The City of SAN DIEGO

Climate Change Vulnerability Assessment

February 2020

Prepared for the City of San Diego by ICF

This report was prepared with support from a California Coastal Commission LCP Local Assistance Grant and a Caltrans Adaptation Planning Grant.

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Executive Summary

Sea level rise, wildfires, flooding, extreme heat, and other climate change related hazards pose important risks to the City of San Diego. In order to begin preparing for these risks, the City must first understand how climate change could affect assets[1] and services owned or managed by the City. Climate change also poses risks to privately held land within the City.

The City therefore completed a Climate Change Vulnerability Assessment, which assessed the vulnerability of City asset types to climate change hazards This report details those findings, which are summarized in the Key Findings at a Glance box, at right.

About the Vulnerability Assessment

In its 2015 Climate Action Plan (CAP), the City committed to develop a standalone climate adaptation plan to identify vulnerabilities, take early action, integrate adaptation into other CAP efforts, capitalize on co-benefits, and increase local resilience. Completing a vulnerability assessment was the first key step in developing the climate adaptation plan.

The vulnerability assessment was completed in two phases:

- Phase 1, the results of which are presented in this report, included a high-level vulnerability assessment of the City's selected critical asset types. Phase 1 also assessed the consequences of climate change hazards for each asset type;
- Phase 2 involved developing more detailed risk profiles for selected assets from identified vulnerable asset types in Phase 1.

Key Findings at a Glance

Many critical City assets and services may be vulnerable to climate change related hazards going out into the future.

The most vulnerable asset types include:

- **Public safety**: lifeguard stations;
- **Water:** water pipes, wastewater pipes, water pump stations, wastewater pump stations;
- **Transportation and storm water**: bridges, major arterials, drain pump stations, outfalls;
- **Open space and environment**: conservation areas/open space/source water land, community parks;
- **Additional assets**: recreation centers, historical, tribal cultural, and archaeological resources.

Consequences

Damage, disruption, or failure of some of these City assets could have major consequences and impede the ability of the City to continue its services and protect public health and safety. Exposure to climate change related hazards could result in consequences such as delays in emergency response, impacts to City facilities, damage to historical, tribal cultural, or archaeological resources; or impacts on protected habitats/species.

Based on the number of asset types that are vulnerable, wildfire is the primary climate-related hazard for San Diego, followed by sea level rise. However, **all the hazards investigated** (wildfire, sea level rise, extreme heat events, and changes in precipitation) **pose potential risks** to City assets and services.

[1] "Assets" in this context refers to infrastructure, buildings, and other built, natural, and cultural assets owned by the City of San Diego. This vulnerability assessment also considers the exposure of state-owned assets and privately-owned land within the City, such as commercial space, offices, and agricultural land.

The Phase 1 assessment focused on four climate change hazards that are especially important for San Diego:

- **Changes in the frequency and severity of wildfire**. Climate change is projected to increase the key drivers of wildfire (high temperatures, dry conditions, and flammable vegetation) in southwestern California, leading to an increase in fire risk.
- **Sea level rise and related coastal hazards**. Sea level in San Diego is expected to rise five to fourteen times faster over the course of this century than it did in the previous century, leading to risks of increased flooding and coastal erosion.
- **Changes in precipitation**, including heavy rain events and drought. Climate models suggest little change in the total amount of annual precipitation over the course of this century but project more variability in rainfall from year to year and more intense transitions between droughts and deluges.
- **Extreme heat events**. By mid-century, heat waves could be occurring in San Diego three to five times more frequently than in the past.

For each of these hazards, the City selected specific scenarios to be considered in the vulnerability assessment based on the best available climate science. The selected scenarios and corresponding sources are:

- Sea level rise projections for the years 2030, 2050, and 2100 based on the November 2018 update to the California Coastal Commission's (CCC) *Sea Level Rise Policy Guidance* and corresponding U.S. Geological Survey (USGS) Coastal Storm Modeling System (CoSMoS) spatial data;
- Best available localized modeling from CoSMoS for coastal erosion in the area, covering shoreline and cliff retreat under a Medium-High Risk Aversion Scenario of sea level rise by 2100 and various options for coastal armoring or retreat;[2]
- Extreme precipitation scenarios based on the 100-year floodplain and 500-year floodplain

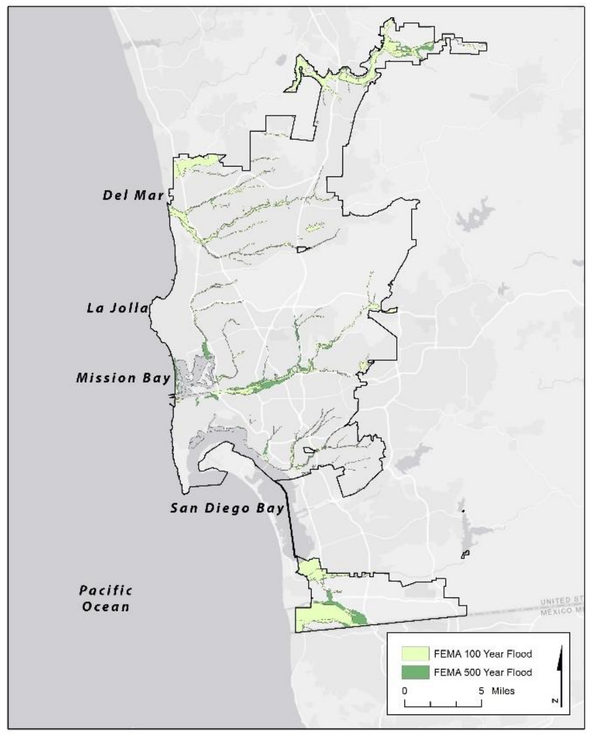

Figure 1. FEMA 100- and 500-year floodplains in the City of San Diego. Floodplain data obtained from FEMA. These reflect 2012 FIRMs for all of the City except South Bay, for which the FIRM was last updated in 2016. Map created: 2019.

[2] The CCC's Medium-High Risk Aversion Scenario indicates a 0.5% probability that sea level rise meets or exceeds a certain height. For 2100, this is 7.0 feet in San Diego. The closest CoSMoS increment for this projection is 2 meters (6.6 feet).

from the Federal Emergency Management Agency (FEMA) Flood Rate Insurance Maps (FIRMs);

- Urban heat island index data from the California Environmental Protection Agency (CalEPA); and
- The City of San Diego's fire hazard and native vegetation zones.

The assessment evaluated the vulnerability of *critical* asset types, which were identified through consultation with City staff based on the following criteria:

- If the asset type/resource (or its function) is necessary for continuity of important City operations;
- If the asset type/resource (or its function) is a key driver in the City's economy;
- If loss of the asset type/resource would present equity concerns;
- If the asset type/resource is critical to safeguarding biological diversity and other environmental priorities.

Evaluating vulnerability entailed assessing the *exposure* of each asset type to each type of climate change hazard, then analyzing the *sensitivity* and *adaptive capacity* of each asset type.[3] The City combined the scores for these three components to determine a vulnerability score for each type of asset for each hazard. Scores for *exposure* indicate the likelihood of the asset types experiencing the climate hazard in question, given the best available science for the predicted spatial extent of the hazard and the location of the assets (Table 1). Scores for *sensitivity* indicate the degree to which a climate hazard might affect an asset type, taking a conservative approach by considering the highest assumed sensitivity within each asset type (Table 2). Scores for *adaptive capacity* indicate the ability of an asset type to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences (Table 3).

Table 1. Rubric for Scoring Exposure of Critical Asset Types to Climate Hazards[4]

	Coastal Erosion	Coastal Flooding[5]	Precipitation	Heat	Wildfire
High	Within the zone eroded under the "Shoreline hold, continued nourish" CoSMoS beach erosion scenario with 2 m sea	Within the zone inundated by the 0.25 m CoSMoS sea level rise scenario (2030)	Within the zone flooded by the FEMA 100-year floodplain	Within the zones with heat score of UHI[6] 80 to 100+	Within the native vegetation zone or its 100-ft buffer

[3] *Exposure* refers to the presence of assets in places that could be affected by climate change hazards (Bedsworth, 2018) citing (IPCC, 2012). *Sensitivity* refers to the degree to which assets are affected by climate change hazards (California Coastal Commission, 2018). *Adaptive capacity* refers to the ability of an asset to cope with the consequences of climate change hazards (California Coastal Commission, 2018) citing (Willows, 2003). Exposure, sensitivity, and adaptive capacity are widely used indicators of vulnerability.

[4] See the Vulnerability Assessment Methodology in the main report for definition of terms in this table.

[5] Coastal flooding refers to both daily flooding and the 100-year storm, given the various sea level rise scenarios.

[6] The urban heat island (UHI) index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree Celsius over an eight-hour period would equal eight

	level rise				
Medium	Within the zone eroded under either the "Cliff let it go" cliff erosion *or* "Shoreline no hold, no nourish" beach erosion scenarios with 2 m sea level rise	Within the zone inundated by the 0.5 to 0.75 m CoSMoS sea level rise scenario (2050)	Within the zone flooded FEMA 500-year floodplain	Within the zones with heat score of UHI 40 to 80	Within the 300-ft buffer of native vegetation
Low	N/A (no low score for erosion)	Within the zone inundated by the 1.0 to 2.0 m CoSMoS sea level rise scenario (2100)	N/A (no low score for precipitation)	Within the zones with heat score of UHI 0 to 40	Within the fire hazard zone outside of brush management zone

Table 2. Rubric for Scoring Sensitivity of Critical Asset Types to Climate Hazards

Score	Rationale
High	If exposed, the asset type becomes damaged beyond repair or destroyed and cannot resume normal function until replaced.
Medium	If exposed, the asset type is damaged such that repairs are necessary before it can resume full functionality.
Low	If exposed, the asset type suffers minor damage but can maintain functionality or is not damaged at all.

Table 3. Rubric for Scoring Adaptive Capacity of Critical Asset Types to Climate Hazards

Score	Rationale
High	The asset can easily be protected from climate impacts (e.g., there are already protective measures in place that adequately prevent impacts; assets can be moved during an event; there are backups available).
Medium	The asset can be protected with some effort (e.g., there are potential protective measures, but they are not yet in place; the asset needs to be retrofitted or upgraded to withstand impacts; backups need to be acquired from other jurisdictions during an event).
Low	The assets cannot be protected (e.g., they are located within an exposed area and cannot be easily moved; there is no level of protection that can fully prevent damage; they are made of sensitive materials and cannot be upgraded; there are no backups available).

The City identified potential consequences that could result from damage, disruption, or failure of critical assets, including impacts on City services; human health; social equity; historical, tribal cultural, and archaeological resources; and natural resources and the environment.

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degree-hours, as would an increase of two degrees Celsius over a four-hour period. Higher scores denote hotter areas.

In addition to these critical City assets, the assessment also considered the exposure of certain non-City asset types to provide a more holistic view of the City overall. Specifically, state highways and freeways are included in the vulnerability assessment to provide a more comprehensive view of the transportation network serving the City. Vulnerability scores were not calculated for these assets, as the City does not have full insight into the sensitivities and adaptive capacities of assets it does not manage.

The City selected and engaged a Stakeholder Advisory Group (SAG) at key points in the vulnerability assessment process. The SAG included representatives from City departments, State government, Federal government, local nonprofits and environmental agencies, community-based organizations, transportation agencies, an energy utility, universities, and other key organizations.

The findings of both Phase 1 and Phase 2 will inform the risk reduction and adaptation strategies developed in the *Climate Resilient SD* Plan.

Findings of the Phase 1 Assessment

Table 4 below presents qualitative (low, medium, and high) vulnerability scores for the City's selected critical asset types to each of the climate change hazards under the scenarios considered in the assessment. Sea level rise hazards are split into coastal flooding and coastal erosion categories, since they represent different types of risks. These vulnerability scores assume no action by the City or implementation of climate adaptation and resilience strategies. Also, the vulnerability scores are based on current best scientific projections of the climate change hazards; there is still uncertainty as to the rate of future global emissions, which will vary based on factors including global population growth, political motivation, and technological changes.

The following critical asset types were determined to be the most vulnerable to climate change hazards based on the combined assessment of exposure, sensitivity, and adaptive capacity:

- **Public safety:** lifeguard stations;
- **Water:** water pipes, wastewater pipes, water pump stations, wastewater pump stations;
- **Transportation and storm water:** bridges, major arterials, drain pump stations, outfalls;
- **Open space and environment:** conservation areas/open space/source water land, community parks, beaches;
- **Additional assets:** recreation centers; historical, tribal cultural, and archaeological resources.

The primary climate change hazard, based on the number of types of assets found to be vulnerable, was wildfire. Twenty-five (out of thirty-one total) asset types were found to have either medium or high vulnerability to wildfire. This is due to an overall high sensitivity to fire, which has the potential to destroy assets in all sectors.

Pale green shading in the table below (and elsewhere throughout the report) indicates asset types that may warrant further study and/or the development of adaptation strategies based on their vulnerability scores. All high vulnerability scores and some of the medium vulnerability scores are shaded green. The shaded medium overall vulnerability scores are those that are comprised of one high scoring component (i.e., exposure, sensitivity, or adaptive capacity) and one medium score (the equivalent of a medium-high score). In practical terms, this approach helps prioritize assets that are on the border between a high and medium, and thus are worthy of further study.

Table 4. Vulnerabilities of all Critical Asset Types to Climate Change Hazards[7]

Sector	Critical Asset	Coastal Flooding: Sea Level Rise (SLR)[8]	Coastal Flooding: Storm Surge with SLR[9]	Coastal Erosion	Precipitation-Based Flooding	Extreme Heat	Wildfire
Public Safety Assets	Fire Stations	N/A	Low	N/A	Low	Low	Medium
	Lifeguard Stations	Medium	Medium	High	Medium	Low	Medium
	Fire Logistics and Dispatch	N/A	N/A	N/A	N/A	Low	N/A
	Maintenance Facilities	N/A	N/A	N/A	Medium	Low	Medium
	Police Stations	N/A	N/A	N/A	N/A	Low	High
	Police Patrol and Specialty Vehicles	N/A	N/A	N/A	Low	Low	Medium
	Other Public Safety	Medium	Medium	N/A	N/A	Low	Medium
Water Assets	Dams	N/A	N/A	N/A	High	Low	Medium
	Water Pipes	Medium	Medium	High	Medium	N/A	N/A
	Wastewater Pipes	Medium	Medium	High	Medium	N/A	N/A
	Water Pump Stations	N/A	N/A	N/A	Medium	Medium	High
	Wastewater Pump Stations	Low	Medium	High	High	Low	N/A
	Distribution Reservoirs	N/A	N/A	N/A	N/A	Medium	Medium
	Water Treatment Plants	N/A	N/A	N/A	N/A	Low	Medium
	Wastewater Treatment Plants	Low	Low	N/A	N/A	Medium	Medium
Transportation and Storm	Airports	N/A	N/A	N/A	Low	Medium	High
	Bridges	High	Medium	High	Medium	Medium	High
	Major Arterials	High	Medium	Medium	Medium	Medium	High
	Drain Pump Stations	High	High	N/A	High	Low	High

[7] Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.
[8] Sea Level Rise (SLR) represents the area that is projected to experience daily flooding at average high tide under each sea level rise scenario.
[9] Storm surge with SLR represents the area that is projected to experience flooding due to the 100-year (1 percent annual chance) storm under each sea level rise scenario.

Sector	Critical Asset	Coastal Flooding: Sea Level Rise (SLR)[8]	Coastal Flooding: Storm Surge with SLR[9]	Coastal Erosion	Precipitation-Based Flooding	Extreme Heat	Wildfire
	Outfalls	High	High	High	High	Medium	Medium
	Levees	Low	Low	N/A	Medium	Low	Medium
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land	High	High	High	High	High	High
	Community Parks	High	Medium	High	Medium	Medium	High
	Miramar Landfill	N/A	N/A	N/A	N/A	Low	Medium
	CNG Fueling Station	N/A	N/A	N/A	N/A	Low	Low
	Beaches	High	Medium	High	Medium	Low	Medium
Additional Assets	Recreation centers	High	Low	N/A	Medium	Medium	Medium
	Libraries	N/A	N/A	N/A	N/A	Low	Medium
	City Buildings	N/A	N/A	N/A	N/A	Low	Medium
	Historical, Tribal Cultural, and Archaeological Resources	High	High	High	High	Medium	High

Consequences of these vulnerabilities could include:

- **Public Safety** – Many public safety assets are associated with key emergency services, such as fire stations and lifeguard stations, which face exposure to most or all hazards. If they are damaged, City services and human health could be affected. Delayed response times could increase the risk of loss of life or injury to people seeking emergency response, and facilities could be called to serve a larger area.
- **Water** – Impacts to wastewater systems could result in loss of the critical service of wastewater removal and treatment. Impacts to water systems could compromise access to clean water. Consequences could include damages to City services, human health and safety, and the environment.
- **Transportation** – Disruptions to transportation systems could delay or inhibit the movement of goods and people, which could reduce economic competitiveness and societal functioning. Emergency vehicles could also be delayed. The extent of damage will depend on the location and traffic load of the asset, and on the redundancy of the system.
- **Storm Water** – Damage to storm water infrastructure could exacerbate the impacts of flooding. Damage, disruption, or failure would primarily impact City services through responses to manage flood risk.
- **Open Space and the Environment** – If these assets are damaged, the City could lose resources that provide recreational opportunities, ecosystem services, and habitat value. There could be significant consequences to City services and natural resources and environment, in addition to some consequences to human health and social equity.
- **Additional Assets** – Recreation centers; libraries; City buildings; and historical, tribal cultural, and archaeological resources could also be damaged by climate-related hazards. Damages to these

assets could have consequences to City services or directly to historical, tribal cultural, and archaeological resources. For example, libraries play an important role in community cohesion, and are used as cooling centers during periods of extreme heat.

Table 5 provides a summary of the types of consequences that could result from damage, disruption, or failure of each critical asset type. For each critical asset class/type, a check mark indicates that damage to the critical asset type could result in a consequence for that consequence category. Each section in the report below provides more details on the potential consequences of impacts to each sector, with illustrative examples of the types of consequences that could occur if critical assets are damaged.

Table 5. Summary of Consequences of Asset Types Being Damaged, Disrupted, or Failing due to Climate Hazards

Sector	Critical Asset	Consequence Categories				
		City Services	Human Health	Social Equity	Historical, Tribal Cultural, and Archaeological Resources	Natural Resources and Environment
Public Safety Assets	Fire Stations	✓	✓		✓	
	Lifeguard Stations	✓	✓		✓	
	Fire Logistics and Dispatch	✓	✓			
	Maintenance Facilities	✓				
	Police Stations[10]	✓	✓	✓	✓	
	Police Patrol and Specialty Vehicles	✓	✓			
	Other Public Safety	✓	✓			
Water Assets	Dams	✓	✓		✓	✓
	Water Pipes	✓	✓			
	Wastewater Pipes	✓	✓			
	Water Pump Stations	✓	✓			
	Wastewater Pump Stations	✓	✓			
	Distribution Reservoirs	✓	✓			

[10] The "social equity" consequence for police stations refers to the Multicultural Storefront station. This is a Police building that is used constantly as a hub for citizens from other countries. It is a location for non-native-English speaking citizens to get services or directed to services, and for police to help with mediation of community groups.

