n/a***
	Sewer Pipes	Med-Low	High	Med	**Med**
	Sewer Treatment	n/a**	High	Low	**n/a***
	Sewer Pump Stations	n/a*	High	Low	**n/a***
	Storm Drain Lines	Med	Med	Med	**Med**
	Storm Drain Blocks	Med	Med	Med	**Med**

**n/a – vulnerability grading not applicable; assets are not exposed to hazards by late century*
*** septic systems are not evaluated in this study but have the potential for high vulnerability*

Section 5

VULNERABILITY DISCUSSION BY SUB-AREA

The City of Malibu has experienced impacts from coastal hazards such as erosion and flooding. Much of the oceanfront development is armored today. With sea level rise, the City's residential and commercial properties and supporting infrastructure along the coast may be impacted more frequently and to a greater degree by coastal erosion and flooding while regular tidal inundation will progress further inland and expose more coastal property and structures to regular high tides. Highway 1 may be exposed to coastal storm flooding in several locations by mid century, while local roads may also be impacted by coastal storm flooding and wave run-up and even regular tidal inundation by late-century.

Many of the narrow beaches along the Malibu coast may disappear with sea level rise, impacting shore ecology and recreation. Beaches in Malibu mostly exist as narrow stretches along beachfront homes, coastal bluffs and Hwy 1, with wider beaches exist at Zuma/Westward Beach and Point Dume State Beach and Malibu Surfrider Beach. Today, approximately one quarter of beaches in Malibu may disappear annually from seasonal fluctuations alone; nearly two thirds may disappear annually by mid century. In addition, beaches may cease to recover along coastal armoring and other hardened shorelines without action. The disappearance of beaches in Malibu would adversely impact ecological functions along the coastline as well as recreation opportunities for Malibu residents and visitors.

The following sections summarize vulnerabilities within each sub-area and how hazard exposure is expected to change with sea level rise. The sub-area discussions are focused on critical infrastructure, development and ecology.

5.1 Nicholas Canyon County Beach to Point Lechuza (Sub-area A)

Source: ESA, ESRI/Maxar

Figure 5-1. Malibu Sub-Area A

Coastal erosion is the dominant hazard that can impact assets in Sub-area A. The vulnerabilities in Sub-area A include a mix of residential development and open space on top of the bluffs as well as bluff-backed beaches. Some residential development exists at the bottom of the bluffs in small pocket beaches that are vulnerable to erosion and flooding. The narrow beaches in Sub-area A and coastal access points are also vulnerable to sea level rise.

Critical Infrastructure

Critical infrastructure in this reach includes the Nicholas Canyon Lifeguard Tower, which may experience erosion impacts late-century. A portion of Highway 1 along Nicholas Canyon Beach is vulnerable to bluff erosion. Several fire hydrants in the eastern subarea may be exposed to bluff erosion. Other important infrastructure includes a sewer pump station at the east end of Subarea A that may be exposed to erosion; while the pump station is not shown to be exposed via the GIS analysis, it is located only 6 feet landward from the bluff erosion hazard zone for 6.6 feet sea level rise.

Development

Vulnerable assets in this reach include residences built on the bluff slope. With sea level rise, development on the beaches or lower bluffs will flood more frequently, leading to property damages and degradation of coastal armoring structures. Some oceanfront homes may become exposed to tidal inundation with 6.6 feet of sea level rise. Bluff erosion may impact upland property and expose other buildings on the bluff slope and top that are not subject to flooding. Supporting utilities and other infrastructure (e.g. sewer, electricity, roads) may also be jeopardized by flooding and erosion, such as Sea Level Drive at the east end of the sub-area. Coastal access points along the sub-area are vulnerable to flooding and erosion with sea level rise.

Ecology

Ecological resources in the sub-area include ESHAs at Nicholas Canyon County Beach, several creek drainages, and El Matador State Beach. There are also sea lion haul outs in this area, as well as kelp beds along the length of Subarea A. Average beach widths in Sub-area A (82 feet existing) may erode by 60 to 81 feet with 2.5 to 6.6 feet SLR, respectively if the bluff and beachfront development are held in place. All of these resources are subject to increasing erosion with higher sea levels.

5.2 Point Lechuza to Point Dume (Sub-area B)

Source: ESA, ESRI/Maxar

Figure 5-2. Malibu Sub-Area B

Sub-area B vulnerabilities include erosion of blufftop development as well as flooding and erosion of low-lying beachfront development.

Critical Infrastructure

Critical infrastructure includes Highway 1 which may be exposed to wave run-up near Trancas Creek by late century. The emergency shelter location at Zuma Beach parking lot, lifeguard facilities and fire hydrants are also exposed.

Development

Vulnerable residential development includes the Broad Beach community and blufftop homes above Zuma Beach and Point Dume State Beach. The Broad Beach residential development is vulnerable to sea level rise and increased erosion and flooding hazards. Some buildings may become exposed to tidal inundation by late century. Most of the shoreline is currently armored. This armoring will be overtopped with increasing frequency and experience more severe flooding with higher sea levels, leading to damage of property (e.g., storm wave run-up and flooding damages to buildings and property). Beachfront parcels may also experience issues with onsite septic systems due to rising groundwater levels with sea level rise. The backshore parking lots along Zuma and Point Dume state Beach are exposed to storm flooding impacts today which will become more frequent and extensive with higher sea levels. Bluff erosion may impact residential structures from terrestrial erosion processes above Zuma Beach, if not a direct result of sea level rise.

Ecology

The sub-area includes Broad Beach, Zuma Beach and Point Dume State Beach. Ecological resources in the sub-area include Pismo clam habitat offshore and some kelp beds at the western most end. ESHAs include Zuma creek and lagoon and adjacent creek canyon to the east. Erosion of ESHA upland areas is likely the greatest vulnerability to ecological resources. The Zuma lagoon has some inland migration space. Shoreline erosion will reduce beach widths along the sub-area. Broad Beach has already experienced beach loss, while Zuma and Point Dume State Beaches are wide enough that they are projected to persist beyond late century (6.6 feet of SLR). Average beach widths in Sub-area B (179 feet existing) may erode by 15 to 88 feet with 2.5 to 6.6 feet SLR, respectively, if the bluff and beachfront development are held in place.

5.3 Point Dume to Escondido Beach (Sub-area C)

Source: ESA, ESRI/Maxar

Figure 5-3. Malibu Sub-Area C

Sub-area C vulnerabilities include erosion of residential development on the top of tall bluffs and some small pocket beaches. The west end of the sub-area includes blufftop open space Point Dume Natural Preserve which transitions to blufftop residential property, all of which is fronted by very narrow beaches.