Sector	Critical Asset	Consequence Categories				
		City Services	Human Health	Social Equity	Historical, Tribal Cultural, and Archaeological Resources	Natural Resources and Environment
	Water Treatment Plants	✓	✓			
	Wastewater Treatment Plants	✓	✓			✓
Transportation and Storm Water Assets	Airports	✓	✓		✓	✓
	Bridges	✓	✓	✓	✓	
	Major Arterials	✓	✓	✓		
	Drain Pump Stations	✓	✓	✓		
	Outfalls	✓	✓			✓
	Levees	✓	✓			
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land	✓	✓		✓	✓
	Community Parks		✓	✓	✓	✓
	Miramar Landfill	✓	✓			
	CNG Fueling Station	✓				
	Beaches	✓	✓	✓	✓	✓
Additional Assets	Recreation centers	✓	✓	✓	✓	
	Libraries	✓	✓	✓	✓	
	City buildings	✓			✓	
	Historical, Tribal Cultural, and Archaeological Resources				✓	

Based on the findings of the Phase 1 assessment and consultations with stakeholders, individual critical assets were selected from highly vulnerable asset types for detailed risk profiles with targeted adaptation strategies. A suite of preliminary adaptation strategies was also developed. These strategies will be furthered refined during the development of *Climate Resilient SD*.

Support for this project comes in part from a California Coastal Commission Local Coastal Program Local Assistance Grant and a Caltrans Adaptation Planning Grant.

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Introduction

The City of San Diego faces both opportunities and risk from climate change. Sea level rise is occurring along the San Diego coast (Kalansky, Cayan, Barba, Brouwer, & Boudreau, 2018), and could lead to more extensive flooding and increased coastal erosion in the years ahead. Inland parts of the City experience periods of extreme heat, which are projected to intensify and become more frequent. To reduce negative impacts on City assets and services, the City is taking proactive steps to understand the risks posed by climate change hazards, identify critical vulnerabilities, and address them to ensure that San Diego remains a thriving and beautiful place to live, work, play, and visit.

Located in Southern California, San Diego is the second largest city in California, home to approximately 1.4 million people. The City boasts seventeen miles of coastline and a strong economy, with key industries such as international trade, manufacturing, military and defense, and tourism.

Figure 2. The primary climate change hazards considered in this vulnerability assessment are precipitation, heat, sea level rise, and wildfire—all of which pose risks to San Diego.

San Diegans are a culturally diverse population: over one-quarter of residents are Hispanic or Latinx, roughly one-sixth are Asian, and less than half are White (US Census Bureau, 2017). Historically, this region was home to the Kumeyaay people. The City's population is also economically diverse; approximately fifteen percent of San Diego's population lived below the federal poverty level in 2017 (US Census Bureau, 2019), while nearly ten percent of households in San Diego had incomes of more than $200,000 (Esri, 2018). Across the United States, Hispanic and Latinx populations are disproportionately vulnerable to and impacted by climate change. The same is true for Native American populations, and thus likely applies to the Kumeyaay people as well. This vulnerability seems to be tied to variables including location, employment type, income level, and access to resources (EDF, 2017; Lynn et al., 2011). As such, assessing vulnerability and defending against climate change is important for San Diegan, and is particularly crucial for its population of disproportionately vulnerable inhabitants.

The San Diego region is also known for its natural plants and animals and is considered a biodiversity hotspot. Many rare, threatened, and endangered plant and animal species call San Diego home, including the Torrey Pine, Southern sea otter, and Peninsular bighorn sheep (San Diego State University, 2005).

Assessing San Diego's Vulnerabilities to Climate Change Hazards

The City of San Diego Climate Change Hazard Vulnerability Assessment is focused on four primary climate change hazards that pose special risks to the City: sea level rise (including coastal flooding and erosion), extreme heat, changes in precipitation (including droughts and heavy rainfall), and wildfire.

Coastal Hazards

With seventeen miles of coastline that are critical to the region's economy, tourism industry, and San Diegan lifestyle, coastal hazards are a primary climate-related concern for San Diego. Coastal hazards include coastal flooding and erosion, both of which are expected to be exacerbated by climate change. Sea levels rose 0.71 feet in San Diego during the 20th century (NOAA, 2018). San Diego could experience another 0.8 feet of sea level rise by 2030, 1.6 to 2.4 feet by 2050, and 3.6 to 10.2 feet by 2100, depending on the rate of climate change and how the world's oceans and glaciers respond (California Coastal Commission, 2018). The frequency of extreme coastal floods is expected to increase under all projections of sea level rise. Rising seas boost the occurrence of severe floods (such as the 500-year flood) more than moderate floods (such as the ten-year flood) along the Pacific coast of the United States (Buchanan, 2017). By elevating storm tide, sea level rise makes it easier for waves to overtop natural barriers, increasing the relative frequency of flooding along the Pacific coast.

Coastal erosion has long been an issue in San Diego, affecting cliff areas such as Sunset Cliffs, La Jolla Cove, and Torrey Pines, as well as beaches. Ongoing erosion has required beach nourishment at certain locations to maintain beach width. Sea level rise and changes in storms are expected to increase coastal erosion, though the timing and specific locations of those impacts are unclear. In this report, "beach erosion" refers to erosion on any non-cliff shorelines.

Precipitation

The primary concerns for precipitation-driven hazards are historical flood areas and changes in annual and extreme precipitation. For the San Diego region, projections show only a slight change in average annual rainfall, but overall there is expected to be more variability in rainfall from year to year and more intense transitions between droughts and deluges (Higbee, 2014; Swain, 2018). Areas of San Diego already flood when there are heavy rainfall events. As rainfall events intensify in the future, inland areas affected by flooding could increase.

Heat

San Diego is known for its moderate temperatures: in the past, extreme highs (93 degrees Fahrenheit) have occurred only about four days per year. By the 2080s, extreme highs could occur up to 30 days a year. Average daily high temperatures are also projected to increase: while historically (1961 to 1990), the annual average daily maximum temperature for San Diego was 73.6 degrees Fahrenheit, climate model projections suggest an increase by mid-century (2035 to 2064) to 77.2 degrees Fahrenheit under a low emissions scenario and to 78.1 degrees Fahrenheit under a high emissions scenario (Cal-Adapt, 2018). By the late century (2070 to 2099), average temperatures are projected to reach 78.5 degrees Fahrenheit under the low emission scenario and 81.3 degrees Fahrenheit under the high emission scenario (Cal-Adapt, 2018). Heat waves are also projected to become more frequent and to last longer.

Wildfire

Historically, southwestern California has been a hot spot for wildfire. Climate change will likely increase all the key drivers of wildfires—high temperatures, dry conditions, and flammable vegetation. While there is uncertainty in wildfire modeling, the City of San Diego anticipates that future wildfire risk will be as severe as or more severe than that observed in recent decades (Kalansky, Cayan, Barba, Brouwer, & Boudreau, 2018).

More information on current and future climate conditions in San Diego is provided in Appendix A: Climate Data and Projections.

Report Overview

This Climate Change Vulnerability Assessment addresses the goal of gaining a comprehensive understanding of the City's climate change vulnerabilities. The assessment is a technical report that presents key findings from the vulnerability analysis and potential consequences of selected critical built, natural, and cultural assets to climate change hazards

This Vulnerability Assessment will provide the technical findings necessary to inform the development of the City's *Climate Resilient San Diego (Climate Resilient SD)* Plan. The need for a standalone climate adaptation plan was identified in the City's 2015 CAP.[11] Accordingly, the City is developing the *Climate Resilient SD* Plan to identify projected climate change hazards and responsibly address future conditions.

The *Climate Resilient SD* Plan's primary goals are to:

- Address climate equity by prioritizing and empowering our most vulnerable populations to climate change, with strong consideration of communities of concern;
- Raise awareness of projected/potential climate change impacts to the City;
- Gain a comprehensive understanding of the City's climate change vulnerabilities;
- Build City capacity for preventive and responsive action; and
- Identify potential climate adaptation and resilience strategies.

The remaining sections of this report describe the context, methodology, and findings of the vulnerability assessment, as follows:

- **The Vulnerability Assessment in Context:** Describes current and ongoing efforts by the City, organizations in the San Diego region, and the State of California to understand and prepare for climate change impacts;
- **Vulnerability Assessment Methodology:** Details the approach, data sources, and research questions used to assess City vulnerability;
- **Summary Vulnerability Assessment Findings:** Provides high-level findings across sectors and climate change hazards;
- The following sections provide detailed vulnerability findings by hazard for each analyzed sector:
  - **Public Safety;**
  - **Water;**
  - **Transportation and Storm Water;**
  - **Open Space and Environment;**
  - **Additional Assets.**

[11] City of San Diego (2015) *Climate Action Plan* https://www.sandiego.gov/sustainability/climate-action-plan.

- **Non-City-Owned Resources:** Presents the exposure of state-owned highways and freeways and privately-owned land within the City, categorized by land use type;
- **Building Toward a Climate Resilient SD:** Discusses plans for using the results of this vulnerability assessment to inform the larger City effort to develop a *Climate Resilient SD* Plan and explains next steps;
- **Glossary**: Defines key terms related to climate, adaptation, and resilience;
- **References:** Identifies references cited in this report;
- **Acknowledgments:** Recognizes the organizations and individual members of the Climate Resilient San Diego SAG;
- **Appendices**
    - **Appendix A: Climate Data and Projections:** Explains the science for current and future climate conditions in San Diego, considering the four key climate change hazards;
    - **Appendix B: Hazard Maps:** Shows where the priority hazards are expected to be experienced in the City;
    - **Appendix C: Exposure Data:** Provides more detailed information on the number of assets exposed to the various climate change hazards;
    - **Appendix D: Energy Efficient Buildings:** Provides a list of buildings identified by the City of San Diego as LEED certified (and therefore energy efficient).

Support for this project comes in part from a California Coastal Commission Local Coastal Program Local Assistance Grant and a Caltrans Adaptation Planning Grant.

The Vulnerability Assessment in Context

San Diego's vulnerability assessment and resilience efforts are being undertaken within the context of related initiatives at the City, regional, and state levels.

City Efforts

Under the CAP, the City has taken bold steps to mitigate impacts of climate change and to reduce its greenhouse gas emissions. *Climate Resilient SD* will complement and build upon these existing efforts. This vulnerability assessment is a foundational element of the *Climate Resilient SD* plan, providing technical information on important vulnerabilities created or exacerbated by four key climate change hazards to the City.

- The City of San Diego's CAP (2015) calls for promoting the City's prosperity and quality of life by building communities that are resilient to climate change, recognizing that some degree of climate change will occur regardless of the City's effort to reduce and mitigate greenhouse gas (GHG) emissions. Chapter 5 of the CAP specifically calls for the development of a standalone climate adaptation plan that will integrate and build upon the strategies and measures in the CAP. This vulnerability assessment will inform the development of the climate adaptation plan (Figure 3).
- The City of San Diego's *2018 General Plan Amendments* (2018) revised the General Plan's Public Facilities, Services and Safety Element to include goals and policies that address wildfire hazard severity zones and to integrate climate resilience and adaptation. These updates were completed in accordance with SB1241.

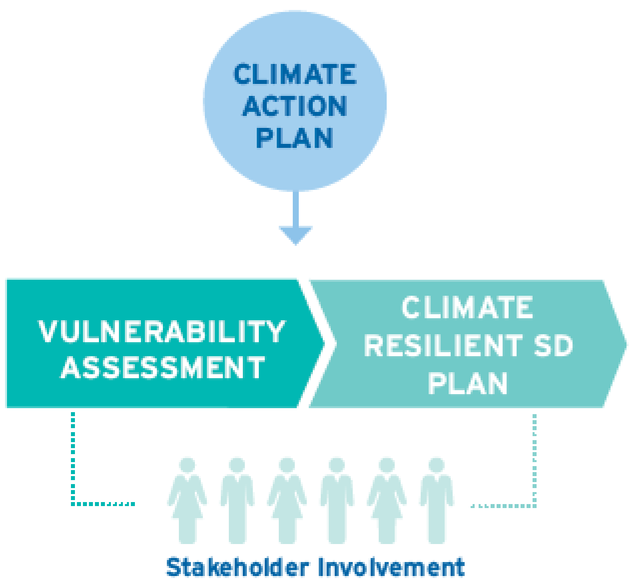

Figure 3. City of San Diego Climate Adaptation Work Interactions

Other Local Efforts

- The San Diego County *Multi-Jurisdictional Hazard Mitigation Plan* was last revised in 2017. The City of San Diego contributes a chapter to this plan, providing information on the City's critical facilities and potential exposures and losses related to climate change hazards including coastal storms and erosion, sea level rise, floods, rain-induced landslides, wildfire, and non-climate-related hazards such as earthquakes, dam failures, and tsunamis. The City's plan includes six hazard mitigation goals, along with objectives and prioritized action items to achieve them. The information relating to climate change hazards gathered by the City for the Hazard Mitigation Plan helped inform this vulnerability assessment and the hazard mitigation goals, objectives, and actions that can inform the *Climate Resilient SD* plan.

- The San Diego Urban Area *Threat and Hazard Identification and Risk Assessment* (SDUATHIRA) is a Department of Homeland Security/FEMA-mandated submission the City provides on a regular basis (one to three years) that identifies threats and hazards to which the region is vulnerable. In the City's latest submission, the sections on Wildfire and Utility Interruption (power outage) specifically mention the role of climate change on these vulnerabilities in the region. This report helps communities in the San Diego Urban Area better understand their risks and determine the level of capability needed to address those risks.
- The ICLEI-Local Governments for Sustainability *Sea Level Rise Adaptation Strategy for San Diego Bay* (2012) provides a high-level analysis of vulnerable sectors and impacts to the San Diego Bay lands. The study focused on flooding, inundation, erosion, saltwater intrusion, and water table rise. The study identified resilience strategies for both regional and local implementation, as well as strategies targeted to the sectors included in the analysis (ecosystems and critical species, contaminated sites, storm water management, wastewater, potable water, local transportation facilities, building stock, emergency response facilities, parks, recreation, and public access, regional airport operations, and vulnerable populations). The high-level vulnerability analysis helped inform this report, and the adaptation recommendations will help inform the *Climate Resilient SD* Plan.
- The ICLEI-Local Governments for Sustainability *San Diego Coastal Resilience Assessment* (2017) is a local sea level rise vulnerability assessment that included the coastal areas from Point Loma to Del Mar, excluding Mission Bay. The assessment identified sea level rise coastline impacts related to changes in flood frequency and extent, inundation, changes in sedimentation supply and movement, high rate of erosion, and saltwater intrusion and groundwater inundation. The assessment focused on building stock, the social sector, storm water, wastewater, water, transportation, beaches and public access, and biodiversity and habitat. These findings helped inform this vulnerability assessment with respect to coastal hazards.
- The Scripps Institute of Oceanography *Beach and Coastal Cliff Survey* (ongoing) is currently collecting data on beach sand levels from La Jolla Shores Beach to Oceanside. These data can provide greater insight into coastal hazards, which are considered in this vulnerability assessment.
- From 2013 to 2019, the City of San Diego partnered with the U.S. Bureau of Reclamation to complete the *San Diego Basin Study*. This study uses the latest climate change modeling tools to perform a quantitative analysis of the uncertainties associated with climate change impacts on the San Diego Basin's local and imported fresh water supplies. A goal of this study is to assist water agencies serving the Basin and San Diego Integrated Regional Water Management planning region in adapting to climate change-related uncertainties.
- The *San Diego Regional Climate Collaborative's Resilient Coastlines Project* (ongoing) is building coastal resilience in the region by translating sea level rise and coastal storm science into planning, building local leadership, and holding living shorelines workshops.

State Guidance and Resources

The following state guidance is applicable to the City's resilience planning efforts:

- The California Ocean Protection Council and California Natural Resources Agency's State of California Sea-Level Rise Guidance 2018 Update (2018) provides: "1) a synthesis of the best available science on sea level rise projections and rates for California; 2) a stepwise approach for state agencies and local governments to evaluate those projections and related hazard information in decision-making; and 3) preferred coastal adaptation approaches."
- The Governor's Office of Planning and Research, California Natural Resources Agency, and California Energy Commission's California's Fourth Climate Assessment (2018) was designed "to address critical information gaps that decision-makers need at the state, regional, and local levels to protect and build resilience of California's people and its infrastructure, natural systems, working lands, and waters." The City is using findings published in the Fourth Assessment that pertain to sector vulnerability, sensitivity, and adaptive capacity.
- The California Natural Resources Agency's Safeguarding California (2018) is "the State's road map for everything state agencies are doing and will do to protect communities, infrastructure, services, and the natural environment from climate change impacts." The City is using this resource to help coordinate adaptation with state efforts and to find examples of adaptation strategies.
- The California Coastal Commission's Sea Level Rise Policy Guidance (2018) provides the best available science on sea level rise specific to California, paired with a recommended methodology for addressing sea level rise in Coastal Commission planning and regulatory actions. The City followed this guidance in assessing its vulnerabilities to sea level rise.
- The Governor's Office of Emergency Services' California Adaptation Planning Guide (2012) provides guidance for local jurisdictions in addressing climate change impacts. The City referred to this guide when developing its framework for adaptation planning. The City is also working with the Governor's Office to inform the development of the updated California Adaptation Planning Guide planned for publication in 2020.

Vulnerability Assessment Methodology

The City is composed of departments, each with a responsibility for the management of particular assets, operations, and services that help the City function and thrive. To gain a comprehensive understanding of the priority concerns posed by climate change to the City's selected priority assets, the vulnerability assessment was conducted in two phases:

- Phase 1 was a screening-level vulnerability assessment of selected critical City asset types. This entailed assessing the exposure of critical asset types to each hazard, then analyzing the sensitivity and adaptive capacity of exposed critical asset types. The City also assessed the consequences of climate change impacts to each sector.
- Phase 2 involved developing detailed risk profiles for selected individual assets that if damaged or lost would have significant consequences to the City. Assets were selected based on the findings of Phase 1 and consultations with stakeholder advisors and City departments.

The vulnerability assessment's findings will inform the development of City-wide climate change adaptation strategies.

This report covers Phase 1 of the vulnerability assessment, which the City conducted using quantitative and qualitative hazard and asset data along with input from its SAG (described on page 32).

Vulnerability vs. Consequences

Vulnerability: "…[The] degree to which a system is exposed to, susceptible to, and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity." (California Coastal Commission, 2018)

Consequences: Impacts on community structures, functions, and populations, and on asset owners' or service providers' ability to maintain a standard condition or level of service (CEMA and CNRA, 2012).

Data Collection and Consultation

The City began this analysis by compiling and reviewing existing information on climate vulnerability and climate change hazard projections for the San Diego region. The analysis provided an understanding of the current state of knowledge, identified remaining information gaps, and summarized the actions the City is already taking to prepare for and respond to climate change.

Collecting and Mapping Climate Change Hazard Data

The City collected data for past, present, and projected future climate change hazards from the best available scientific sources. These include the California Coastal Commission, the U.S. Geological Survey's Coastal Storm Modeling System (CoSMoS), Cal-Adapt (the state's central resource for climate science), the Federal Emergency Management Agency (FEMA), the CalEPA, and internal City data sources for information on past exposure, such as areas that have historically flooded or been exposed to wildfire.

Appendix A provides detailed information on the selection of hazard scenarios; an overview of data sources for each climate change hazard analyzed is provided below.

The City collected and analyzed data on the following hazards:

Sea Level Rise

- Coastal Flooding

  According to the November 2018 update to the California Coastal Commission's (CCC) *Sea Level Rise Policy Guidance,* sea levels in San Diego may rise by 0.6 to 1.1 feet (0.25 m) by 2030, 1.2 to 2.8 feet (0.5 to 0.75 m) by 2050, and 3.6 to 10.2 feet (1 to 2 m) by 2100 (California Coastal Commission 2018). The City used this information to select corresponding data from localized sea level rise modeling produced by CoSMoS, which were used to develop exposure maps. CoSMoS provides maps of coastal flooding that could result from sea level rise and storms while factoring in changes in beaches and the retreat of cliffs and bluffs along the California coast (USGS, n.d.). Table 6 shows how the CCC 2018 projections were translated to the closest data available from CoSMoS.

  Based on this data selection process, the City used the following sea level rise projections to estimate the exposure from daily average flooding and storm surge (100-year) flooding: 0.25 m of sea level rise (0.8 feet) (2030 timeframe), 0.5 m and 0.75 m of sea level rise (1.6 to 2.5 feet) (2050 timeframe), and 1.0 m, 1.5 m, and 2.0 m of sea level rise (3.3 to 6.5 feet) (2100 timeframe). Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day assuming each sea level rise scenario. Storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm assuming each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

  The sensitivity and adaptive capacity ratings of the sea level rise with storm surge flooding focuses on the temporary duration of extreme flood scenarios, while sea level rise alone focus on the impacts of chronic inundation. Thus, while the area expected to be exposed to sea level rise with storm surge flooding is greater, the impacts of periodic storm-based flooding are generally less than the impacts of chronic flooding. Generally it is easier to prepare for periodic flooding than for chronic flooding.

Table 6. Coastal Flooding Scenario Selection Based on CCC 2018 Projections and Closest CoSMoS Increments

Year	Low Risk Aversion Scenario[12] 17% probability SLR meets or exceeds		Medium-High Risk Aversion 0.5% probability SLR meets or exceeds		Extreme Risk Aversion Scenario H++ scenario, no assigned probability	
	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment
2030	0.6 ft.	0.25 m (0.8 ft.)	0.9	0.25 m (0.8 ft.)	1.1 ft.	0.25 m (0.8 ft.)
2050	1.2 ft.	0.25 m (0.8 ft.)	2.0 ft.	0.5 m (1.6 ft.)	2.8 ft.	0.75 m (2.5 ft.)
2100	3.6 ft.	1 m (3.3 ft.)	7.0 ft.	2 m (6.6 ft.)	10.2 ft.	2 m (6.6 ft.)

- Coastal Erosion

  The relatively soft sandstone bluffs that are common along the San Diego coast are prone to erosion from waves and from storm water runoff. In addition, sea level rise together with increased storm frequency may accelerate beach and other shoreline erosion. The last City-wide coastal erosion assessment, consisting of geotechnical reports, site visits, and photographic documentation of erosion, was completed in 2003 (City of San Diego 2003). The City worked with consultants to update this coastal erosion assessment in 2018 and found that while the City has made improvements to pedestrian access and safety along the erosion sites, additional sites pose threats to pedestrian access or safety.

  Based on this identified vulnerability, the City selected the best available localized modeling from CoSMoS for coastal erosion in the area, covering shoreline and cliff retreat under a Medium-High Risk Aversion Scenario of 2.0 m of sea level rise by 2100 (see Table 6) for four scenarios (USGS, n.d.):

  - Beach erosion:
    - "No hold, no nourish" assumes the shoreline is allowed to retreat unimpeded and with no human increases in sediment (i.e., beach nourishment).

[12] The recent California Coastal Commission Sea Level Rise Policy Guidance November 2018 update provides three sets of sea level rise projections: low, medium-high, and extreme risk aversion. The sea level rise projections associated with low risk aversion should be used to inform planning for development with high adaptive capacity and relatively low associated consequences if impacted by sea level rise, such as temporary or seasonal development, or development that can be easily moved. The projections labeled "medium-high risk aversion" are appropriate for informing less adaptive, more vulnerable land uses that will experience medium to high consequences if impacted by sea level rise, including residential and commercial development. The projections labeled "extreme risk aversion" and "H++" are appropriate for development that, if impacted by sea level rise, would be irreversibly destroyed, would be significantly costly to repair, and/or would have considerable public health, public safety, or environmental impacts—such as critical infrastructure.

- “Hold, continued nourish” assumes the shoreline retreat is limited to an urban boundary and sediment is increased.
- Cliff retreat:
  - “Let it go” avoids coastal armoring and allows the cliff to retreat and cliff erosion rates to increase as sea level rises.

For the purpose of this assessment, beach erosion considers erosion of non-cliff shorelines, while cliff retreat considers erosion of cliffs along the coastline.

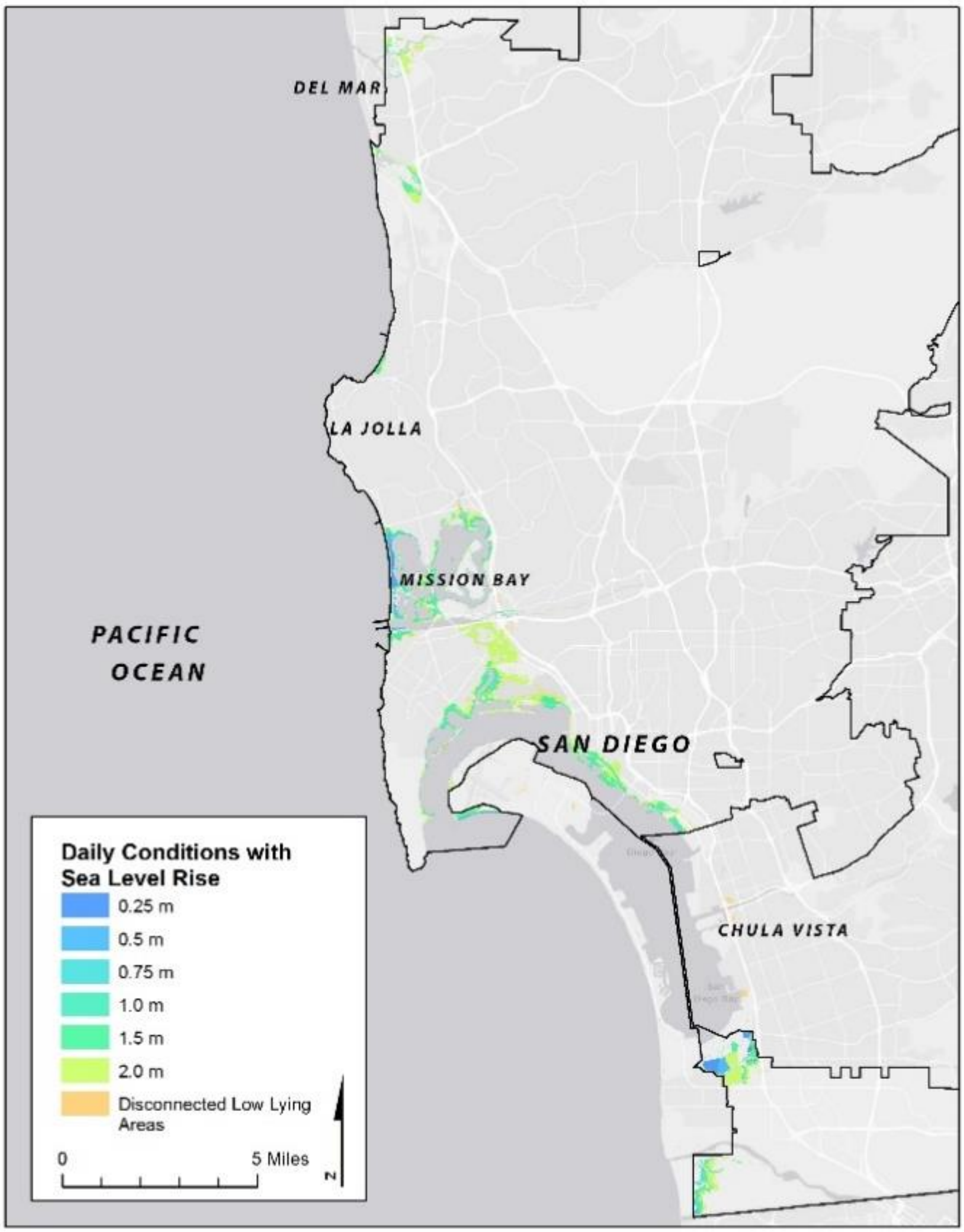

Figure 4. Daily coastal flooding in the City of San Diego given varying sea level rise scenarios. Flooding data obtained from USGS. Maps created: 2019.

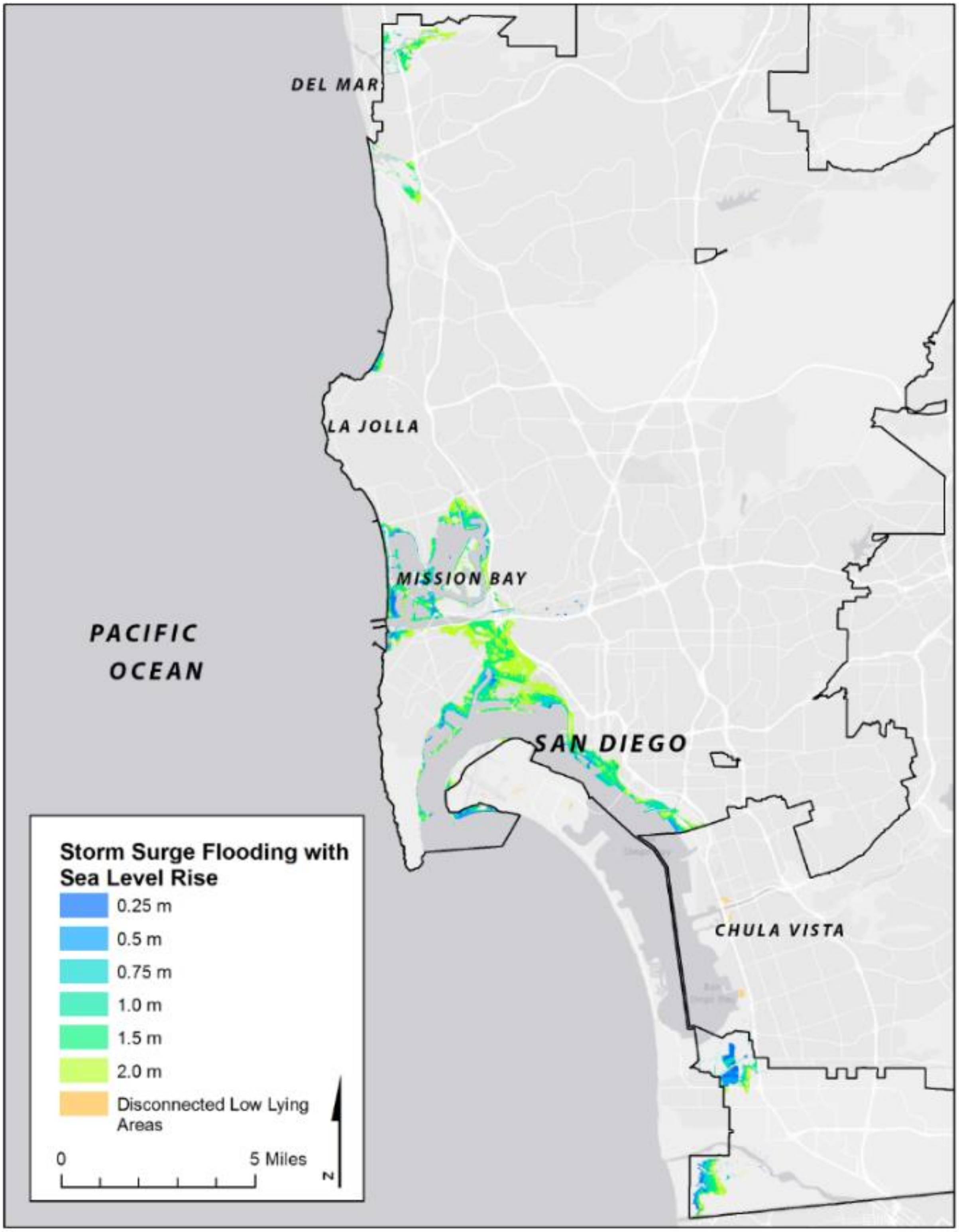

Figure 5: Storm surge (100-year) coastal flooding in the City of San Diego given varying sea level rise scenarios. Flooding data obtained from USGS. Maps created: 2019.

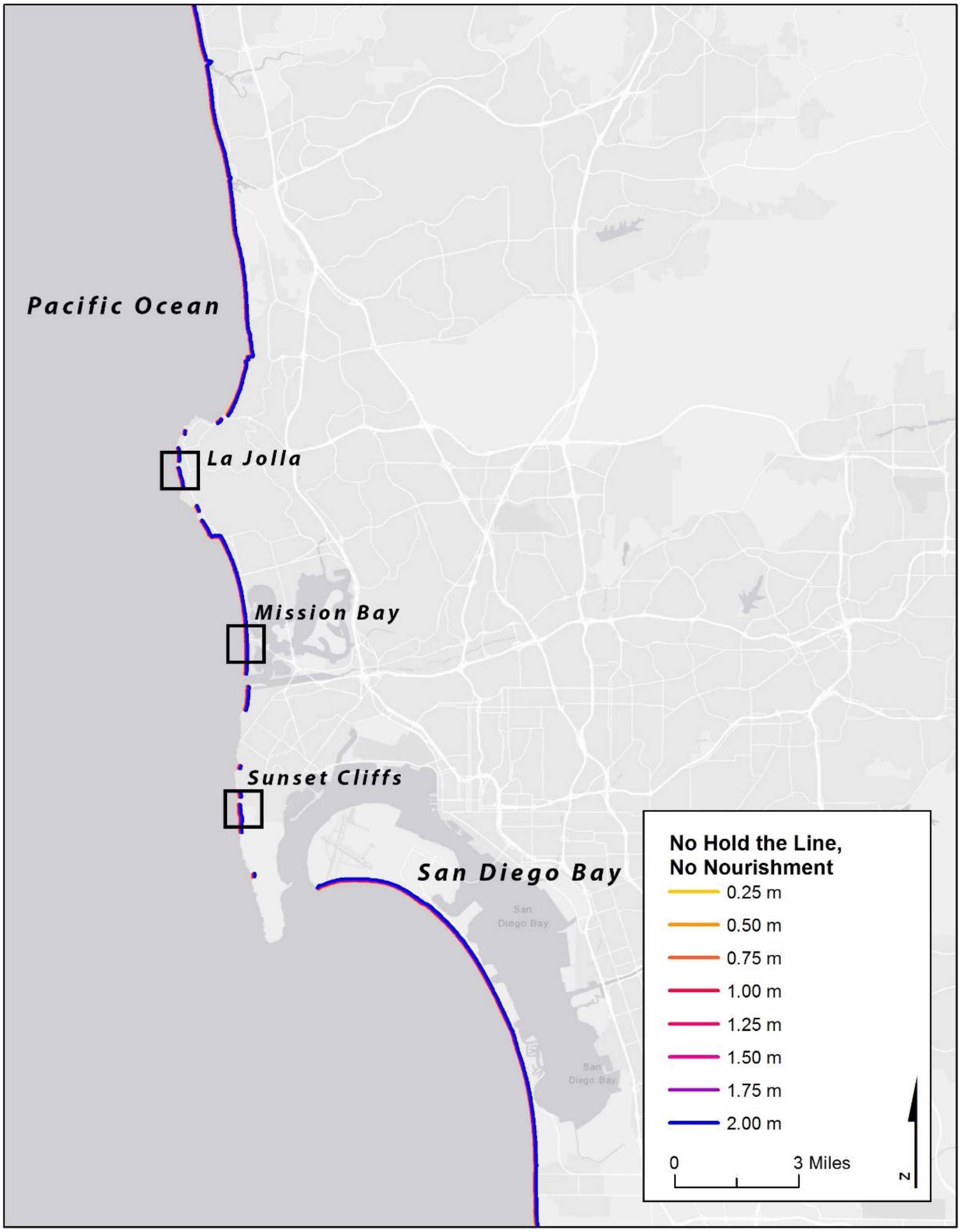

Figure 6. Beach erosion in the City of San Diego under the no hold the line, no nourishment scenario. Erosion data obtained from USGS. See Appendix B: Hazard Maps for the scaled-up insets at La Jolla, Mission Bay, and Sunset Cliffs. Map created: 2019.

Changes in Precipitation

Annual average precipitation projections from Cal-Adapt and other sources suggest only modest changes in total annual precipitation in the decades ahead (Seager, 2015), but there is expected to be more variability in rainfall from year to year and more intense transitions between droughts and deluges (Swain, 2018). This is in part due to an expected intensification of atmospheric rivers, which are often responsible for extreme precipitation events that punctuate dry spells in Southern California (Kalansky, Cayan, Barba, Brouwer, & Boudreau, 2018). To examine potential flooding vulnerabilities from intense precipitation events, the City selected the best available spatial data that reflect current, highly localized precipitation-driven flood vulnerability: the 100-year floodplain and 500-year floodplain from the Federal Emergency Management Agency Flood Insurance Rate Maps (FIRMs) (FEMA, 2016). These reflect 2012 FIRMs for all of the City except South Bay, for which the FIRM was last updated in 2016.

Extreme Heat

The City used urban heat island index data from CalEPA to project areas that could be exposed to extreme heat. These data were the best available spatial information for heat within the City at the time of the vulnerability assessment. The geographic patterns revealed by CalEPA's urban heat island data are likely to persist even as temperatures change over time. This source thus identifies areas of the City that are likely to be more or less vulnerable to future extreme heat events. In general, these data show that areas near the coastline are cooler, and temperatures increase moving inland. The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[13] A score of zero indicates that there is no difference in temperature over time between an urban Census tract and nearby upwind rural reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

Wildfire

The City of San Diego used a conservative approach to plan for a future wildfire risk of equal or greater severity than that of recent decades. The City based its wildfire vulnerability assessment on its four current measures of fire risk: The City's brush management zone, a 100-foot and 300-foot buffer around the brush management zone, and the fire hazard severity zone. These areas indicate where fuel for potential wildfires exists within the City.