Critical Infrastructure

Critical infrastructure in this sub-area includes fire hydrants, two of which are subject to bluff erosion with higher sea levels.

Development

Blufftop residences are vulnerable to bluff erosion, while beachfront buildings along the eastern sub-area are also vulnerable to shoreline erosion and coastal storm flooding and wave run-up. The Paradise Cove Pier, which was damaged in the 1987-88 El Niño, will become more vulnerable to coastal storm damage with higher sea levels. Coastal armoring structures are vulnerable to increased wave action with higher sea levels. Bluff erosion with higher sea levels threatens the most seaward blufftop roads on either side of Paradise Cove. Coastal access stairways are vulnerable to flooding and erosion by mid century.

Ecology

Ecological resources in the sub-area include ESHA-designated Point Dume Natural Reserve and the sea lion haul outs and clam habitat at Point Dume. Kelp beds stretch along most of the shore in Sub-area C. Existing beaches are mostly limited to small pockets along the western sub-area; the beach widens slightly east of Paradise Cove.

Average beach widths in Sub-area C (91 feet existing) may erode by 51 to 86 feet with 2.5 to 6.6 feet SLR, respectively, if the bluff and beachfront development are held in place.d

5.4 Escondido Beach to Malibu Surfrider Beach (Sub-area D)

Source: ESA, ESRI/Maxar

Figure 5-4. Malibu Sub-Area D

Vulnerabilities along Sub-area D include the more extensive residential development at or near beach elevations and Highway 1, which are vulnerable to erosion, coastal storm flooding and wave run-up.

Critical Infrastructure

Critical assets in Sub-area D include fire, lifeguard, and other public safety facilities. Fire hydrants along the backshore development access roads are vulnerable to erosion. Fire Station #88 on Malibu Road is vulnerable to coastal storm wave run-up flooding today and more significant flooding with sea level rise. Lifeguard towers are exposed to coastal erosion and flooding hazards but are more easily movable, whereas the permanent lifeguard structure at Malibu Surfrider Beach is vulnerable to erosion in the long term.

By mid century, segments of Highway 1 are vulnerable to erosion on both sides of Solstice Canyon. By late century, Highway 1 is vulnerable to erosion at Escondido Creek and Malibu Surfrider Beach as well as flooding east of the Malibu Creek bridge.

Development

Much of the beachfront residential development is armored in Sub-area D, indicating existing exposure to erosion and flooding. Sea level rise will lead to greater wave forces on the coastal armoring structures as well as increased wave run-up and overtopping into properties. Beachfront parcels may also experience issues with onsite septic systems due to rising groundwater levels with sea level rise. Access roads to beach-level development include Escondido Beach Road, Malibu Colony Cove Drive, Latigo Shore Road, Malibu Road and

Malibu Colony Road. Nearly all of these roads are vulnerable to erosion by late century (Malibu Colony Road is also vulnerable to tidal inundation late century), while some are vulnerable to erosion and or coastal storm flooding by mid century. Many coastal access points are vulnerable to erosion in the short term while others may be impacted by coastal storms; all access points are vulnerable to erosion by late century.

Malibu Pier is vulnerable to coastal storm impacts by mid century.

Ecology

Ecological resources in Sub-area D include beaches, ESHAs in most creek canyons and Malibu Lagoon. Average beach widths in Sub-area D (57 feet existing) may erode by 45 to 53 feet with 2.5 to 6.6 feet SLR, respectively, if the bluff and beachfront development are held in place.

5.5 Malibu Surfrider Beach to Topanga Beach (Sub-area E)

Source: ESA, ESRI/Maxar

Figure 5-5. Malibu Sub-Area E

Sub-area E vulnerabilities include beachfront residential development seaward of Highway 1 with narrow fronting beaches.

Critical Infrastructure

By mid century, Highway 1 may be exposed to erosion in a few locations along Sub-area E and storm wave run-up at the western end of Subarea E (east of Malibu Pier). By late century, Highway 1 may be widely exposed to coastal erosion and storm wave run-up along Sub-area E. Several Lifeguard towers are also vulnerable to erosion and flooding. Some of the fire hydrants serving the beachfront properties are also vulnerable to erosion by mid century, threatening the fire main that serves much of the properties seaward of Highway 1.

Development

Vulnerable development in Sub-area E includes beach front residential and commercial properties/buildings built seaward of Highway 1. Much of these properties are already protected with some form of coastal armor. Existing coastal armoring will require maintenance and upgrades with future sea level rise if development is protected in place.

Ecology

Ecological resources in the sub-area include narrow beaches, streams and some upland ESHAs landward of Highway 1. Average beach widths in Sub-area E (52 feet existing) may erode by 33 to 50 feet with 2.5 to 6.6 feet SLR, respectively, if the bluffs and beachfront development are held in place. Several coastal access points are vulnerable to erosion by mid century. Most access points are vulnerable to erosion and tidal inundation by late century.

Section 6

TOOLBOX OF POTENTIAL ADAPTATION MEASURES

This report identifies the degree of vulnerability that Malibu's beaches, wetlands, visitor-serving amenities, public access areas, residential and commercial areas, and public facilities and infrastructure could face as a result of sea level rise. There exist many individual tools, called measures, to address coastal hazards along the coast of Malibu. In fact, many such adaptation measures are currently in use throughout the City or planned by others to address existing coastal flooding and beach/bluff erosion, creek and lagoon flooding, and rising groundwater.

The following subsections describe ongoing adaptation planning by others and present a toolbox of potential adaptation measures that could be used in Malibu to address existing and future coastal hazards with sea level rise. Finally, next steps for the City of Malibu's adaptation planning process are summarized.

6.1 Sea Level Rise Adaptation Planning By Others

To assemble a toolbox of options for Malibu, it is important to understand the existing adaptation measures that are in place as well as current planning studies and projects by others. Today, many beachfront structures are either armored, structurally elevated or both due to existing coastal hazards (see Section 1.2.3). Additionally, several regional agencies and groups are involved in sea level rise adaptation planning activities in Malibu or that may influence Malibu adaptation. Each of the agencies and groups is summarized below to provide important context for Malibu's own adaptation planning efforts and the potential adaptation measures.