[13] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

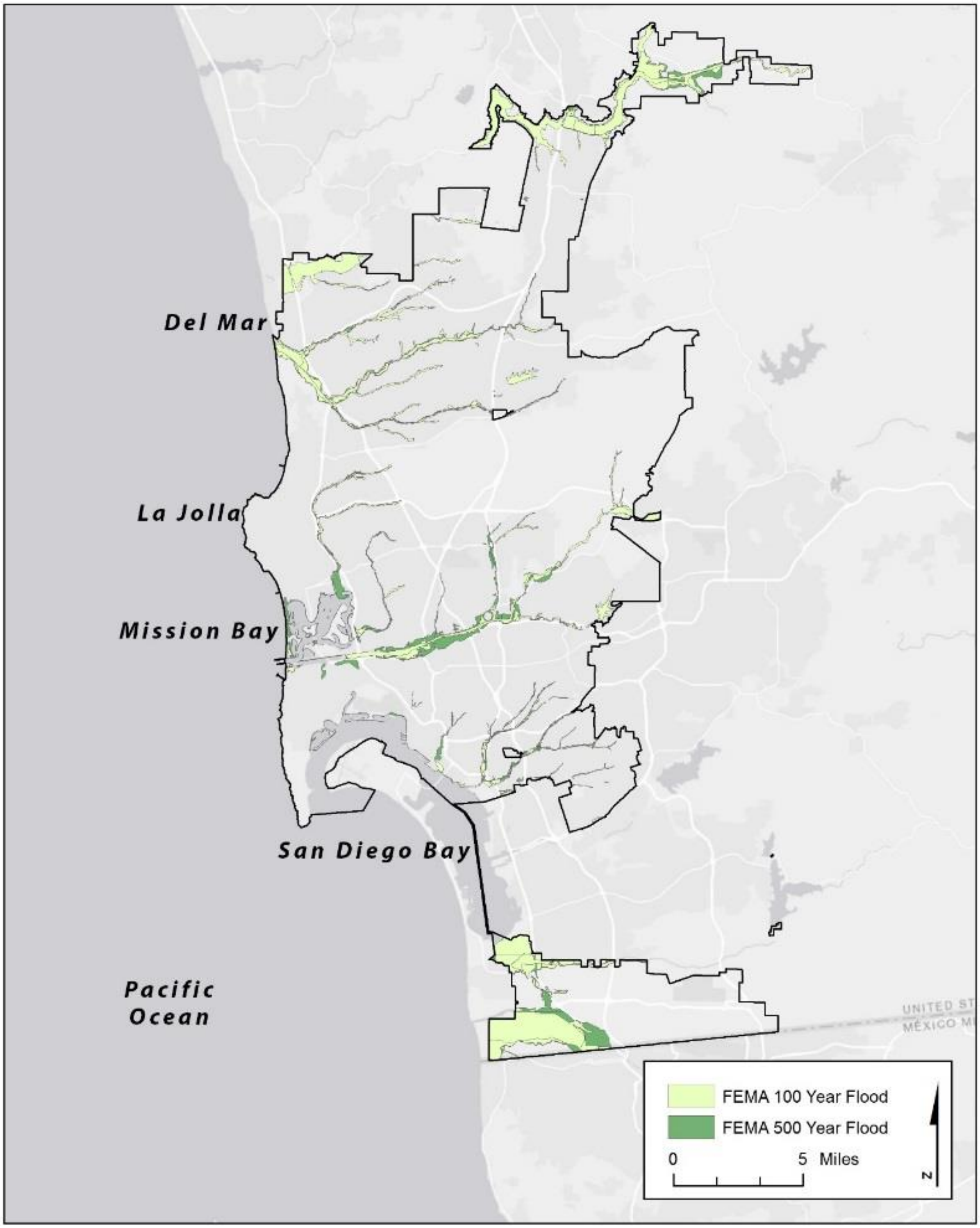

Figure 7. Precipitation exposure to the 100-year and 500-year floods in the City of San Diego. Floodplain data obtained from FEMA. These reflect 2012 FIRMs for all of the City except South Bay, for which the FIRM was last updated in 2016. Map created: 2019.

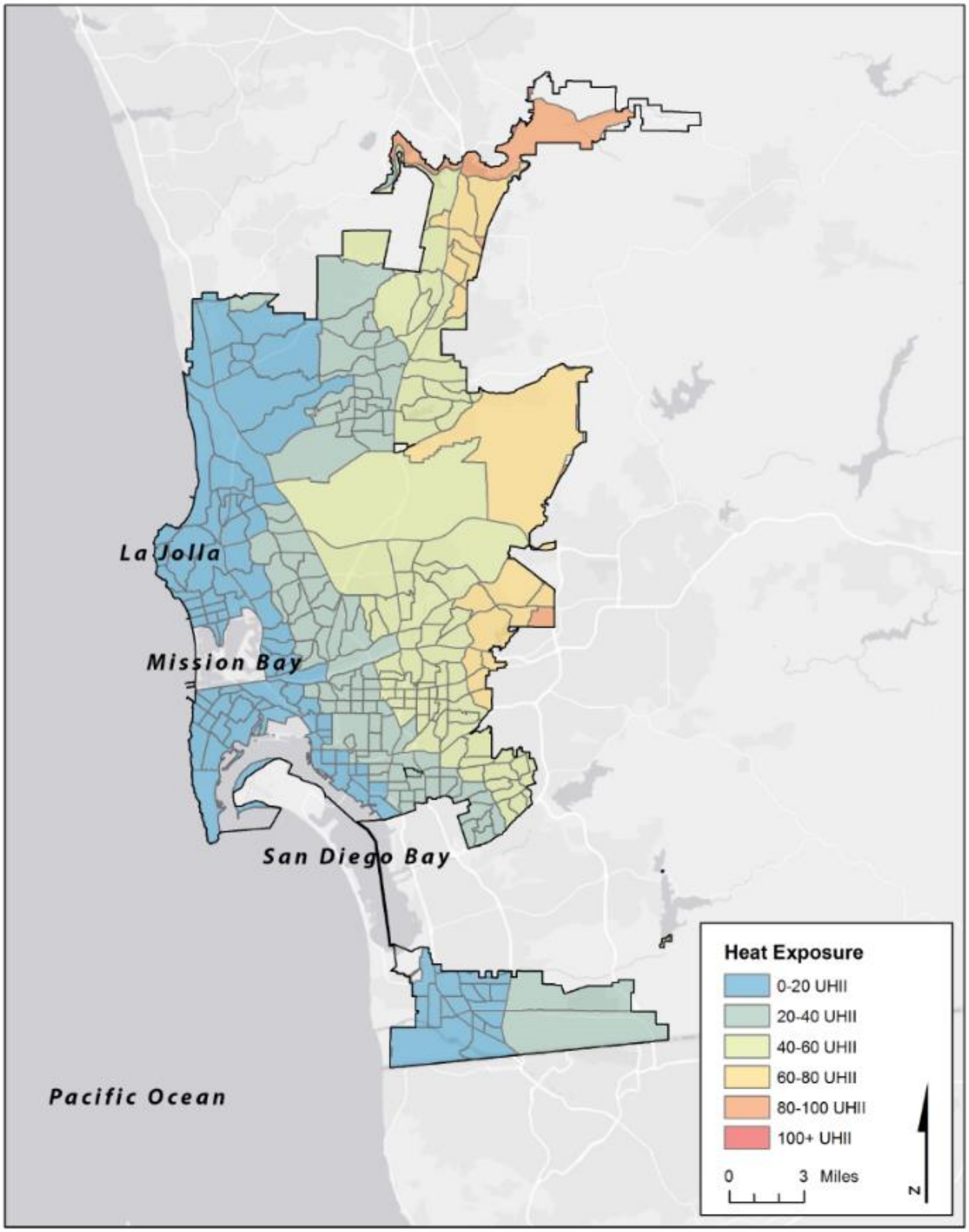

Figure 8. Urban heat island zones in the City of San Diego. Urban heat island data obtained from CalEPA. Map created: 2019.

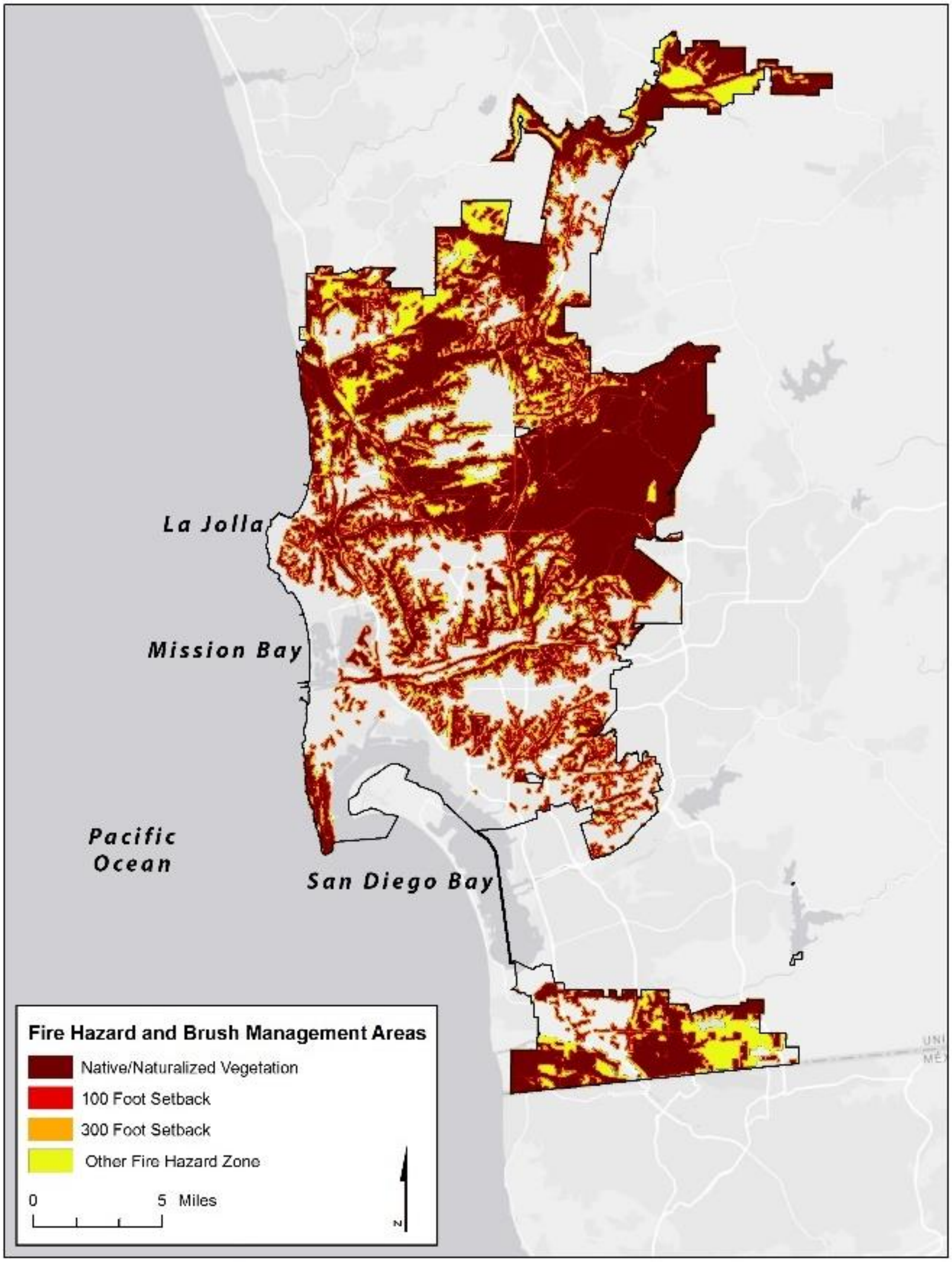

Figure 9. Wildfire hazard zones in the City of San Diego. Fire zone data obtained from the City of San Diego. Map created: 2019.

Selecting Critical City Assets

At the outset of this assessment, the Planning Department consulted other City departments to identify which built, natural, and cultural asset types owned and/or managed by the City could be considered critical. The selection criteria were:

- If the asset type/resource (or its function) is necessary for continuity of important City operations;
- If the asset type/resource (or its function) is a key driver in the City's economy;
- If loss of the asset type/resource would present equity issues;
- If the asset type/resource is critical to safeguarding biological diversity and other environmental priorities.

Table 7 provides a breakdown of the sectors that were considered, the responsible City departments, and the specific asset types that were identified as critical. Only critical asset types are included in the vulnerability assessment. Not all critical asset types in this list were found to be exposed to climate hazards.

Table 7. City of San Diego Departments and Corresponding Critical Assets

Sector	City Department(s) (or other managing entity)	Critical Asset Types
Public Safety	Fire-Rescue, Police	Fire stations, police stations, lifeguard stations, police patrol and specialty vehicles, maintenance facilities, other public safety assets (Critical Incident Management Unit equipment locations, police evidence storage buildings, police vehicle maintenance, police trailers, portable fire station trailers, logistics and dispatch facilities, DRC emergency operations, police air support hangers, multicultural storefront[14])
Water Infrastructure	Public Utilities	Dams, water pipes, wastewater pipes, water pump stations, wastewater pump stations, distribution reservoirs, water treatment plants, wastewater treatment plants
Transportation[15]	Transportation and Storm Water; Real Estate Assets	Major arterials, Brown Field Municipal Airport, Montgomery-Gibbs Executive Airport, bridges

[14] The multicultural storefront is a Police building that is used constantly as a hub for citizens from other countries. This is a location for non-native-English speaking citizens to obtain services or to be directed to services, and for police to help with mediation of community groups.
[15] Bridges and major arterial assets were broken down into roadway segments as defined in the City's asset management system.

Sector	City Department(s) (or other managing entity)	Critical Asset Types
Storm Water	Transportation and Storm Water	Drain pump stations, outfalls, levees (These critical assets included in the analysis are part of a larger storm water conveyance system of pipes and channels)
Open Space/ Environment	Parks and Recreation, Environmental Services; Public Utilities	Conservation areas/open space/source water land,[16] community parks, Miramar Landfill, CNG fueling station, beaches
Additional	Real Estate Assets; Parking Organization; Commission for Arts and Culture	Recreation centers, libraries, City buildings, historical, tribal cultural, and archaeological resources

In addition to these critical City assets, the assessment also considered the exposure of certain non-City asset types to give a more holistic view of climate change risks. Specifically, state highways and freeways are assessed for exposure to provide a more comprehensive view of the transportation network serving the City. Vulnerability scores were not calculated for these assets, as the City does not have full insight into the sensitivities and adaptive capacities of assets it does not manage.

Each private parcel was assigned one or more land use type based on the tax assessors' land use code. The City identified seventy-two building types and grouped them into seventeen land use categories: agricultural, commercial, community, cemetery, entertainment, health, hotel/motel, industrial, institutional, marina docks, office space, open space, residential, restaurant, rural, not defined, and vacant.

Establishing a Stakeholder Advisory Group

The City formed a Stakeholder Advisory Group (SAG) with diverse representation from regional stakeholders, including internal City departments, State and federal agencies, local nonprofit and environmental organizations, community-based organizations, transportation agencies, energy utilities, academic institutions, and other key stakeholders (see the Acknowledgments section for a list). The SAG was created to provide feedback and input at key points in the vulnerability assessment and *Climate Resilient SD* planning process.

[16] "Source water land" refers to open space land managed by the Public Utilities Department that serves the primary purpose of capturing and protecting native source water.

The City held a SAG kickoff meeting on December 17, 2018, during which the City introduced SAG members to the City's climate resilience efforts and the need for stakeholder involvement. At the first stakeholder workshop on April 9, 2019, the City presented the initial findings of this vulnerability assessment to the SAG. The stakeholders provided feedback based on their experience and knowledge of vulnerabilities and assets. The workshop included brainstorming sessions where the City worked alongside stakeholders to draft possible adaptation strategies for the identified vulnerabilities. At the second stakeholder workshop on September 19, 2019, the City presented its framework for evaluating the adaptation strategies and worked with stakeholders to utilize the framework to evaluate potential adaptation strategies. The stakeholders help to vet the evaluation criteria and provide feedback on what criteria were important to consider.

Vulnerability Analysis

This report details the findings of Phase 1 of the City vulnerability assessment, which included an asset type level screening for vulnerability and consequences. Vulnerability is assessed by evaluating exposure, sensitivity, and adaptive capacity. Consequences are the potential impacts to the City, the public, the economy, and the environment if the asset type were exposed to climate change. The following sections describe the methodology used to assess and score each of these components.

Exposure

Exposure: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm (Bedsworth, 2018) citing (IPCC, 2012).

The goal of the exposure assessment was to understand which selected critical City asset types could be subject to the hazards considered in this analysis and which scenarios would lead to exposure (e.g., would a particular asset type experience flooding at 0.25 m or only at 2 m of sea level rise?).

To determine exposure, the project team overlaid geospatial climate change hazard data with the locations of critical assets. This information was then used to calculate how many individual assets would be exposed under each scenario. The project team obtained spatial data for projected climate change hazards from the USGS Coastal Storm Modeling System (CoSMoS), FEMA, the City of San Diego, CalEPA, and SanGIS through the SanGIS Regional Data Warehouse.

The exposure score for each type of critical asset (e.g., for all police stations) was based on the highest level of exposure experienced by any asset within that group. For example, for the fire station asset type, if one fire station was found within the FEMA 100-year floodplain for precipitation and received an exposure score of "high," then fire stations as a whole asset type were scored as "high" for their exposure to precipitation-based flooding. The breakdown of scoring for each hazard is shown in Table 8.

Table 8. Rubric for Scoring Exposure of Critical Asset Types to Climate Hazards

	Coastal Erosion	Coastal Flooding[17]	Precipitation	Heat	Wildfire
High	Within the zone eroded under the "Shoreline hold, continued nourish" CoSMoS beach erosion scenario with 2 m sea level rise	Within the zone inundated by the 0.25 m CoSMoS sea level rise scenario (2030)	Within the zone flooded by the FEMA 100-year floodplain	Within the zones with heat score of UHI[18] 80 to 100+	Within the native vegetation zone or its 100-ft buffer
Medium	Within the zone eroded under either the "Cliff let it go" cliff erosion *or* "Shoreline no hold, no nourish" beach erosion scenarios with 2 m sea level rise	Within the zone inundated by the 0.5 to 0.75 m CoSMoS sea level rise scenario (2050)	Within the zone flooded FEMA 500-year floodplain	Within the zones with heat score of UHI 40 to 80	Within the 300-ft buffer of native vegetation
Low	N/A (no low score for erosion)	Within the zone inundated by the 1.0 to 2.0 m CoSMoS sea level rise scenario (2100)	N/A (no low score for precipitation)	Within the zones with heat score of UHI 0 to 40	Within the fire hazard zone outside of brush management zone

Sensitivity

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli (California Coastal Commission, 2018).

The sensitivity analysis aimed to identify potential impacts to critical asset types that could be exposed to the climate change hazards considered in this assessment. Information on critical asset type sensitivity was gathered from relevant literature.[19] The project team also gathered City-specific information on asset sensitivity by holding interviews with City departments[20] and reviewed documentation collected by City

[17] Coastal flooding refers to both daily flooding and the 100-year storm given the various sea level rise scenarios.
[18] The urban heat island (UHI) index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree Celsius over an eight-hour period would equal eight degree-hours, as would an increase of two degrees Celsius over a four-hour period. Higher scores denote hotter areas.
[19] A full list of sources is presented in the References section at the end of this report.
[20] Parks and Recreation, Chief Operating Officer Homelessness Strategies, Office of Homeland Security, Risk Management, Debt Management, Department of Finance, City Treasurer, Sustainability, Fleet Services, Purchasing and Contracting, Human Resources, Transportation and Storm Water (TSW), Public Works (PW), Public Utilities

departments pertaining to previous emergencies and natural hazard impacts. These documents, such as Initial Damage Estimates (IDE) drawn up in the aftermath of FEMA-declared disasters, provided information such as the type of hazard experienced, level of damage, costs incurred, and asset condition.

The City scored sensitivity based on the highest assumed sensitivity within each critical asset type. For example, flooding from precipitation has historically led to mild to medium damage to fire stations, with more severe damage occurring when water enters drywall. This higher end of potential damage resulted in fire stations having a medium sensitivity to precipitation. The rubric for scoring sensitivity is shown in Table 9.