Caltrans is planning for climate and sea level rise adaptation along the Pacific Coast Highway (PCH) in Malibu as part of its broader climate resilience efforts. The planning process is informed by statewide vulnerability assessments (Caltrans 2019) and Caltrans District 7 adaptation priorities report (Caltrans 2021). The key transportation assets assessed include at-grade roadway segments of PCH, bridges, and both large and small culverts. Caltrans considers a range of sea level rise adaptation measures ranging from roadway realignment, elevation of roads and bridges, lengthening bridges, setting back abutments, shoreline armoring, burying seawalls in the shoulder, and nature-based solutions like beach nourishment and dune restoration.

Los Angeles County Department of Beaches and Harbors is currently working on its Regional Coastal Strategic Adaptation Plan (RCSAP, Los Angeles County 2025). The County manages public beaches, lifeguard stations, parking lots and bike paths. County beaches in Malibu include Nicholas Canyon, Zuma, Point Dume, Latigo Shores, Dan Blocker, Malibu Surfrider, and Las Tunas. Additionally, LACDBH has evaluated beach nourishment and dune habitat at Zuma and Point Dume Beaches (Coastal Frontiers 2025) and designated Zuma Beach as a receiver site for opportunistic beach nourishment in its Sand Compatibility and Opportunistic Use Program (LACDBH 2025).

The Bay Foundation is advancing living shoreline projects including dune restoration in many of the region's beaches. In Malibu, they have constructed and are monitoring dunes at Zuma and Point Dume Beaches (The Bay Foundation 2023).

Southern California Beach Sand Collaborative[8] (SCSC) is a multi-agency partnership of governments and agencies working on regional sediment management to improve the resilience of Southern California's beaches and shorelines. The collaborative spans 430 miles of Southern California coastline including Santa Barbara, Ventura, Los Angeles, Orange and San Diego Counties. The group is presently focused on advancing coordination and securing state and federal funding, evaluating the feasibility of a California-based dredge (the current practice is to opportunistic use of Gulf or East-coast ported dredges), and advancing large-scale beach nourishment projects for the region.

United States Army Corps of Engineers (USACE) is a key player for sea level rise adaptation in the region. While not directly engaged in sea level rise adaptation activities in Malibu, USACE has provided foundational science and planning and is leading projects and management efforts that influence Malibu's beaches and coastal resilience. For example, the Malibu Creek Ecosystem Restoration Project[9] could unlock an upland sediment source for eastern Malibu. Their participation in the Coastal Regional Sediment Management Plan (CRSMP) and California Coastal Sediment Management Workgroup (CCSMW) influences offshore sand resources identification, regional receiver sites prioritization, upcoast harbor sediment bypassing, beach nourishment and living shorelines (Zuma Beach is an example for both). (LACo CRSMP, 2017)

[8] More information at https://www.sanclemente.gov/DocumentCenter/View/1419/Southern-California-Sand-Collaborative-Information-Flyer-PDF

[9] More information at https://www.spl.usace.army.mil/Missions/Civil-Works/Projects-Studies/Malibu-Creek-Study/

6.2 Potential Adaptation Measures

ESA developed a list of potential sea level rise adaptation measures that could be considered to address anticipated coastal hazards in the different physical coastal settings along the City of Malibu. The adaptation measures include many that are currently in use throughout CA and in Malibu, and span a range of types including traditional engineered structures, natural infrastructure such as dunes and wetlands, and regulatory or land use measures. The following subsections describe the typical objectives and approaches to adaptation (i.e., strategies) and summarize the potential adaptation measures that could be applied in Malibu to increase the City's resilience to coastal hazards and future sea level rise. The following measures are summarized for the benefit of the City and public to inform initial discussion on adaptation options. The project team acknowledges there is a diversity of opinions and preferences regarding shoreline adaptation and that the City Council will ultimately direct the City staff on next steps regarding adaptation planning. Each of the following adaptation measures may be applicable in Malibu but should be thoroughly evaluated for application at specific sites in future adaptation planning as directed by City Council.

6.2.1 Potential Adaptation Strategies

Sea level rise adaptation can be characterized in terms of the intended strategy or goal in what is accomplished. Sea level rise adaptation approaches might follow one or more thematic strategies: protect, accommodate, or retreat:

- **Protect –** use an engineered structure or other measure to defend development (or resources) in its current location without changing the development itself. Example protection measures include: shoreline armoring devices such as seawalls, revetments, and levees, which defend against coastal hazards like wave impacts, erosion, and flooding; natural or "green" methods (i.e., living shorelines) like beach nourishment and constructed dunes or cobble berms buffer coastal areas from hazards; and hybrid approaches using both engineered structures and natural infrastructure elements.
- **Accommodate –** modify existing development or infrastructure or design in a way that decreases hazard risks and increases the resiliency of development. Examples include elevating and/or retrofitting structures and using materials that increase the strength of development. In Malibu, this could include floodproofing the first floor of non-residential buildings or raising buildings, roads, and utilities to accommodate high-water-level flooding events.
- **Retreat –** also referred to as managed retreat or transform, relocate or realign existing development and infrastructure or limit substantial redevelopment or new development in vulnerable areas. Development setbacks, buyouts, and easements are examples of adaptation measures that use a retreat strategy.

The preferred adaptation strategy for a location may vary depending on the type of asset (e.g., private development or public infrastructure). Additionally, the most appropriate strategy may evolve over time as conditions change (e.g., protection in the near-term and accommodation or retreat in the longer-term). Note that specific adaptation measures may be relevant under more than one strategy. For example, dune restoration can play a role as a protection strategy (i.e., restore dunes on the beach to reduce wave runup and erosion) as well as part of a retreat strategy (i.e., restore dunes along the shore after relocating buildings and infrastructure).

6.2.2 Toolbox of Potential Adaptation Measures

This study compiles a range of potential adaptation measures that the City may choose from to manage coastal hazards today and with future sea level rise. Compiled adaptation measures include several that are in use and/or being explored by other local agencies/entities (see above) and include measures to address a range of assets. The adaptation measures are categorized into three groups: natural or nature-based infrastructure, traditional engineered structures, and non-structural measures (i.e., regulatory or financial mechanisms to encourage or enforce adaptation).

In addition to the individual adaptation measures below, hybrid measures could employ more than one of the following listed measures. For example, a traditional rock revetment could be buried with sand and dunes to create a hybrid protection strategy.

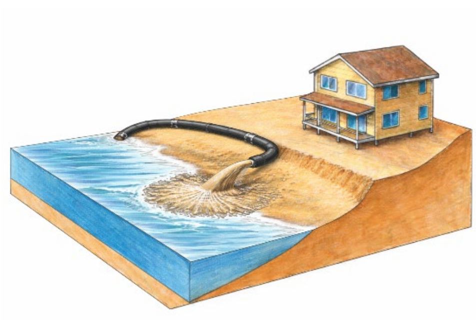
Table 6-1 below lists potential adaptation measures by category. Descriptions of each measure are provided in the subsections that follow. A high-level summary matrix of the adaptation measures toolbox is provided in **Appendix F**, which lists each adaptation measure and its applicability alongside relative rankings and key considerations for the range of evaluation criteria: Engineering (feasibility, effectiveness and resilience), Environmental (impacts and benefits), Regulatory (permitting requirements, etc.), Social (recreation, access), and Economic.

Table 6-1. Toolbox of Potential Coastal Adaptation Measures for Malibu

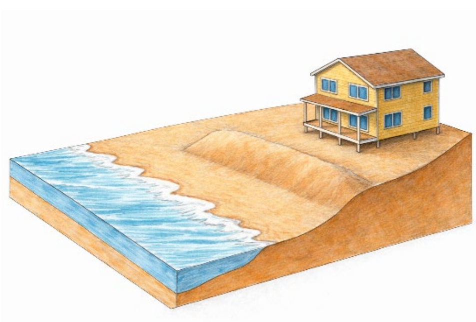
Category	Adaptation Measure
Natural and Nature-Based Measures	Beach Nourishment Temporary Sand Berms Vegetated Dunes Cobble-gravel Berms Artificial Reefs Submerged Aquatic Vegetation Restoration (e.g. kelp, eelgrass, seagrass) Artificial Outcrops and Headlands Ecotone Levees Creek and Wetland Restoration and Sediment Management
Traditional Engineering Measures	Breakwaters (emergent and submergent) Groins Rock Revetments Seawalls Flood Walls and Levees Elevating Structures and Infrastructure Floodproofing Structures and Infrastructure Raising Grades Stormwater Management Systems Groundwater Management Systems Onsite Wastewater Treatment Systems Modification Community Wastewater Treatment System Modify Utilities And Stormwater Infrastructure Managed Retreat, Removal and Realignment
Non-structural Measures	Zoning and Overlay Zones Setbacks and Buffers Building Codes and Building Retrofits Redevelopment Restrictions Acquisitions and Buyouts Tax incentives and Special Assessments Geologic Hazard Abatement Districts Conservation and Rolling Easements Transfer of Development Rights

Natural and Nature-Based Measures

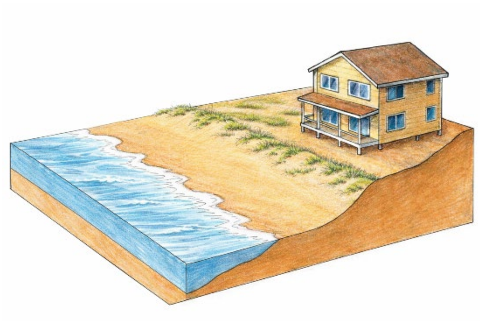
Natural and nature-based adaptation measures as well as hybrid measures that combine natural and traditional structures can perform similarly or better than traditional structures and provide increased resilience benefits to recreation and ecology. The State of California is emphasizing the use of nature-based approaches to sea level rise adaptation.



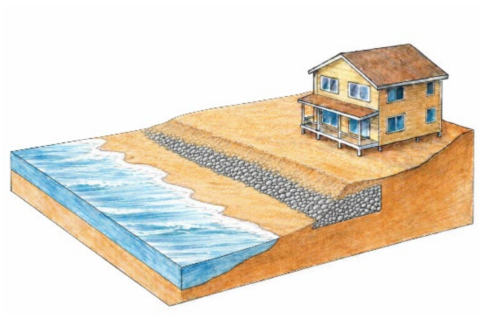
Beach Nourishment – Beach nourishment is an adaptation measure that provides protection against coastal storm erosion while supporting natural conditions, beach habitat, and processes (such as the ability of the beach to erode in response to winter coastal storms and build up sand in response to summer wave conditions). Beach nourishment refers to placement of sand to widen a beach, which can be accomplished by placing a sediment-water slurry directly on the beach or mechanical placement of sediment with construction equipment. Impacts to beach species can occur during construction but may be temporary, and impacts to other marine habitats should be avoided. Sand can be obtained from inland sources (e.g., construction projects, debris basins, dams, etc.) and can be dredged from harbors (as part of bypassing or backpassing) or offshore deposits and delivered to shore via barge and dredge line (such as recent projects at Encinitas/Solana Beach and San Clemente). Beach nourishment could be suitable to maintain wider beaches like Zuma and Westward Beach, and potentially other places with sand deficits such as Broad Beach. Importantly, beach nourishment can be short lived without additional sand retention measures (e.g. groins), depending on the type of sand placed, placement method, and coastal setting/exposure.



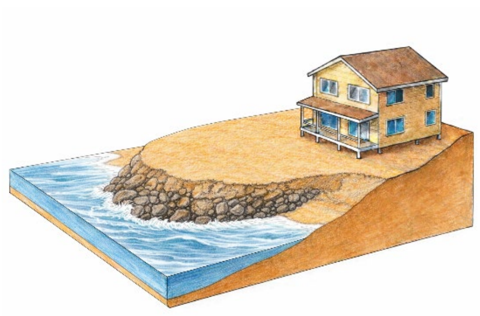
Temporary Sand Berms - The creation of beach berms is a temporary adaptation measure that provides protection to coastal development against coastal storm flooding and waves during anticipated high water and wave events or over the winter season. Sand is scraped from the beach using bulldozers to construct berms along exposed facilities that range in height and length depending on space and anticipated wave hazards. Los Angeles County Department of Beaches and Harbors regularly constructs temporary seasonal sand berms at County beaches (including Zuma Beach) to reduce winter flooding of the lifeguard facilities, restrooms, maintenance yards, bike paths, public parking lots and other infrastructure along the coast (LA County 2016). The County considers temporary sand berms to be one of the most cost-effective strategies to protect coastal assets. However, as sea levels rise and beaches erode, the temporary winter berms may become less effective and harder to construct each season as beach space and available sand diminish. Additionally, winter berms can cause temporary impacts to the nearshore ecological community, since berm creation can smother species and grading of the beach can lower diversity and abundance of animals associated with beach wrack (natural seaweed and organic material that washes ashore).