Table 9. Rubric for Scoring Sensitivity of Critical Asset Types to Climate Hazards

Score	Rationale
High	If exposed, the asset type may become damaged beyond repair or destroyed and cannot resume normal function until replaced.
Medium	If exposed, the asset type may be damaged such that repairs are necessary before it can resume full functionality.
Low	If exposed, the asset type may suffer minor damage but can maintain functionality or is not damaged at all.

Adaptive Capacity

Adaptive Capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences (California Coastal Commission, 2018) citing (Willows, 2003).

The goal of the adaptive capacity analysis was to identify actions the City has already taken and put in place to prepare for current and future natural hazards, as well as to understand the potential for further adaptive action. Adaptive actions are assumed to reduce vulnerability by avoiding exposure or reducing sensitivity to exposure. This can occur through physical protection measures, operational changes to avoid exposure, changing the nature of an asset so that it is less sensitive to exposure, and other strategies.

The City has a history of proactively managing extreme weather events. This includes being an active contributor to the County Hazard Mitigation Plan, last updated in 2018, under which the City developed specific goals, objectives, and actions to mitigate climate change hazards. Many of these actions are ongoing and are currently being implemented, such as:

- Creating fire buffer zones around residential and non-residential structures and other infrastructure systems by removing or reducing flammable vegetation;

(PUD) Environmental Services (ESD), Real Estate Assets (READ), Police, Fire-Rescue, and Development Services (DSD).

- Installing and maintaining permanent alternative power generators at all water and wastewater treatment plants and pumping stations;
- Updating the Land Development Code to require private development in the Coastal Zone to account for anticipated sea level rise;
- Restoring the conveyance capacity of key channels;
- Conducting staff training in the City's Emergency Operations Center (City of San Diego, 2017a).

The City held internal consultations and analyzed asset management data to understand the ability of critical assets to adapt to climate change hazards and to determine where adaptive measures or practices are already in place or planned. To assess adaptive capacity, City departments were asked whether:

- Any assets are made of materials that are particularly susceptible to damage from climate exposure;
- The assets could be moved when extreme weather events occur;
- The department currently deploys protective measures to prevent exposure during extreme weather events;
- Any backup features are available to maintain functionality if some assets become damaged; and
- Any additional current or planned action to address climate change hazards.

The City scored adaptive capacity based on the rubric in Table 10. Adaptive capacity has an inverse relationship to vulnerability, whereas exposure and sensitivity have a direct relationship with vulnerability. High exposure, high sensitivity, and low adaptive capacity contribute to high vulnerability, whereas low exposure, low sensitivity, and high adaptive capacity contribute to low vulnerability.

Table 10. Rubric for Scoring Adaptive Capacity of Critical Asset Types to Climate Hazards

Score	Rationale
High	The asset can easily be protected from climate impacts (e.g., there are already protective measures in place that adequately prevent impacts; assets can be moved during an event; there are backups available; the system or asset type has redundancies).
Medium	The asset can be protected with some effort (e.g., there are potential protective measures, but they are not yet in place; the asset needs to be retrofitted or upgraded to withstand impacts; backups need to be acquired from other jurisdictions during an event). While short-term options are available, longer-term or more permanent measures are more difficult to achieve.
Low	The assets cannot be protected (e.g., they are located within an exposed area and cannot be easily moved; there is no level of protection that can fully prevent damage; they are made of sensitive materials and cannot be upgraded; there are no backups available; possible adaptation measures are prohibitively expensive).

Bringing it all Together to Assess Asset Vulnerability

Vulnerability is a function of exposure, sensitivity, and adaptive capacity. The City combined the scores for these three components to determine a vulnerability score for each type of critical asset for each climate change hazard (that is, scores were assigned to the asset type level and not to individual assets).

Scores were assigned at the *asset class* level and not to individual assets, and were determined as follows:

- If all three components contributed to low vulnerability (low exposure, low sensitivity, high adaptive capacity), then the vulnerability score was low;

- If all three contributed to high vulnerability (high exposure, high sensitivity, and low adaptive capacity), then the vulnerability score was **high**;
- If all were medium, then the vulnerability score was **medium**;
- Two component scores that contributed to high vulnerability warranted a **high** vulnerability score;
- Two component scores that contributed to low vulnerability warranted a **low** vulnerability score if the third component was medium, and a **medium** vulnerability score if the third component was a high vulnerability score.

Consequences Screening

Consequence: The outcome, either positive or negative, of an event (ISO, 2018).

The goal of the consequences screening was to understand the types of potential outcomes that could occur due to damage, disruption, or failure of assets, focusing on outcomes that would interfere with achieving City objectives. Consequences were assessed across the set of categories listed and described below. These categories were selected based on a review of best practices found in municipal climate risk assessments, which focus on identifying consequences to municipal objectives and priorities. Categories were also selected based on priority City functions, including the provision of City services, public health and wellbeing, social equity, community and cultural support, and environmental protection.

Historical, tribal cultural, and archaeological resources were identified as a consequence category as well as an asset type, because these resources can be found across all sectors. The City's register of designated historical resources includes libraries, police facilities, dams, water storage and pumping stations, airport facilities, bridges, roads, cemeteries, and archaeological and tribal cultural resources within parks and open space areas. Thus, impacts to these asset types may also result in impacts to historical, tribal cultural, and archaeological resources, which must be acknowledged, understood, and planned for.

The City screened for consequences by considering the impacts of asset damage, disruption, or failure to the following categories:

- City Services (e.g., whether City departments would still be able to service the community, and which critical emergency services would be affected);
- Human Health (e.g., whether impacts to assets would result in loss of life, injury, disease, or hospitalization);
- Social Equity (e.g., how impacts to assets would affect the community, particularly vulnerable communities);

- **Historical, Tribal Cultural, and Archaeological Resources** (e.g., whether impacts to assets would affect the cultural identity of San Diego through damage to or loss of historical, tribal cultural, or archaeological resources);
- **Natural Resources and the Environment** (e.g., which habitats, species, and/or ecosystem services[21] would be lost, and how impacts to assets would affect local and regional biodiversity and ecosystem health).

In most cases, the consequences identified would be due to damage, disruption, or failure of critical assets, irrespective of the cause. This hazard-agnostic approach works because the drivers are captured by the vulnerability components. For all cases, if an asset is no longer functioning, it will result in a major consequence.

The consequences assessment was conducted at a screening level to identify asset types whose vulnerabilities to climate change hazards could lead to significant consequences for the City. In future updates to this vulnerability assessment, the consequence assessment could be refined beyond the screening level by conducting consultations and more asset-specific analysis to score these consequences on an asset-specific scale.

Limitations

As mentioned earlier, the objective of Phase 1 of the vulnerability assessment was to screen all critical City assets to determine the types of assets and hazards that require further in-depth review. Due to data limitations and the hundreds of thousands of assets across many City departments, vulnerability scores were developed at the asset type level rather than for individual assets. The exposure of individual assets was analyzed, but the sensitivity and adaptive capacity of the assets were developed at the asset type level, and therefore the final vulnerability scores are also at the asset type level. The scores for sensitivity and adaptive capacity were based on a combination of literature review, expert knowledge, and department consultations. As such, the scores do not capture the nuanced and full range of vulnerability represented by each individual asset within the City.

The asset type vulnerability scores do not represent an average or summary of individual asset scores. They are meant to provide a relative understanding of the risk that selected climate change hazards could pose to the asset category.

The City does not present the findings in this report as a basis for policymaking or planning for individual assets. Instead, the vulnerability findings presented herein are meant to help the City identify which types of assets and hazards may warrant additional attention for further analysis and planning. Phase 2 of the

[21] Ecosystem services are services provided by nature that contribute to human and environmental well-being; they include provisioning services (e.g., providing food and water), regulating services (e.g., climate control and flood prevention), supporting services (e.g., nutrient cycling), and cultural services (e.g., recreation and heritage).

vulnerability assessment took a closer look at a representative sample of asset types that were found to warrant further attention.

Summary Vulnerability and Consequence Assessment Findings

This section summarizes the findings of the vulnerability assessment and consequence screens across sectors and climate change hazards. Detailed findings for each sector, organized by climate change hazard, are available in the sections below.

Vulnerability Assessment Findings

Based on the vulnerability assessment, which considered exposure, sensitivity, and adaptive capacity of each type of asset to each climate change hazard, the following critical asset types were determined to be the most vulnerable to climate change hazards:

- **Public safety:** lifeguard stations;
- **Water:** water pipes, wastewater pipes, water pump stations, wastewater pump stations;
- **Transportation and storm water:** bridges, major arterials, drain pump stations, outfalls;
- **Open space and environment:** conservation areas/open space/source water land, community parks, beaches;
- **Additional assets:** recreation centers; historical, tribal cultural, and archaeological resources.

The primary climate change hazard, based on the number of types of assets found to be vulnerable, was wildfire. Twenty–five (out of thirty-one total) asset types were found to have medium or high vulnerability to wildfire. This is due to an overall high sensitivity to fire, which has the potential to destroy assets in all sectors.

The results of the vulnerability assessment are presented in Table 11 below. “N/A” is used to indicate that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were determined not to be vulnerable to the climate change hazard.

Cells that are shaded in green indicate asset types that may warrant further study and/or the development of adaptation strategies based on their vulnerability scores. All high vulnerability scores and some of the medium vulnerability scores are flagged in green. The flagged medium overall vulnerability scores are those that are composed of one high-scoring component (i.e., exposure, sensitivity, or adaptive capacity) and one medium score. This is essentially equivalent to a medium-high score rather than a medium-low score. In practical terms, this approach helps prioritize assets that are on the border between a high and medium, and thus are worthy of further study.

Table 11. Vulnerabilities of all Critical Asset Types to Climate Change Hazards[22]

Sector	Critical Asset	Coastal Flooding: SLR[23]	Coastal Flooding: Storm Surge with SLR[24]	Coastal Erosion	Precipitation-Based Flooding	Extreme Heat	Wildfire
Public Safety Assets	Fire Stations	N/A	Low	N/A	Low	Low	Medium
	Lifeguard Stations	Medium	Medium	High	Medium	Low	Medium
	Fire Logistics and Dispatch	N/A	N/A	N/A	N/A	Low	N/A
	Maintenance Facilities	N/A	N/A	N/A	Medium	Low	Medium
	Police Stations	N/A	N/A	N/A	N/A	Low	High
	Police Patrol and Specialty Vehicles	N/A	N/A	N/A	Low	Low	Medium
	Other Public Safety	Medium	Medium	N/A	N/A	Low	Medium
Water Assets	Dams	N/A	N/A	N/A	High	Low	Medium
	Water Pipes	Medium	Medium	High	Medium	N/A	N/A
	Wastewater Pipes	Medium	Medium	High	Medium	N/A	N/A
	Water Pump Stations	N/A	N/A	N/A	Medium	Medium	High
	Wastewater Pump Stations	Low	Medium	High	High	Low	N/A
	Distribution Reservoirs	N/A	N/A	N/A	N/A	Medium	Medium
	Water Treatment Plants	N/A	N/A	N/A	N/A	Low	Medium
	Wastewater Treatment Plants	Low	Low	N/A	N/A	Medium	Medium
Transp	Airports	N/A	N/A	N/A	Low	Medium	High

[22] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections and localized modeling for the chosen climate hazard scenarios, and an assumption of asset type-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

[23] Sea Level Rise (SLR) represents the area that is projected to experience daily flooding at average high tide under each sea level rise scenario.

[24] Storm surge with SLR represents the area that is projected to experience flooding due to the 100-year (1 percent annual chance) storm under each sea level rise scenario.

Sector	Critical Asset	Coastal Flooding: SLR[23]	Coastal Flooding: Storm Surge with SLR[24]	Coastal Erosion	Precipitation-Based Flooding	Extreme Heat	Wildfire
	Bridges	High	Medium	High	Medium	Medium	High
	Major Arterials	High	Medium	Medium	Medium	Medium	High
	Drain Pump Stations	High	High	N/A	High	Low	High
	Outfalls	High	High	High	High	Medium	Medium
	Levees	Low	Low	N/A	Medium	Low	Medium
Open Space and	Conservation Areas/Open Space/Source Water Land	High	High	High	High	High	High
Open Space and	Community Parks	High	Medium	High	Medium	Medium	High
Open Space and	Miramar Landfill	N/A	N/A	N/A	N/A	Low	Medium
Open Space and	CNG Fueling Station	N/A	N/A	N/A	N/A	Low	Low
Open Space and	Beaches	High	Medium	High	Medium	Low	Medium
Additional Assets	Recreation centers	High	Low	N/A	Medium	Medium	Medium
Additional Assets	Libraries	N/A	N/A	N/A	N/A	Low	Medium
Additional Assets	City Buildings	N/A	N/A	N/A	N/A	Low	Medium
Additional Assets	Historical, Tribal Cultural, and Archaeological Resources	High	High	High	High	Medium	High

Consequences Assessment Findings

Damage, disruption, or failure of critical City assets could have major consequences that impede the City's ability to serve the community. Climate change impacts to these assets could compromise City services, such as emergency response, water treatment, or transportation; cause loss of life or injury; disproportionately impact communities of concern; damage historical, tribal cultural, and archaeological resources; or cause environmental damage. Assessing these consequences is important to understanding the significance of asset vulnerabilities.

The consequences for each sector (in bold) are described below.

- **Public Safety** – Many public safety assets are associated with key emergency services, such as fire stations and lifeguard stations, which face exposure to most or all hazards. If they are damaged, City services and human health could be affected. Delayed response times could increase the risk of loss of life or injury to people seeking emergency response, and facilities could be called to serve a larger area.
- **Water** – Impacts to wastewater systems could result in loss of the critical service of wastewater removal and treatment. Impacts to water systems could compromise access to clean water.

Consequences could include damages to human health and safety, social equity, and the environment.

- **Transportation** – Disruptions to transportation systems could delay or inhibit the movement of goods and people, which could reduce economic competitiveness and societal functioning. Emergency vehicles could also be delayed. The extent of damage will depend on the location and traffic load of the asset, and on the redundancy of the system.
- **Storm Water** – Damage to storm water infrastructure could exacerbate the impacts of flooding. Damage, disruption, or failure would primarily impact City services through responses to manage flood risk.
- **Open Space and the Environment** – If these assets are damaged, the City could lose resources that provide recreational opportunities, ecosystem services, and habitat value. There could be significant consequences to City services and natural resources and environment, in addition to some consequences to human health and social equity.
- **Additional Assets** – Libraries; City buildings; and historical, tribal cultural, and archaeological resources could also be damaged by climate-related hazards. Damages to these assets could have consequences to City services or directly to historical, tribal cultural, and archaeological resources. For example, libraries play an important role in community cohesion, and are used as cooling centers during periods of extreme heat.

Table 12 provides a summary of the types of consequences that could result from damage, disruption, or failure of each critical asset type. For each critical asset class/type, a check mark indicates that damage to the critical asset type could result in a consequence for that consequence category. Each section in the report below provides more details on the potential consequences of impacts to each sector, with illustrative examples of the types of consequences that could occur if critical assets are damaged.

Table 12. Summary of Consequences of Asset Types Being Damaged, Disrupted, or Failing due to Climate Hazards

Sector	Critical Asset	Consequence Categories				
		City Services	Human Health	Social Equity	Historical, Tribal Cultural, and Archaeological Resources	Natural Resources and Environment
Public Safety Assets	Fire Stations	✓	✓		✓	
	Lifeguard Stations	✓	✓		✓	
	Fire Logistics and Dispatch	✓	✓			
	Maintenance Facilities	✓				

Sector	Critical Asset	Consequence Categories				
		City Services	Human Health	Social Equity	Historical, Tribal Cultural, and Archaeological Resources	Natural Resources and Environment
	Police Stations[25]	✓	✓	✓	✓	
	Police Patrol and Specialty Vehicles	✓	✓			
	Other Public Safety	✓	✓			
Water Assets	Dams	✓	✓		✓	✓
	Water Pipes	✓	✓			
	Wastewater Pipes	✓	✓			
	Water Pump Stations	✓	✓			
	Wastewater Pump Stations	✓	✓			
	Distribution Reservoirs	✓	✓			
	Water Treatment Plants	✓	✓			
	Wastewater Treatment Plants	✓	✓			✓
Transportation and Storm Water Assets	Airports	✓	✓		✓	✓
	Bridges	✓	✓	✓	✓	
	Major Arterials	✓	✓	✓		
	Drain Pump Stations	✓	✓	✓		
	Outfalls	✓	✓			✓
	Levees	✓	✓			
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land	✓	✓		✓	✓
	Community Parks		✓	✓	✓	✓
	Miramar Landfill	✓	✓			

[25] The "social equity" consequence for police stations refers to the Multicultural Storefront station. This is a Police building that is used constantly as a hub for citizens from other countries. It is a location for non-native-English speaking citizens to get services or directed to services, and for police to help with mediation of community groups.

Sector	Critical Asset	Consequence Categories				
		City Services	Human Health	Social Equity	Historical, Tribal Cultural, and Archaeological Resources	Natural Resources and Environment
	CNG Fueling Station	✓				
	Beaches	✓	✓	✓	✓	✓
Additional Assets	Recreation centers	✓	✓	✓	✓	
	Libraries	✓	✓	✓	✓	
	City buildings	✓			✓	
	Historical, Tribal Cultural, and Archaeological Resources				✓	

Public Safety Vulnerability Findings

Public safety assets include those under the Fire-Rescue and Police departments and the Office of Homeland Security. Within these departments, the following asset types are critical: fire stations, police stations, lifeguard stations, fire logistics and dispatch, maintenance facilities, police patrol and specialty vehicles, and other public safety assets (e.g., the Critical Incident Management Unit (CIMU) equipment location, police communications, evidence and property locations, and the emergency operations center). Not all assets in this list were found to be exposed to climate hazards.

The results of the vulnerability assessment for public safety are shown in Table 13. Assets that were not exposed to the climate change hazard are not vulnerable and therefore were not assessed for sensitivity and adaptive capacity.

The public safety critical asset type with the highest overall vulnerability is lifeguard stations, which face some level of exposure to all hazards and are highly vulnerable to coastal erosion.

Wildfire is the highest priority hazard, with all asset types aside from fire logistics and dispatch showing medium to high vulnerability.

Table 13. Vulnerability of Critical Public Safety Asset Types to Climate Change Hazards[26]

	SLR	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
Fire Stations	N/A	Low	N/A	Low	Low	Medium
Lifeguard Stations	Medium	Medium	High	Medium	Low	Medium
Fire Logistics and Dispatch	N/A	N/A	N/A	N/A	Low	N/A
Maintenance Facilities	N/A	N/A	N/A	Medium	Low	Medium
Police Stations	N/A	N/A	N/A	N/A	Low	High
Police Patrol and Specialty Vehicles	N/A	N/A	N/A	Low	Low	Medium
Other Public Safety	Medium	Medium	N/A	N/A	Low	Medium

Public Safety Consequences

Given the nature of public safety assets, their damage, disruption, or failure could result in significant consequences to City services and human health. Many of these assets are associated with key emergency services that would be affected. Delayed response of emergency services could increase risks and result in m potential injury or fatality. In addition, if some elements of the system are damaged or disrupted, other facilities may be called to serve a larger area.