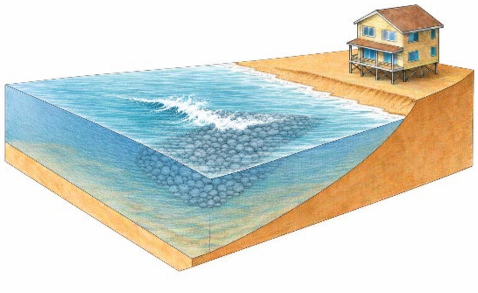
Vegetated Dunes - Dune restoration is recognized as a natural way of mitigating backshore erosion. Compared to other traditional approaches, dunes can also maintain a wider beach because erosion of sand dunes due to storms and/or sea level rise contributes sand to the adjacent beach. Dune construction includes placing sand, grading, and planting to form "living" back beach dunes. More passive forms of dune restoration rely on wind and vegetation to build dunes by fencing off beach area and planting/seeding or allowing natural recruitment of native dune vegetation. Dune restoration can provide aesthetic, ecologic, and recreational benefits, but can also limit access and "towel space." Dune restoration can also include placement of cobble/gravel berms (rounded rock), which is often naturally present below beaches in California. Burying a layer of cobble under a beach and/or dunes provides a "backstop" that is more erosion resistant and dissipates waves to a greater degree (for example, as implemented at Surfer's Point in Ventura). Dunes may be suitable for adaptation in areas with sufficient beach width/space, such as Zuma Beach and Point Dume, which are a current focus for dune restoration efforts.



Cobble-gravel Berms – Cobble/gravel berms are dynamic revetments made of rounded cobble and gravel that absorb wave energy and reduce erosion. Cobble-gravel deposits are a natural feature that occur along the California coastline. Cobble-gravel features form at the base of bluffs and near river mouths and can be covered by sand seasonally. A constructed cobble-gravel berm is a mass of rounded rock in a layer placed in the upper tide range just below dry beach elevations, seasonally buried by sand and exposed during high surf conditions. The cobble-gravel berm is also called a "dynamic revetment" because it provides flood and erosion protection to landward areas but is more malleable than traditionally engineered rock revetments during elevated wave breaking and runup. Depending on available space/beach width, cobble-gravel berms could be placed as a softer armoring approach along Malibu's upper beach zones, including where natural cobble deposits already exist.



Artificial Headlands and Outcrops - Engineered rocky features could be designed to mimic natural coastal landforms such as headlands, shore platforms, or bedrock outcrops. Like natural headlands and engineered groins, these artificial headlands can be used to alter shoreline dynamics and help trap sand on one side of the structure, which can contribute to shoreline and/or bluff stability. Small artificial headlands are currently proposed in Oceanside in conjunction with beach nourishment. Another example includes engineered rock "fingers" to mimick natural rocky ridges formed by exposed bedrock. A combination of rock fingers and a cobble berm was constructed to stabilize a narrow eroding beach along the Pillar Point Harbor West Trail in Half Moon Bay.

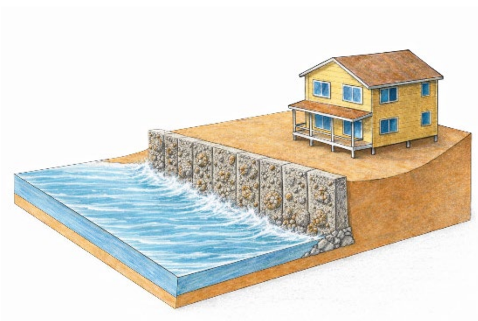


Artificial Reefs – Artificial reef structures can be constructed offshore or nearshore to provide ecological and/or hazard reduction benefits. In deeper water offshore, artificial reefs function primarily as habitat by providing hard substrate for kelp and other marine life; however, offshore reefs would likely be too deep to affect wave heights and reduce coastal flooding. When located closer to shore in shallower water, artificial reefs can function as submerged breakwaters that promote wave breaking and reduce the wave energy that reaches the shore. Nearshore reefs can offer multiple benefits, including providing ecological (habitat) and recreational value, promoting sand retention on the shoreline within the area of reduced wave energy behind the reef, and potentially providing surfing resources. Engineering criteria must balance for surfing and shore protection goals that can be conflicting, as surf reefs are low enough to remain submerged at low tides while shore protection reefs ideally protect shoreline assets during high tide and wave events. Artificial reefs may be possible in some areas of Malibu depending on geotechnical considerations (such as depth to hard substrate) and environmental considerations (such as existing marine habitats and protections).

Submerged Aquatic Vegetation Restoration – Submerged aquatic vegetation is the term used for rooted plants that grow underwater and play a crucial role in aquatic ecosystems, such as kelp, eelgrass, and seagrass. Kelp restoration could be accomplished in areas that once supported kelp (for example with urchin removal and/or kelp outplantings on hard substrate/rock outcrops near shore). Kelp restoration could also be included with new offshore artificial reefs. Kelp restoration can benefit marine ecosystem functions and reduce currents, but have been found to be ineffective in reducing wave heights and associated coastal flooding in a recent study in Santa Monica Bay (SCC 2018). Other submerged aquatic vegetation restoration could include eelgrass in protected estuaries such as Malibu Lagoon or surfgrass in nearshore coastal areas to improve ecosystem functions, but are also expected to be minimally effective in flood reduction.

Ecotone Levees – Ecotone levees or "living" levees are a variation on traditional levees that include flatter, wider slopes on the flooding side that are vegetated with native plants and span the elevation range from upland (above tides and flooding) to intertidal in wetland environments. Ecotone levees can provide higher value for habitat and recreation when constructed to avoid sensitive habitats. Ecotone levees could potentially be applicable in limited low-lying areas around Malibu Lagoon, but may not be viable due to space constraints. Successful implementations of this concept have occurred at Warm Springs Marsh (south San Francisco Bay) and the Hamilton Wetlands Restoration Project (Novato, Marin County, ESA PWA 2013).

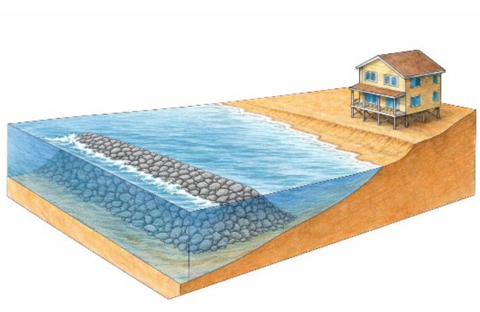
Creek and Wetland Restoration and Sediment Management - Restoring creeks and both riparian and coastal wetlands can improve flood resilience and water quality while supporting biodiversity. Most historic wetlands have been filled in California, and restoration feasibility depends on available space and/or the ability to remove development or infrastructure to expand existing wetlands. Nearby wetland restoration projects that are in planning/design include Topanga Lagoon and Ormond Beach Wetlands. Malibu Lagoon and Zuma Lagoon and adjacent creek/wetland areas may offer opportunities for additional wetland restoration and enhancement to enhance habitats and improve flood resilience, and could potentially be coupled with ecotone levees. Note that the Malibu Creek Ecosystem Restoration Project (a.k.a. Rindge Dam Removal) would restore creek habitat as well as restore the sediment delivery from the upper watershed of Malibu Creek. Additionally, sediment management methods can be used to assist wetland resilience, such as thin-layer sediment placements on existing wetlands so wetlands are not increasingly submerged by sea level rise (e.g. as piloted at Seal Beach National Wildlife Refuge).



Living Coastal Armoring (seawalls, revetments) – Living coastal armoring structures are typical structures such as seawalls or revetments that include additional attributes or features that provide ecological benefits. Living armor structures are constructed and/or incorporate design elements that mimic natural functions such as pockets to hold water, a range of surface textures/materials and structure (cracks, ledges, tunnels, caves, etc) to promote establishment and growth of marine organisms and provide better habitat for native species. Living seawalls are a relatively new concept that has been deployed within San Francisco Bay and San Diego Bay. A pilot seawall project[10] in the San Francisco Bay Area provides promising early results for ecological benefits of textured panels incorporated onto the seawall face. Another pilot project[11] is underway by Port of San Diego to test a precast concrete interlocking revetment construction that creates small tidepools.

Traditional Structural Measures

Traditional engineered measures can be effective to protect against erosion and flooding within the range of conditions for which they are designed, but may have negative side effects such as leading to the squeeze of beach and wetland habitats or increasing flood or erosion risks to adjacent areas/assets.

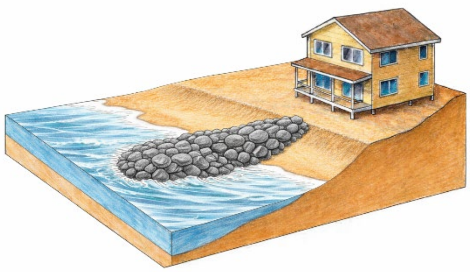


Breakwaters (emergent and submergent) – Breakwaters are long, constructed barriers (linear or curved) that reduce wave energy and protect the shoreline. Breakwaters can be emergent (top of breakwater is fully above high tides) or submergent (partially or fully underwater within the normal tide range). Detached breakwater examples exist nearby at Santa Monica Pier

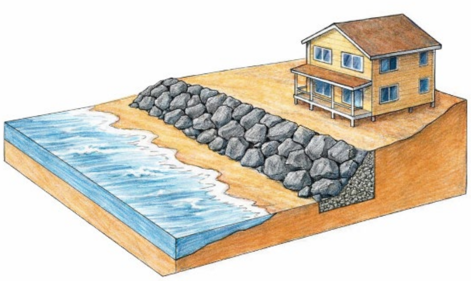
[10] More information at https://www.sfport.com/wrp/living-seawall

[11] More information at https://econcretetech.com/wp-content/uploads/2025/11/ECOncrete-Port-of-San-Diego-Coastalock-Revetments-Monitoring-Report-26MPD.pdf

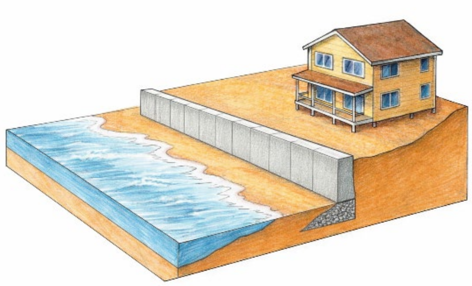
(which has slowly deteriorated from emergent to a partially submergent breakwater), Venice Beach, and Marina Del Rey. Breakwaters often impact surfing resources as they block waves and effect sediment transport. Permitting in California for new breakwaters has become rare, so building a new breakwater may be infeasible. Due to very low likelihood of success in permitting, construction of new breakwaters is not recommended.



Groins - Groins are engineered sand retention structures that extend perpendicular to the shoreline and trap sand from drifting downcoast, typically placed as a series along a shoreline. Where wave conditions are ideal, groins have been successfully used along some parts of the California coast and other locations to maintain a wider beach (for example, Will Rogers Beach). In other cases, groins can induce and/or accelerate erosion downcoast of the groin, especially if the segments between groins are not pre-filled with sand when they are built. Groins have the potential to negatively affect horizontal access along the beach. Constructing rock groins on the beach and/or in the ocean typically requires habitat mitigation (e.g., restoration of comparable habitat in another location) and could alter the character of the natural shoreline. Construction of groins is generally considered along stretches of the coast where large amounts of sand move along the shoreline. Groins could be considered at sediment-deficient beaches as an additional retention measure coupled with nourishment.



Rock Revetments - Rock revetments are shoreline armoring structures built along the coast to provide flood and erosion protection for properties. Revetments provide protection to slopes and are constructed of sturdy materials such as quarry stone. Revetments work by absorbing or dissipating wave energy. Shoreline armoring can be effective in providing a hard back-stop to the shoreline and protect landward property or infrastructure. However, as the shoreline and beach in front of the structure erodes, waves can hit the armoring and bounce back towards the ocean rather than dissipating. This can cause increased sand erosion in front of and downcoast of the device, with associated impacts to beach habitats and/or adjacent unarmored backshore areas. Also, erosional beaches in front of rock revetments can cause beach narrowing or "squeeze" against the revetment and eventual beach loss over time. As such, rock revetments can be more difficult to permit than other, less impactful measures. Rock revetments are in use at many locations in Malibu, including at Broad Beach and Malibu Colony and other residential areas as well as along sections of Pacific Coast Highway.



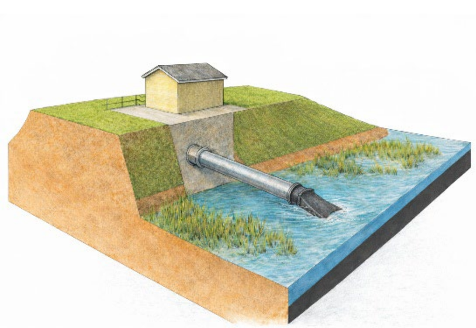
Seawalls - Seawalls are vertical structures constructed along a beach or coastal bluff used to protect structures and property from wave action, flooding and erosion. They may be either gravity- or pile-supported structures and are normally constructed with reinforced concrete. Seawalls can have similar, if not more pronounced effect on eroding beaches compared to rock revetments above. Given the long-term impacts to beaches, seawalls can be difficult to permit in lieu of other less impactful measures. Seawalls are present along much of Malibu's developed shoreline, in the form of grouted stone, reinforced concrete, or timber construction. Caltrans has also buried seawalls (cast-in-drilled-hole secant pile walls) in the shoulder of Pacific Coast Highway at Point Mugu State Park near Sycamore Cove, which will eventually become exposed as coastal erosion impacts the bluffs seaward of the secant pile wall.