Illustrative examples of the consequences of public safety asset damage, disruption, and failure are presented in Table 14. This table is provided purely to illustrate potential impacts; it is not meant to imply that these impacts will definitively occur, nor is this list fully comprehensive of all potential consequences to all asset types.

Table 14. Illustrative Consequences of Public Safety Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Fire Stations	City Services Human Health	Fire services could be disrupted by climate-related hazards. If damages to a fire station were significant enough to warrant changes in operations or evacuation, response times could be extended if

[26] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections and localized modeling for the chosen climate hazard scenarios, and an assumption of asset type-level (general) of sensitivity and adaptive capacity based on literature reviews and high-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
	Historical, Tribal Cultural, and Archaeological Resources	operational functionality was reduced or if fewer operable fire stations were able cover the area. If one fire station is closed, another may need to take calls from a wider radius. Wildfires may put pressure on firefighters and department resources if the frequency and intensity of fires increase (IRSST, 2013). La Jolla Fire Station Engine Company 14, Old Fire Station 14, Fire Station 4, and Fire Station 6 are City-owned designated historical resources. Additionally, other fire stations that are not currently designated may be eligible for designation pending evaluation. Damage to these buildings could impact their ability to convey historical and cultural information and value.
Lifeguard Stations	City Services Human Health Historical, Tribal Cultural, and Archaeological Resources	If stations became inoperable, the City's capacity to conduct safety patrols on the beaches could be reduced. This could put a greater number of people, particularly those engaging in water activities, at risk of drowning or injury. The San Diego Lifeguard Headquarters on Quivira Court is a City-owned building that may be eligible for designation as a historical resource. Additionally, other lifeguard stations that are not currently designated may be eligible for designation pending evaluation. Damage to these buildings could impact their ability to convey historical and cultural information and value. In addition, exposure to hazards such as heat could impact worker safety and lead to heat illness (Occupational Safety and Health Administration (OSHA), n.d.).
Fire Logistics and Dispatch	City Services Human Health	If the fire logistics and dispatch facilities are impacted by climate hazards, the ability of the Fire-Rescue Department to respond to emergency calls and send out resources could be compromised. Additionally, the logistics facility is used to provide storage and reserve apparatus that can be used if a fire station is compromised. Disruption in this service could impact the Department's ability to maintain full service and quick response times during an event.
Maintenance Facilities	City Services	Maintenance facilities help keep the Fire-Rescue Department fleet up and running. If these facilities were to be impacted by climate hazards, it could potentially slow down updates and repairs to fire and rescue vehicles. In addition, exposure to hazards such as heat could impact worker safety and lead to heat illness (Occupational Safety and Health Administration (OSHA), n.d.).

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Police Stations	City Services Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources	Police stations and services could be disrupted by climate-related hazards. If police operations are compromised, response times to emergencies could be prolonged. The Multicultural Storefront is a City police station and functions as a key source of information for community members who are not native English speakers. Disruptions to this service and/or damage to this facility could disproportionately impact this population. Climate change hazards, such as wildfire, could be costly, requiring police officer overtime, traffic control, evacuation assistance, emergency operation centers and provision of food and water ($1.8 million for the October 2007 fires) (City of San Diego, 2007). The San Diego Police Pistol Range is a City-owned designated historical resource. Additionally, other police stations that are not currently designated may be eligible for designation pending evaluation. Damage to these buildings could impact their ability to convey historical and cultural information and value. In addition, exposure to hazards such as heat could impact worker safety and lead to heat illness (Occupational Safety and Health Administration (OSHA), n.d.).
Police Patrol and Specialty Vehicles	City Services Human Health	If police patrol and specialty vehicles were to be impacted by climate hazards, response times to emergencies could be compromised. Additionally, certain specialty vehicles serve a unique purpose (e.g., a decontamination bay; SWAT tactical vehicles) that have limited to no backup; disruption to these vehicles could limit the ability of the Police Department to pursue certain operations.
Other Public Safety	City Services Human Health	Other public safety assets include evidence and storage buildings, trailers, hangars, and the Critical Incident Management Unit (CIMU) Equipment Location. If these facilities were to be impacted by climate hazards, it could limit the ability of the Fire-Rescue and Police Departments to carry out their operations smoothly and quickly. In addition, exposure to hazards such as heat could impact worker safety and lead to heat illness (Occupational Safety and Health Administration (OSHA), n.d.).

Public Safety Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day assuming each sea level rise scenario. Storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm assuming each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

The City found that only three public safety critical asset types may be exposed to coastal hazards: fire stations, lifeguard stations, and other public safety assets. Lifeguard stations and other public safety assets are vulnerable to chronic flooding through sea level rise, all three are vulnerable to periodic flooding through storm surge with sea level rise, and lifeguard stations are vulnerable to erosion. All erosion scenarios assume 2.0 meters of sea level rise by 2100 (which is the upper range for 2100).

The results of the vulnerability assessment of critical public safety asset types to sea level rise, storm surge with sea level rise, and coastal erosion are shown in Table 15, Table 16, and Table 17, respectively. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to coastal hazards. Table 18 provides the rationale for the sensitivity and adaptive capacity scores.

Table 15. Vulnerability of City of San Diego Public Safety Critical Asset Types to Sea Level Rise

SLR	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Not exposed	High	Not exposed	Not exposed	Not exposed	Not exposed	Low
Sensitivity	N/A	Medium	N/A	N/A	N/A	N/A	High
Adaptive Capacity	N/A	Medium	N/A	N/A	N/A	N/A	Medium
Vulnerability	**N/A**	Medium	**N/A**	**N/A**	**N/A**	**N/A**	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 16. Vulnerability of City of San Diego Public Safety Critical Asset Types to Storm Surge with Sea Level Rise (One Hundred-Year storm)

Storm Surge with SLR	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Low	High	Not exposed	Not exposed	Not exposed	Not exposed	Low
Sensitivity	Medium	Low	N/A	N/A	N/A	N/A	High
Adaptive Capacity	Medium	High	N/A	N/A	N/A	N/A	Medium
Vulnerability	Low	Medium	**N/A**	**N/A**	**N/A**	**N/A**	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City *department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.*

Table 17. Vulnerability of City of San Diego Public Safety Critical Asset Types to Coastal Erosion at Medium-High Risk Aversion Scenario of 2m of Sea Level Rise

Coastal Erosion	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Not exposed	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed
Sensitivity	N/A	High	N/A	N/A	N/A	N/A	N/A
Adaptive Capacity	N/A	Medium	N/A	N/A	N/A	N/A	N/A
Vulnerability	**N/A**	**High**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Public Safety Exposure to Coastal Hazards

Sea Level Rise Projections for San Diego

2030: 0.25 m

2050: 0.5 to 0.75 m

2100: 1.0 to 2.0 m

Most public safety assets are not exposed to sea level rise, as shown in Figure 10. However, lifeguard stations and other public safety assets may face exposure to inundation from sea level rise.

Figure 11 shows that more public safety assets may be exposed to storm surge with sea level rise than are projected to be exposed to sea level rise alone. Ten percent of permanent lifeguard stations could be exposed to storm surge with sea level rise starting at 0.25 meters (2030), and twenty to forty percent of these stations may be exposed by 2100. Storm surge with sea level rise also brings some fire stations into the inundation zone: at 2.0 meters of sea level rise, two fire stations may be exposed to storm surge with sea level rise. Other public safety assets face exposure to storm surge starting at 0.75 meters of sea level rise (approximately 2050).

As Figure 12 shows, only lifeguard stations face exposure to cliff erosion. Thirty percent of permanent lifeguard stations may be affected if cliffs erode.

Figure 13 shows that only lifeguard stations could be exposed to beach erosion. Lifeguard stations may be more exposed to beach erosion than to cliff erosion, with forty percent of stations facing exposure.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

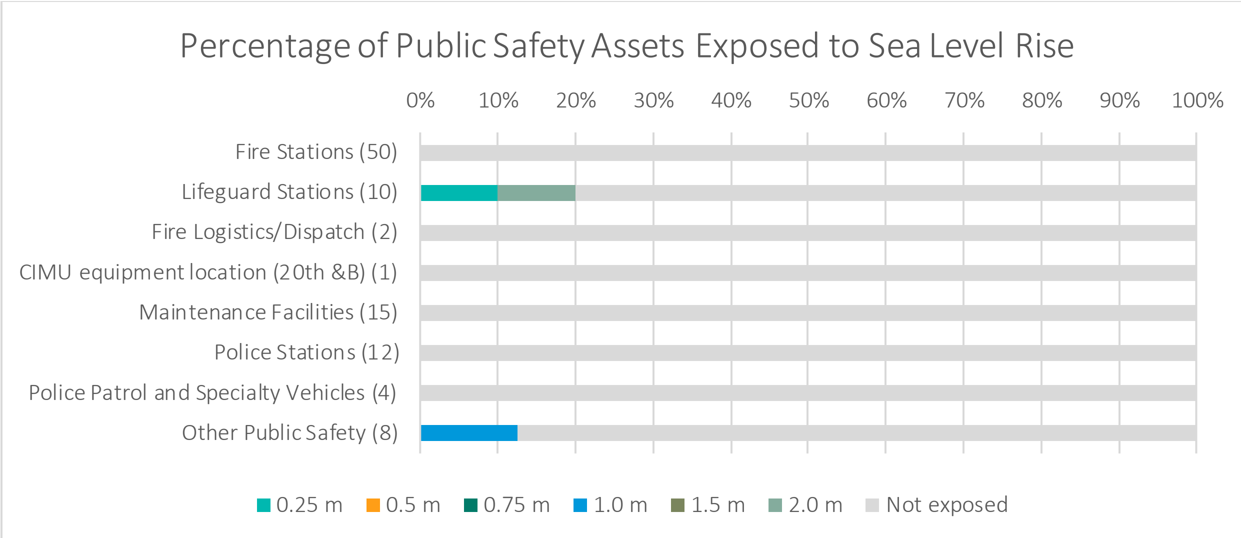

Figure 10. Public safety critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

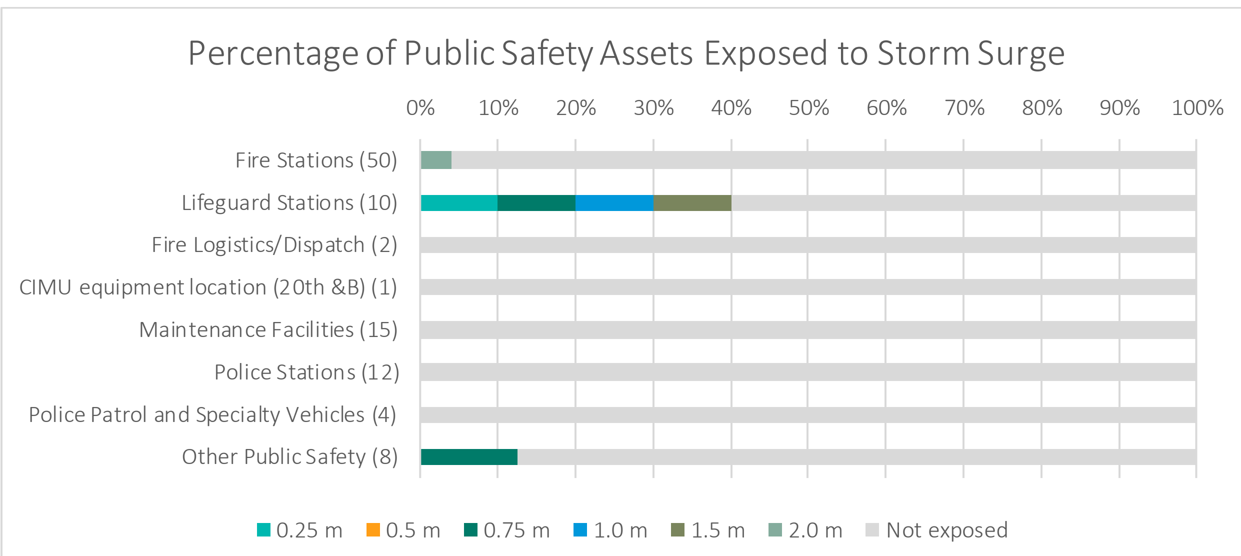

Figure 11. Public safety critical assets exposed to sea level rise + 100-year storm surge. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

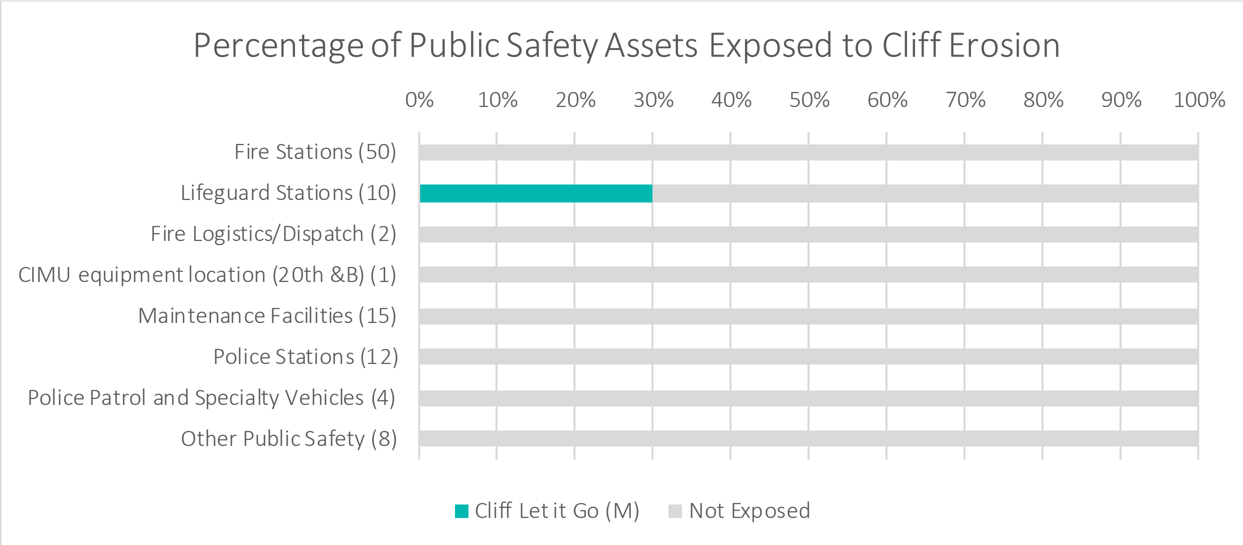

Figure 12. Public safety critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

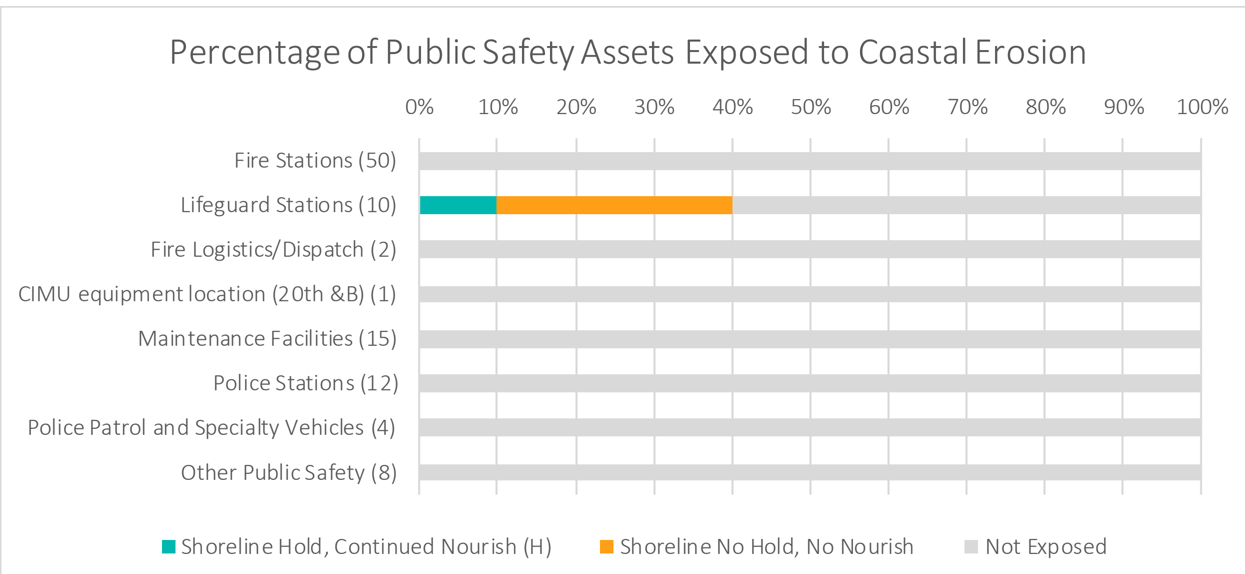

Figure 13. Public safety critical assets exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

Public Safety Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure analysis, fire stations, lifeguard stations, and other public safety assets were included in the sensitivity and adaptive capacity analysis. The ratings and corresponding rationale for these asset types are shown in Table 18.

Table 18. Sensitivity and Adaptive Capacity of Public Safety Critical Asset Types Exposed to Coastal Hazards

Fire Stations	
SLR Sensitivity: Not exposed	*SLR Adaptive Capacity: Not exposed*
Storm Surge with SLR Sensitivity: Medium Exposure of fire stations to storm flooding events could increase wear and tear on buildings. Storm-induced flooding could temporarily limit access to and use of a station (USAID, 2014).	*Storm Surge with SLR Adaptive Capacity: Medium* Short-term solutions exist for flood protection (e.g., sandbags); longer-term adaptation is more difficult and costly. Affected stations can operate remotely if necessary, and the Fire-Rescue department has a Ready Reserve Fleet with thirty-two fully equipped fire engines that are ready for use if a weather event puts other engines out of commission.
Erosion Sensitivity: Not exposed	*Erosion Adaptive Capacity: Not exposed*
Lifeguard Stations	
SLR Sensitivity: Medium Sea level rise could permanently inundate buildings within the projected sea level rise zone, could increase the erosion of structures, and could damage or destroy buildings and equipment (USAID 2014). Sensitivity varies across lifeguard stations: newer stations have been designed to accommodate sea level rise, but older stations have not.	*SLR Adaptive Capacity: Medium* Short term solutions exist for flood protection (e.g., opening doors to allow water to flow through and out), but longer-term adaptation for chronic flooding is more difficult. Lifeguard stations are reconstructed approximately every thirty years, and all new designs now account for sea level rise.
Storm Surge with SLR Sensitivity: Low Sensitivity varies across lifeguard stations: newer stations have been designed to accommodate sea level rise, but older stations have not. In addition to the permanent stations considered in this assessment, San Diego has seasonal mobile towers that could easily be brought back into service after experiencing flooding, assuming they do not wash away.	*Storm Surge with SLR Adaptive Capacity: High* Lifeguard stations are reconstructed approximately every thirty years. The City has plans to build new stations to accommodate storm-based inundation (by locating all facilities on the second floor). In most existing towers, equipment could be relocated to the second floor to avoid exposure to periodic ground-level flooding (Consultation with City of San Diego Fire-Rescue Department, 2019). In addition, in the event of temporary flooding, mobile lifeguard stations and other lifeguard stations could serve as a backup resource.
Coastal Erosion Sensitivity: High If coastal erosion were to threaten the building structure of a permanent lifeguard station, the facility would need to be moved.	*Coastal Erosion Adaptive Capacity: Medium* Mobile lifeguard towers could be moved to safer locations; however, permanent lifeguard stations cannot easily be moved, and it is recognized that

	the lifeguard stations need to be located immediately adjacent to the coast. At some stations, there are some concrete erosion barriers that have been built to better protect stations against coastal erosion.
Other Public Safety	
SLR Sensitivity: High The Police Department's evidence and property building is highly sensitive to flooding (Consultation with City of San Diego Police Department, 2019). Sea level rise could permanently inundate buildings within the projected sea level rise zone, could increase the erosion of structures, and could damage or destroy buildings and equipment (USAID 2014).	*SLR Adaptive Capacity: Medium* Longer-term adaptation may be necessary if chronic flooding within the coastal zone becomes a highly likely scenario (Consultation with City of San Diego Police Department, 2019).
Storm Surge with SLR Sensitivity: High The Police Department's evidence and property building is highly sensitive to flooding (Consultation with City of San Diego Police Department, 2019).	*Storm Surge with SLR Adaptive Capacity: Medium* Short-term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation is more difficult and costly (Consultation with City of San Diego Police Department, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*

Public Safety Vulnerability to Precipitation-driven Flooding

The City found that public safety critical asset types have near-negligible vulnerability to precipitation-driven flooding. Fire stations and police patrol and specialty vehicles have low vulnerability to precipitation-driven flooding. These asset types have low exposure, meaning that none of them are located within the 100-year floodplain. Fire stations, lifeguard stations, and police patrol and specialty vehicles show low to medium sensitivity, as exposure to precipitation-driven flooding could result in temporary damage that requires repair but would not require a complete replacement of the asset. Lifeguard stations and police patrol and specialty vehicles have high adaptive capacity due to current and planned measures to protect these assets against precipitation-driven flooding. Maintenance facilities show medium sensitivity and high adaptive capacity but are rated as medium vulnerability due to their location within the 100-year floodplain, giving them a high exposure score.