Flood Walls and Levees - Flood walls and levees are flood and erosion protection measures built along creeks and sheltered waterbodies that function similarly to seawalls and revetments on the open coast. Flood walls and levees limit flooding of low-lying areas from creeks and estuaries due to high tides, high rainfall/creek flooding and/or high wave events. Flood walls are a more compact form of flood protection that use a combination of structural materials (reinforced concrete, steel etc.) while levees are comprised of compacted soil that occupies a larger footprint. Flood walls and levees may include additional armoring where exposed to fast moving waters. Flood walls and levees may need to be paired with stormwater management measures such as culverts and pump stations to convey stormwater from the inland side of the flood wall or levee to the creek/lagoon. Levees can be designed as ecotone or living levees (discussed above) by creating gently sloping upland, transition, and vegetated habitats between the levee and the waterway. Flood walls and levees may be applicable near Malibu Lagoon, Trancas Creek or other low lying areas that lack the space for wider ecotone levees.

Structural Elevation - Elevating buildings, roads, bridges, and above-ground utility infrastructure with structural methods lifts development and infrastructure above coastal flooding elevations. Elevating beachfront development on pile foundations can allow for some limited beach migration and continued presence of a beach in front of the structure in the near-term compared to armoring approaches (many of Malibu's beachfront homes and other buildings are already elevated with some dry or intertidal beach extending beneath the structure). When elevating roads onto pile-supported causeways, associated buried utilities may also need to be modified or waterproofed to avoid damage. While much beachfront development throughout Malibu is currently elevated, older elevation supports may require additional modifications or upgrades to maintain the structure as is or to elevate it higher. Any building undergoing structural elevation may also require utilities and access modifications. For beachfront properties where retaining a beach is a priority, elevating buildings can extend the lifetime of the structure while maintaining some fronting beach area as natural coastal processes continue. Over time, migration of the public trust boundary (mean high tide line) under an elevated structure could create a conflict between public trust lands and private property. Additionally, elevating a structure can lead to increased coastal erosion and flooding exposure of development behind the elevated structure (e.g. wave run-up on the bluff/embankment that supports Coast Highway).

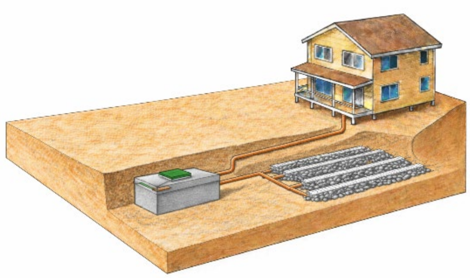
Floodproofing Structures and Infrastructure - Floodproofing (aka waterproofing) involves structural or non-structural modifications to buildings or other infrastructure to reduce or eliminate damage during flooding events without otherwise changing or elevating the building itself. Note that dry floodproofing entails sealing a structure completely to keep floodwaters out, while wet floodproofing entails waterproofing the interior and components so that the structure and contents are not damaged during a flood. Guidance exists for floodproofing non-residential and mixed-use buildings in Zone A flood hazard areas (FEMA 2021). However, FEMA National Flood Insurance Program (NFIP) regulations do not permit the use of floodproofing for residential buildings in Zone A flood zone (100-year flood hazard). Furthermore, floodproofing is not permitted for any building that is subject to high velocity wave action in what are called coastal high hazard areas and designated by FEMA as Zones V and VE. Flood proofing may be applicable for non-residential structures outside high wave zones, which in Malibu is limited to areas adjacent to creeks and Malibu Lagoon.

Raising Grades - Buildings, roads, pedestrian trails, and other at-grade (on the ground) development can be elevated by importing soil or other fill material to raise the ground elevation, whether for new or existing development. Utilities such as gravity sewer pipelines and storm drains that are vulnerable to flooding, erosion, or increased groundwater levels can also be raised in conjunction with raising grades, so long as gravity flow is maintained or pumps are installed. Note that if one road is raised, all connecting roads, trails, and utilities must be reconfigured to slope up to the new grade. Roads exposed to high velocity creek flows or waves on the coast may also require armoring and/or nature based stabilization with elevation.. Elevating grades requires significant amounts of fill material, may only be feasible for areas of limited size, and may be infeasible for development in constrained areas. Additionally, filling an area changes the hydrology of both the area filled and neighboring areas that can receive diverted flows and runoff. Raising grades with fill may require additional drainage improvements to effectively manage stormwater and avoid increasing flood risks elsewhere.



Stormwater Management Systems – Water control structures (gates and valves) and pumps are often used in conjunction with coastal or riverine barriers such as seawalls and levees or with roadways that function as levees. A common unintended effect of flood barriers is that they impede gravity drainage of stormwater flows from the land side of the barrier, trapping waters within the area behind the barrier. Pumping systems are needed to move stormwater over or through the barriers to prevent flooding of the protected area. Water control systems could be used near Malibu Lagoon or other creeks, for example to manage potential flooding in low lying areas with higher sea levels. Other green stormwater management tools include rain gardens, bioswales, cisterns/rainwater harvesting, permeable pavement, creek daylighting, green roofs, urban forestry and more. These tools help retain and slow stormwater upland in an urban watershed, allowing it to infiltrate into the ground or be diverted and reused for beneficial purposes like irrigation before it is collected in storm drains and shunted to receiving waters. This can reduce storm sewer, creek, and combined sewer-related flooding, which will become increasingly important with sea level rise and increased storminess associated with climate change.

Groundwater Management Systems - Measures to control elevated or rising groundwater include improved drainage systems, underground impermeable barriers, and dewatering wells. Onsite wastewater treatment system performance depends on adequate distance of the leach field above groundwater levels. Elevated groundwater may also affect buried utilities near Malibu Lagoon and other areas with shallow groundwater and/or exacerbate roadway and pavement deterioration. The effectiveness of groundwater management measures depends on soil conditions, site elevation and proximity to water bodies (ocean, creek, lagoon). Groundwater management could be used to address rising levels in low lying areas around Malibu Lagoon.