The results of the vulnerability assessment of critical public safety asset types to precipitation-driven flooding are shown in Table 19. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to precipitation-driven flooding. Table 20 provides the rationale for the sensitivity and adaptive capacity scores.

Table 19. Vulnerability of Public Safety Critical Asset Types to Precipitation-driven Flooding

	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Low	High	Not exposed	High	Not exposed	Low	Not exposed
Sensitivity	Medium	Low	N/A	Medium	N/A	Medium	N/A
Adaptive Capacity	High	High	N/A	Medium	N/A	High	N/A
Vulnerability	Low	Medium	N/A	Medium	N/A	Low	N/A

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Public Safety Exposure to Precipitation-Driven Flooding

Figure 14 shows critical public safety asset types that may face exposure to precipitation-driven flooding. Fire stations, lifeguard stations, maintenance facilities, and police patrol and specialty vehicles parking lots all face some exposure to heavy precipitation-driven flooding risks (that is, exposure to the 100- and/or 500-year floodplains). Only a few public safety assets face exposure to precipitation-driven hazards: in total, four assets lie in the 500-year floodplain and two face exposure to the 100-year floodplain.

The only public safety assets that lie in the 100-year floodplain are a permanent lifeguard station and a maintenance facility. One fire station, one lifeguard station, one maintenance facility, and a police patrol and specialty vehicle lot lie in the 500-year floodplain. However, because there are only four police patrol and specialty vehicle parking lots in the City, this puts a high proportion of that asset type at risk.

Additionally, many command vehicles are kept at 20th and B, which has flooded in the past, but was not shown to be exposed to the FEMA 100- or 500-year floodplains.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

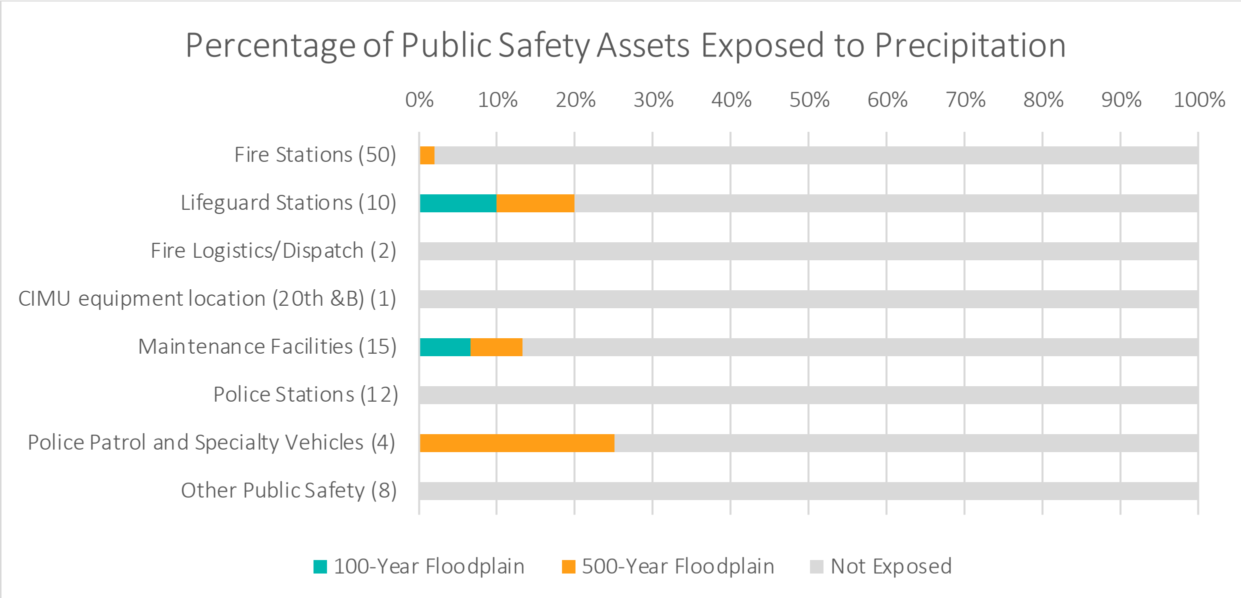

Figure 14. Public Safety critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

Public Safety Sensitivity and Adaptive Capacity to Precipitation-driven Flooding

Based on the exposure assessment, the City reviewed sensitivity and adaptive capacity for fire stations, lifeguard stations, maintenance facilities, and police patrol and specialty vehicles. The results of this assessment are shown in Table 20.

Table 20. Sensitivity and Adaptive Capacity of Public Safety Critical Asset Types to Precipitation-driven Flooding

Fire Stations	
Precipitation Sensitivity Rating: Medium	*Precipitation Adaptive Capacity Rating: High*
Previous precipitation events have caused water leaks and damage. The greatest damage occurs when rainwater gets into drywall (Consultation with City of San Diego Police Department, 2019).	Responding to damage caused by water leaks is relatively inexpensive; previous events have caused damage ranging from $500 to $7,500 per repair project (City of San Diego, 2017b; City of San Diego, 2017c). Protective measures include building berms and setting up sandbags. However, limitations to access in or out of the fire station could be posed by floodwater or the berms or sandbags themselves. Infrastructure critical to functioning (e.g., fire engines) must be kept on the ground floor, however the fire department is able to move equipment (e.g., fire engines) to another station and dispatch from a different location if necessary during a storm event.

	Affected stations can operate remotely if necessary, and the Fire-Rescue department has a Ready Reserve Fleet with thirty-two fully equipped fire engines that are ready for use if a weather event puts other engines out of commission.
Lifeguard Stations	
Precipitation Sensitivity Rating: Low Mobile towers could easily be brought back into service after experiencing flooding, assuming they do not wash away.	*Precipitation Adaptive Capacity Rating: High* The City has plans to build new stations to accommodate inundation (by locating all facilities on the second floor). In existing towers, equipment will be relocated to the second floor (Consultation with City of San Diego Fire-Rescue Department, 2018). Mobile lifeguard towers could be moved to safer locations; however, permanent lifeguard stations do not have such flexibility. Short-term solutions exist for temporary flood protection (e.g., opening doors to allow water to flow through and out). In addition, in the event of temporary flooding, mobile lifeguard stations and other lifeguard stations could serve as a backup resource.
Maintenance Facilities	
Precipitation Sensitivity Rating: Medium Only one facility (Chollas) has previously experienced water damage from flooding. This damage included rot to the wood entry door, time taken to squeegee out water before and during shifts and shutting down the paint booth and body/welding repairs in three bays due to standing water. Significant flooding has the potential to negate the ability to maintain and fuel vehicles (Consultation with City of San Diego Fleet Operations, 2019).	*Precipitation Adaptive Capacity Rating: Medium* Sandbags are deployed when necessary to protect against flood damages, and most facilities have adequate drainage to handle heavy rain events. Drainage could be improved at the one station (Chollas) that has previously experienced water damage (Consultation with City of San Diego Fleet Operations, 2019).
Police Patrol and Specialty Vehicles	
Precipitation Sensitivity Rating: Medium Heavy rain events pose the risk of engine inundation, which could lead to engine stall and/or damage. Flooding on roads could decrease visibility and increase risk of hydroplaning and accidents (NIST, 2006). Vehicle replacement cost could be high (Consultation with City of San Diego Police	*Precipitation Adaptive Capacity Rating: High* Vehicles not in use could be temporarily relocated if necessary; this is already standard practice in the City. However, a standard number must remain in all areas for emergency response (Consultation with City of San Diego Fleet Operations, 2018).

Department, 2018).	

Public Safety Vulnerability to Heat

The City found that all public safety critical asset types are vulnerable to heat, because all face some level of exposure. However, all public safety asset types were found to have low vulnerability to heat. See Figure 8 for a map of urban heat island zones in the City. The zones are scored from 0 to 100+, with lower scores denoting less heat (these are usually coastal areas, with high heat areas farther inland).

The results of the vulnerability assessment of public safety asset types to heat are shown in Table 21. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to heat. Table 22 provides the rationale for the sensitivity and adaptive capacity scores.

Table 21. Vulnerability of Public Safety Critical Asset Types to Heat

	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Medium	Low	Medium	Medium	Medium	Medium	Medium
Sensitivity	Low	Low	Low	Low	Low	Low	Low
Adaptive Capacity	High	Medium	Medium	High	High	High	High
Vulnerability	Low	Low	Low	Low	Low	Low	Low

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10.

Public Safety Exposure to Heat

The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[27] A score of zero indicates that there is no difference in temperature over time between an urban Census tract and nearby upwind rural

In San Diego, coastal areas are relatively cooler than inland areas due to the moderating impacts of the ocean and offshore winds. This coastal effect dominates the urban heat island effect in the City.

[27] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

Public safety assets have varying degrees of exposure to high temperatures (Figure 15). Almost all of these exposures are in the 0 to 20, 20 to 40, and 40 to 60 UHI zone ranges; only six public safety assets face heat exposure in the 60 to 80 range.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the heat levels.

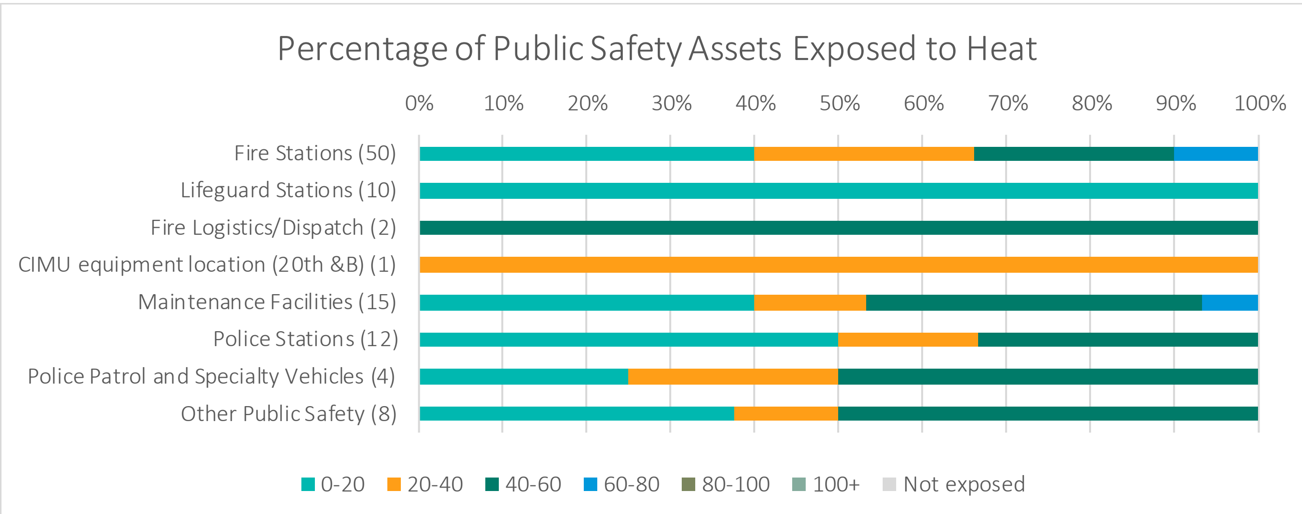

Figure 15. Public safety critical assets exposed to heat. The value after each asset name indicates the asset count. The colored bars represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

Public Safety Sensitivity and Adaptive Capacity to Heat

Based on the exposure analysis, the City reviewed the sensitivity and adaptive capacity of all public safety critical asset types to heat. The results of this analysis are shown in Table 22 below.

Table 22. Sensitivity and Adaptive Capacity of Public Safety Critical Asset Types to Heat

Fire Stations	
Heat Sensitivity Rating: Low Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	*Heat Adaptive Capacity Rating: High* All fire stations have air conditioning to help maintain a safe work environment during high heat, but not all systems are energy efficient (Consultation with City of San Diego Fire-Rescue Department, 2019).
Lifeguard Stations	
Heat Sensitivity Rating: Low Thermal stress could cause wear on building materials and place an increased load on	*Heat Adaptive Capacity Rating: Medium* Not all lifeguard stations have air conditioning, and not all electric equipment at stations is

mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	energy efficient. Equipment is upgraded to energy efficient versions when it is replaced (Consultation with City of San Diego Fire-Rescue Department, 2019).
Fire Logistics and Dispatch	
Heat Sensitivity Rating: *Low* Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011)	*Heat Adaptive Capacity Rating:* *Medium* New buildings (built within the last five to eight years) are guaranteed to be energy efficient. New City design standards require all buildings to either be LEED certified or energy efficient. All buildings built before this standard would likely not be energy efficient (City of San Diego Facilities, 2019).
Maintenance Facilities	
Heat Sensitivity Rating: *Low* Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	*Heat Adaptive Capacity Rating:* *High* Two types of facilities have designated spaces with air conditioning (police repair and fire repair); the Rose Canyon and Chollas facilities have no air conditioning. Newer facilities have energy efficient equipment, and older facilities upgrade to energy efficient equipment as the older equipment fails (Consultation with City of San Diego Fleet Operations, 2019).
Police Stations	
Heat Sensitivity Rating: *Low* Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	*Heat Adaptive Capacity Rating:* *High* The heat-related policy for the Police Department could be easily updated to consider current and future needs for water, cover, and relief associated with future heat conditions (Consultation with City of San Diego Police Department, 2019).
Police Patrol and Specialty Vehicles	
Heat Sensitivity Rating: *Low* Vehicles may overheat on high heat days, which may cause damage to engine components (OFCM, 2002). Additionally, worker safety risk and the chance of accidents increase under high heat conditions (Koetse & Rietveld, 2009; OFCM, 2002; Stern & Zehavi, 1990).	*Heat Adaptive Capacity Rating:* *High* In the event that those vehicles in operation become overheated, the San Diego Police Department, CIMU, Parking Enforcement Unit, and Air Support Unit all have backup vehicles (Consultation with City of San Diego Police Department, 2019).
Other Public Safety	

Heat Sensitivity Rating: Low	*Heat Adaptive Capacity Rating: High*
Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	All other fire public safety assets [CIMU Equipment Location (19th and B), DRC basement emergency operations] have air conditioning, but not all systems are energy efficient (Consultation with City of San Diego Fire-Rescue Department, 2019). Some, but not all, other police safety assets have air conditioning, some of these assets are energy efficient (Consultation with City of San Diego Fleet Operations, 2019).

Public Safety Vulnerability to Wildfires

The City found that nearly all critical public safety asset types face high exposure to wildfires. Only fire logistics and dispatch facilities were found to be wholly outside of the fire hazard zone and therefore not vulnerable.

Fire stations and police stations were the only asset types with assets located within 100 feet of the City's brush management zone, which indicates high potential exposure to wildfire. Lifeguard stations, maintenance facilities, police patrol and specialty vehicles, and the CIMU equipment location at 20th and B (which is considered one of the "other public safety" assets) all have assets within 300 feet of the City's brush management zone, indicating medium potential exposure to wildfire. All of these asset types have high sensitivity to wildfire, as exposure could potentially damage them beyond repair or destroy the asset.

The results of the vulnerability assessment of public safety asset types to wildfire are shown in Table 23. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to wildfire. Table 24 provides the rationale for the sensitivity and adaptive capacity scores.

Table 23. Vulnerability of Public Safety Critical Asset Types to Wildfire

	Fire Stations	Lifeguard Stations	Fire Logistics and Dispatch	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	High	Medium	Not exposed	Medium	High	Medium	Medium
Sensitivity	Medium	High	N/A	High	High	High	High
Adaptive Capacity	High	Medium	N/A	High	Medium	High	Medium
Vulnerability	Medium	Medium	N/A	Medium	High	Medium	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Public Safety Exposure to Wildfires

Of public safety assets, only one type—fire logistics and dispatch facilities—has no assets within the wildfire hazard zones (Figure 16).

The remaining six asset types vary greatly in their exposure to wildfires, though none have a majority of their assets facing potential wildfire exposure. Lifeguard stations, maintenance facilities, police patrol and specialty vehicles, and other public safety assets have most exposed assets facing medium exposure to wildfire. Only four fire stations and one police station potentially face high exposure to wildfire.

> **Wildfire Hazard Zones for San Diego**
>
> High: Native vegetation and 100-foot setback zones
>
> Medium: 300-foot setback zone
>
> Low: Fire hazard zone outside native vegetation zone and setbacks

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

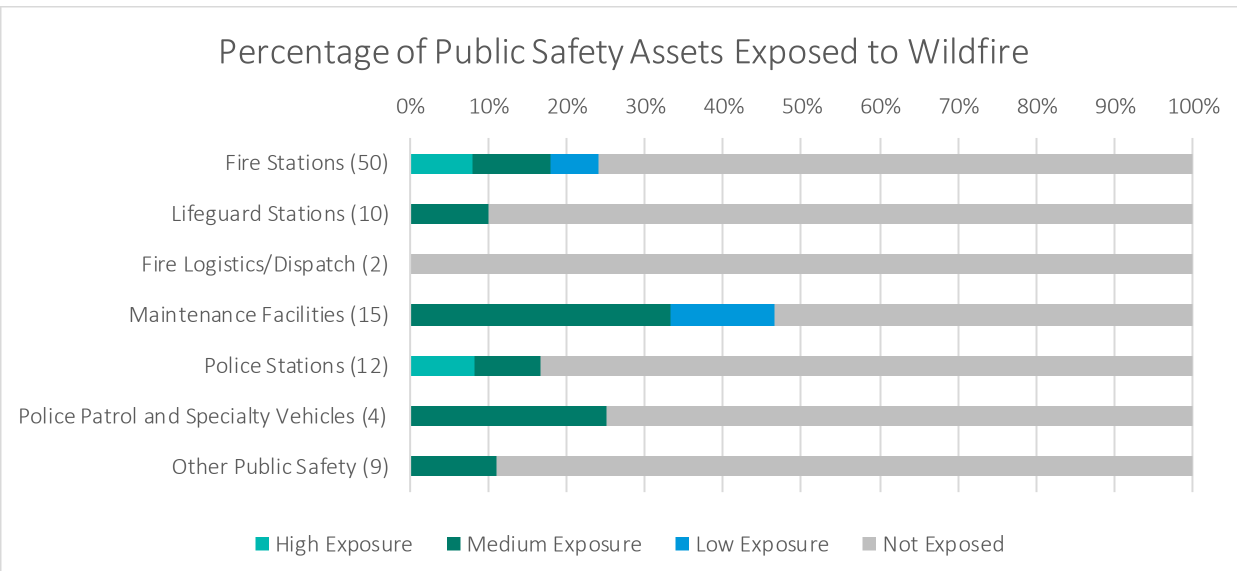

Figure 16. Public safety critical assets exposed to wildfire. The value after each asset name indicates the asset count.