Onsite Wastewater Treatment Systems Modification – Malibu wastewater is primarily treated by onsite wastewater treatment systems (OWTS, a.k.a. septic systems) consist of a septic tank for primary treatment (solids separation), and a soil-based dispersal bed (leach field) for final purification. With higher sea levels and groundwater, OWTS will need to be modified, relocated or upgraded with more resilient designs to maintain wastewater treatment efficacy, prevent groundwater contamination and preserve public/environmental health. Example upgrades include raising/relocating dispersal beds and/or addressing tank buoyancy issues in areas with high groundwater as well as relocating components that may be exposed to coastal erosion. The feasibility of OWTS upgrades and conversions depends on several factors including available space, depth to groundwater and proximity to erosion hazards.

New OWTS typically include alternative pretreatment devices, raised dispersal beds, and telemetry control panels with continuous alarm and pump monitoring. In general, dispersal beds may be raised up to 12-inches above native soil to meet a minimum 36-inch separation to seasonal high groundwater elevations. Further increasing the raised bed heights above native grade jeopardizes both wastewater treatment and dispersal. As groundwater levels rise (i.e. with sea level rise), raised dispersal beds will eventually no longer meet minimum groundwater separation requirements. Interim methods for OWTS include partial treatment systems that hold wastewater and require regular pump outs and trucking to another treatment facility.

Community Wastewater Treatment System - Centralized wastewater treatment systems reduce pollution and improve groundwater and surface water quality. Malibu recently completed Phase 1 of its Civic Center Water Treatment Facility (CCWTF) in 2018 that serves properties in the Civic Center area and provides recycled water to those properties. Phase 2 of the project consists of expanding the capacity of the existing facility and increasing the collection system, pump stations and recycled water distribution lines to serve portions of the Civic Center, Malibu Colony and Serra Retreat communities. Creating other additional wastewater treatment plants in Malibu would require substantial investment and space. Alternatively, installing new collection systems to convey wastewater to CCWTF or another existing regional treatment facility could further reduce/phase out reliance on OWTS, but would involve extensive pressurized mains and additional pump stations and may require expansion/upgrade of the receiving facility. Both options would improve resilience against sea level rise, but further study is needed to assess costs, environmental impacts, and engineering feasibility to address wastewater treatment challenges for Malibu's communities.

Modify Utilities and Stormwater Infrastructure - Upgrading pipes and culverts can reduce corrosion and flooding from groundwater and storm events. Older and corroded underground utilities conduits may need to be replaced with more durable materials. Stormwater infrastructure may also require modification/replacement due to typical corrosion and/or development changes around Malibu's coastal roads and low-lying areas.

Managed Removal and Realignment – Realigning or relocating infrastructure and development away from hazard zones can eliminate the hazard exposure and facilitate natural shoreline processes. Implementing a managed retreat approach faces significant challenges. Many affected parcels in Malibu are fully developed, leaving little or no room for structures to relocate within existing lots. Relocating development elsewhere raises uncertainties about funding mechanisms and logistics, while property owner reluctance to move away from the coast adds social and political complexities. However, recent events like the destruction of numerous homes in the 2025 Palisades Fire present a unique opportunity to explore relocation options for destroyed properties. It is also important to note that realigning sections of Pacific Coast Highway in areas where the roadway backs directly against the bluffs would be extremely challenging.

Non-structural Measures (Policy, Regulatory and Financial)

Policy, regulatory and/or financial measures will be needed to facilitate the implementation of most of the physical/structural adaptation measures listed above. Regulatory and policy measures are used to manage how communities develop/redevelop and maintain themselves in a way that responds to or prepares for sea level rise (e.g., via an LCP or General Plan update). Financial measures are measures that encourage or facilitate adaptation through incentives or funding mechanisms. Brief descriptions of several such non-structural measures are provided below.

- **Zoning and Overlay Zones -** Overlay zones may add restrictions onto existing zoned areas related to flood or erosion preparedness.

- **Setbacks and Buffers -** Requiring development to be placed away from hazard zones reduces future risk. Effective for new or redeveloped parcels along Malibu's eroding coastline.

- **Building Codes and Building Retrofits -** Building codes regulate new construction to help development withstand flooding. For the existing built environment, building retrofits may be imposed by ordinance, through an overlay zone, or may be implemented by incentives instead of regulation.

- **Buyouts -** Purchasing vulnerable properties is a way to facilitate managed retreat and restoration of the natural shoreline. Applicable to high-risk beachfront parcels in Malibu.

- **Tax Incentives and Special Assessments -** Tax policy could be used to create incentives and disincentives for various land uses and the location of development. Special assessments are fees added to property taxes to pay for benefits that serve the whole area or district that pays these fees.

- **Geologic Hazard Abatement Districts -** Geologic Hazard Abatement Districts (GHAD) are independent governmental districts that can assess properties within a defined area and dedicate the revenue to abating or controlling hazards such as landslides, earthquakes, and erosion. GHADs have been used in parts of Malibu, such as Broad Beach.

- **Conservation and Rolling Easements -** Legal agreements preserve shoreline access and allow landward migration of beaches. Useful for maintaining public trust lands and ecological functions.

- **Transfer of Development Rights -** Redirects development from hazard-prone areas to safer zones through zoning incentives. Could be explored for Malibu if suitable receiver sites are available.

6.3 NEXT STEPS

The City of Malibu has much to consider as it plans its next steps regarding sea level rise adaptation. Some key topics include:

- **Regional coordination** (coordinate with others on regional efforts)
- **Living shorelines** (monitor existing projects and expand efforts to other areas)
- **Fire rebuilding** (ensure resilient reconstruction)
- **Beach nourishment** (continue ongoing efforts and coordinate with others in the region)
- **Adaptation planning and funding** (continue adaptation planning process and coordination with other agencies and groups, explore existing funding sources, SB 272 requirements for adaptation planning and projects)

Following this study and considering the public input received throughout the project process, Malibu's City Council will provide direction to City staff on how to proceed with sea level rise adaptation planning.

Section 7

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Section 8

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Appendix A

Data Sources and Processing

Appendix B

Malibu Asset Maps

Appendix C

Coastal Hazard Exposure Maps

Appendix D

Malibu Asset Exposure Maps (Assets with overlaid Hazards)

Appendix E

Malibu Asset Exposure Summary Table

Appendix F

Toolbox of Potential Adaptation Measures for Malibu (Summary Matrix)