Public Safety Sensitivity and Adaptive Capacity to Wildfires

Based on the exposure assessment, the City assessed the sensitivity and adaptive capacity of all critical public safety asset types (except fire logistics and dispatch facilities) and other public safety assets to wildfire. The findings of this assessment are shown in Table 24 below.

Table 24. Sensitivity and Adaptive Capacity of Public Safety Critical Asset Types to Wildfire

Fire Stations	
Wildfire Sensitivity Rating: Medium Wildfires could directly damage buildings and could accelerate building material deterioration	*Wildfire Adaptive Capacity Rating: High* In the event of a fire station fire, there are backup personnel and equipment within the City to

due to increased smoke and particulate matter (USAID, 2014). Several fire stations have a wood frame covered with stucco and one station has wood siding. Heating Ventilation and Air Conditioning (HVAC) filters at the stations are changed at least once a year. Of the total forty-nine fire stations, thirteen of the new stations have fire suppression systems and sprinklers installed. Newer facilities are built to a more fire-resistant standard and use building materials such as concrete block walls and aluminum frames.	respond and maintain service. The San Diego Fire-Rescue has forty-nine fire stations that are staffed 24/7/365. Affected stations can operate remotely if necessary, and the Fire-Rescue department has a Ready Reserve Fleet with thirty-two fully equipped fire engines that are ready for use if a weather event puts other engines out of commission. In addition, the fire department is able to move apparatus and personnel to an alternate station in the event that the original station is threatened by fire (Consultation with City of San Diego Fire-Rescue Department, 2019).
Lifeguard Stations	
Wildfire Sensitivity Rating: *High* Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014).	*Wildfire Adaptive Capacity Rating:* *Medium* All buildings have fire extinguishers in compliance with OSHA and public building safety practices, and newer stations have adequate air system filters and fire suppression systems (Consultation with City of San Diego Fire-Rescue Department, 2019).
Maintenance Facilities	
Wildfire Sensitivity Rating: *High* Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014). The main fire repair facility at Miramar does not have any wooden construction. The Rose Canyon and Chollas facilities are built with cement walls and a wood roof structure (Consultation with City of San Diego Fleet Operations, 2019).	*Wildfire Adaptive Capacity Rating:* *High* All police and fire repair facilities have fire suppression systems. The Rose Canyon facility has a sprinkler system and fire extinguishers throughout the building. The Chollas facility has fire extinguishers throughout the building but the sprinkler system is only in the paint booth (Consultation with City of San Diego Fire-Rescue Department, 2019).
Police Stations	
Wildfire Sensitivity Rating: *High* Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014).	*Wildfire Adaptive Capacity Rating:* *Medium* The Police Department currently has a backup dispatch communications center with limited functional capacity. If one station were to be compromised due to wildfire, those personnel and vehicles would be dispatched to or stored at one of the other eleven police stations (Consultation with City of San Diego Police Department, 2019).
Police Patrol and Specialty Vehicles	

Wildfire Sensitivity Rating: High Wildfires could directly damage vehicles. Smoke and particulates could cause dangerously low visibility (Peterson, McGuirk, Houston, Horvitz, & Wehner, 2008).	*Wildfire Adaptive Capacity Rating: High* Backup patrol and specialty vehicles are maintained at police stations, police headquarters, San Diego Police Plaza, and Central Garage, which are within the area potentially exposed to fire. However, vehicles could be moved if necessary to areas not threatened by fire.
Other Public Safety	
Wildfire Sensitivity Rating: High Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014). Of the other police assets, the Air Support Unit hangar, twelve out of fourteen property and evidence facilities, and the buildings at 20th and B are made of fire-susceptible materials (Consultation with City of San Diego Fire-Rescue Department, 2019).	*Wildfire Adaptive Capacity Rating: Medium* Some, but not all, have air filters or fire suppression systems that include sprinklers (Consultation with City of San Diego Police Department, 2019).

Water Assets Vulnerability Findings

Water infrastructure assets include those managed by the Public Utilities Department (PUD). The following asset types are considered to be critical: dams, water pipes, wastewater pipes, water pump stations, wastewater pump stations, distribution reservoirs, water treatment plants, and wastewater treatment plants. "Water pipes" refers to transmission and distribution mains. Not all assets in this list were found to be exposed to climate hazards. In order to focus the assessments on the most critical assets, "wastewater pump stations" includes the eight largest and most important wastewater pump stations, not all City wastewater pump stations.

Separately, PUD owns and manages open space land that serves the primary purpose of capturing and protecting native source water. This land is included under the "Conservation Areas/Open Space/Source Water Land" asset type in the Open Space and Environment Vulnerability Findings section of this report.

The results of the vulnerability assessment for water infrastructure are shown in Table 25. "N/A" indicates that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were deemed not vulnerable.

Generally, the adaptive capacity scores for the water asset types are conservative. PUD has operational plans for individual assets, which may address flooding, power outages, and other hazards and events. The protection already conferred by these plans is not captured in the adaptive capacity scores, as the scores are based on limitations and opportunities at the asset type scale rather than for individual assets.

The critical asset types with highest overall vulnerability are wastewater pump stations, which were found to be exposed to all climate change hazards except wildfire, with high potential vulnerability to coastal erosion and precipitation. Heat and wildfire are the most prevalent hazards for this sector, as they impact nearly all water asset types included in this assessment.

Table 25. Vulnerability of Critical Water Asset Types to Climate Change Hazards[28]

	SLR	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
Dams	N/A	N/A	N/A	High	Low	Medium
Water Pipes	Medium	Medium	High	Medium	N/A	N/A
Wastewater Pipes	Medium	Medium	High	Medium	N/A	N/A
Water Pump Stations	N/A	N/A	N/A	Medium	Medium	High
Wastewater Pump Stations	Low	Medium	High	High	Low	N/A
Distribution Reservoirs	N/A	N/A	N/A	N/A	Medium	Medium
Water Treatment Plants	N/A	N/A	N/A	N/A	Low	Medium
Wastewater Treatment Plants	Low	Low	N/A	N/A	Medium	Medium

Water Asset Consequences

Water assets include those that capture, store, treat, and distribute water supplies and wastewater in the City. In many cases, failure could result in flooding, which could have a variety of damaging consequences. In addition, impacts to the water supply infrastructure could have negative consequences for human health, social equity, and the environment. Impacts that result in flooding could result in impacts to the transportation system such as delays or rerouting. If wastewater systems are impacted, sewage contamination and a loss of the critical service of wastewater removal and treatment could follow, however these are considered to be rare events; the City has many contingencies plans in place to prevent this occurrence.

Illustrative examples of the consequences of water system damage, disruption, and failure are presented in Table 26. This table is provided purely to illustrate potential impacts; it is not meant to imply that these impacts will definitively occur, nor is this list fully comprehensive of all potential consequences to all asset types.

[28] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections and localized modeling for the chosen climate hazard scenarios, and an assumption of asset type-level (general) of sensitivity and adaptive capacity based on literature reviews and high-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 26. Illustrative Consequences of Critical Water Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Dams	City Services Human Health Natural Resources and Environment Historical, Tribal Cultural, and Archaeological Resources	It is important to note that dams are closely managed in such a way to prevent overtopping or failure and to meet all requirements set forth by the California Division of Safety of Dams. Weather forecasting and water-level management in compliance with these requirements enables safe operation of dams during periods of high precipitation. If it were to happen, dam failure could result in flooding and damages to structures or the environment, depending on the depth and velocity of water. The potential consequences include loss of life and injury, damage to structures and infrastructure, loss of services, and road closures (CVCOG, 2018; NSW Dams Safety Committee, 2011; FEMA, 2012). The risk will depend on volume of water retained at the time of failure, occupancy in the surrounding area and warning time. Given sufficient time to evacuate downstream, loss of life could be minimized but there could be disruptions to daily life from flooding. The Morena Dam has been evaluated and found eligible for historical designation. Additionally, other dams that are not currently designated may be eligible for designation pending evaluation. Damage to these structures could impact their ability to convey historical and cultural information and value (City of San Diego Historic Preservation Planning, 2020).
Pipes and Pump Stations (water and wastewater)	City Services Human Health	Consequences of failure would vary depending on the pipeline and location of failure. While one small pipe or pump may have minimal consequences for the system overall, a large pipe or pump or critical part of the system could have significant negative impacts across the system. Damage to pipes and pumps could result in property damages, loss of production, environmental damages, or human health consequences. For example, leakages due to pipe failure in the wastewater system could release hazardous materials into the environment. Leakages due to pipe failure in the water system could also result in localized flooding, erosion and loss of water service.
Distribution Reservoir	City Services Human Health	If distribution reservoirs are compromised, it could affect potable water service for customers in San Diego.
Water Treatment Plants	City Services Human Health	Water treatment plants play a key role in supplying water to the City. If these facilities were to be compromised by climate-related hazards, it could temporarily limit water supplies in the City.
Wastewater Treatment	City Services	Damage or failure of wastewater treatment plants could have a range of impacts, due primarily to water contamination. In addition, there could be a risk of waterborne illness. In the event of a sewer spill, the

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Plants	Human Health Natural Resources and Environment	City could be responsible for millions of dollars in fines. However, these are considered to be rare occurrences; the City has many contingencies plans in place to prevent this occurrence. Water quality impacts due to pollution could have ripple effects on habitat or species in the affected area if water is released back into the environment or flooding of wastewater spills into the surrounding environment.

Water Asset Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day under each sea level rise scenario. Storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm under each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

The City found that water pipes, wastewater pipes, and wastewater pump stations show low to medium vulnerability to coastal flooding and high vulnerability to coastal erosion. Flooding would not have a severe impact on underground pipes or pump stations, but erosion could compromise the functionality of the system. All erosion scenarios assume 2.0 meters of sea level rise (which is the upper range for 2100).

The results of the vulnerability assessment of critical water asset types to coastal hazards are shown in Table 27, Table 28, and Table 29. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to coastal hazards. Table 30 provides the rationale for the sensitivity and adaptive capacity scores.

Table 27. Vulnerability of Water Critical Asset Types to Sea Level Rise

SLR	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribution Reservoirs	Water Treat-ment Plants	Waste-water Treat-ment Plants
Exposure	Not ex-posed	High	High	Not exposed	Low	Not exposed	Not Exposed	Low
Sensitivity	N/A	Low	Medium	N/A	Low	N/A	N/A	Medium
Adaptive Capacity	N/A	High	High	N/A	High	N/A	N/A	Medium
Vulnerability	N/A	Medium	Medium	N/A	Low	N/A	N/A	Low

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 28. Vulnerability of Water Critical Asset Types to Storm Surge with Sea Level Rise (One Hundred-Year storm)

Storm Surge with SLR	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribu-tion Reservoirs	Water Treat-ment Plants	Waste-water Treat-ment Plants
Exposure	Not ex-posed	High	High	Not exposed	High	Not exposed	Not exposed	Low
Sensitivity	N/A	Low	Medium	N/A	Low	N/A	N/A	Low
Adaptive Capacity	N/A	High	High	N/A	High	N/A	N/A	High
Vulnerability	**N/A**	Medium	Medium	**N/A**	Medium	**N/A**	**N/A**	Low

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 29. Vulnerability of Water Critical Asset Types to Coastal Erosion at Medium-High Risk Aversion Scenario of 2m of Sea Level Rise

Coastal Erosion	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribu-tion Reservoirs	Water Treatment Plants	Waste-water Treatment Plants
Exposure	Not exposed	High	High	Not exposed	High	Not exposed	Not exposed	Not exposed
Sensitivity	N/A	High	High	N/A	High	N/A	N/A	N/A
Adaptive Capacity	N/A	Low	Low	N/A	Low	N/A	N/A	N/A
Vulnerability	**N/A**	High	High	**N/A**	High	**N/A**	**N/A**	**N/A**

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Water Asset Exposure to Coastal Hazards

Of all water asset types, wastewater pump stations face the highest relative exposure to sea level rise: seven out of the eight primary wastewater pump stations face exposure to sea level rise starting at 1.0 m of sea level rise (2100 timeframe). Water pipes and wastewater pipes face

Sea Level Rise Projections for San Diego

2030: 0.25 m

2050: 0.5 to 0.75 m

2100: 1.0 to 2.0 m

less exposure: less than five percent of both pipe types are projected to be exposed to sea level rise by 2100 (Figure 17).

Water and wastewater pipes and wastewater pump stations also face flooding from storm surge with sea level rise (100-year flood) (Figure 18). In this case, half of wastewater pump stations may be exposed starting at 0.25 meters of sea level rise (2030), with sixty-three percent of wastewater pump stations potentially exposed to flooding from storm surge with sea level rise by 2100 (2.0 m sea level rise, which is the upper range for 2100). Less than five percent of water and wastewater pipes may be exposed to storm surge with sea level rise.

Water pipes, wastewater pipes, and wastewater pump stations face limited exposure to cliff erosion (Figure 19). Cliff erosion poses the greatest risk for wastewater pump stations: one location, or thirteen percent of total wastewater pump stations, may be exposed to cliff erosion.

A small portion of water pipes, wastewater pipes, and wastewater pump stations may be exposed to beach erosion (Figure 20). As with cliff erosion, wastewater pump stations face the greatest relative exposure to beach erosion, with twenty-five percent of these assets facing exposure. The figures below show water asset exposure to sea level rise, sea level rise plus storm surge, and erosion, respectively. The value after each asset name indicates the total number of assets in that asset type. The colored bars for each increment show how many additional assets become exposed under that sea level rise or erosion scenario.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

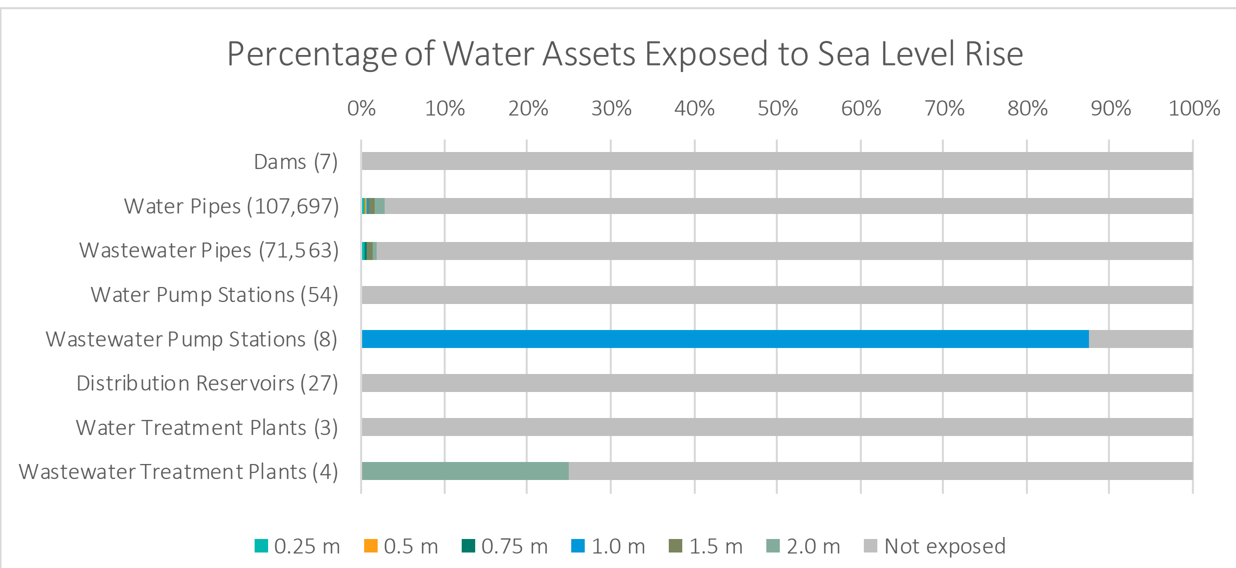

Figure 17. Water critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

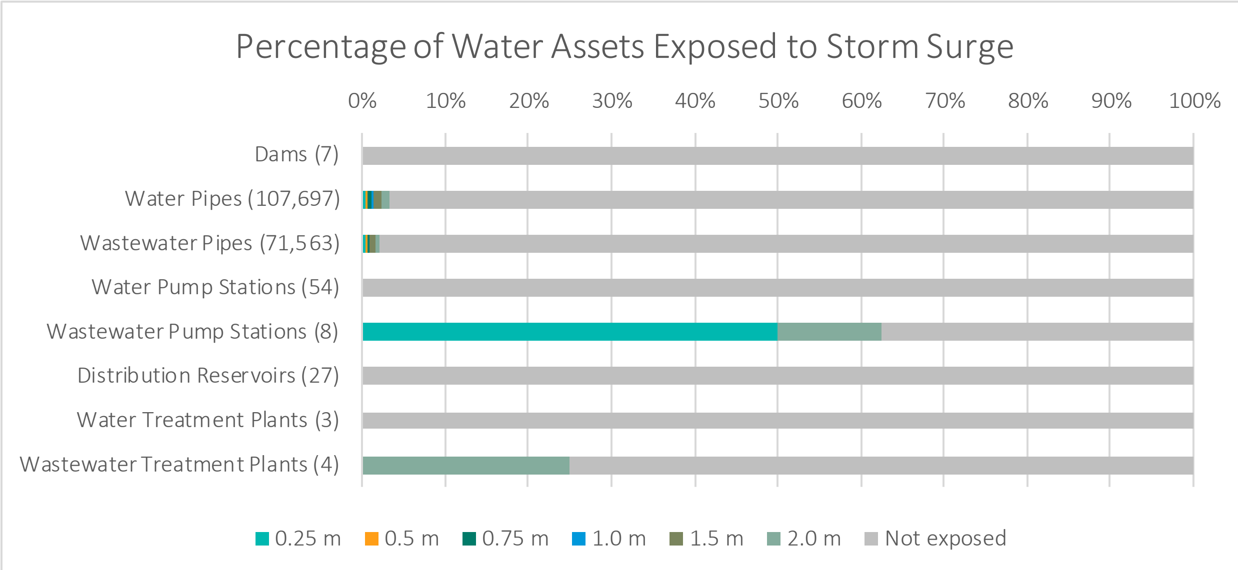

Figure 18. Water critical assets exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average daily flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

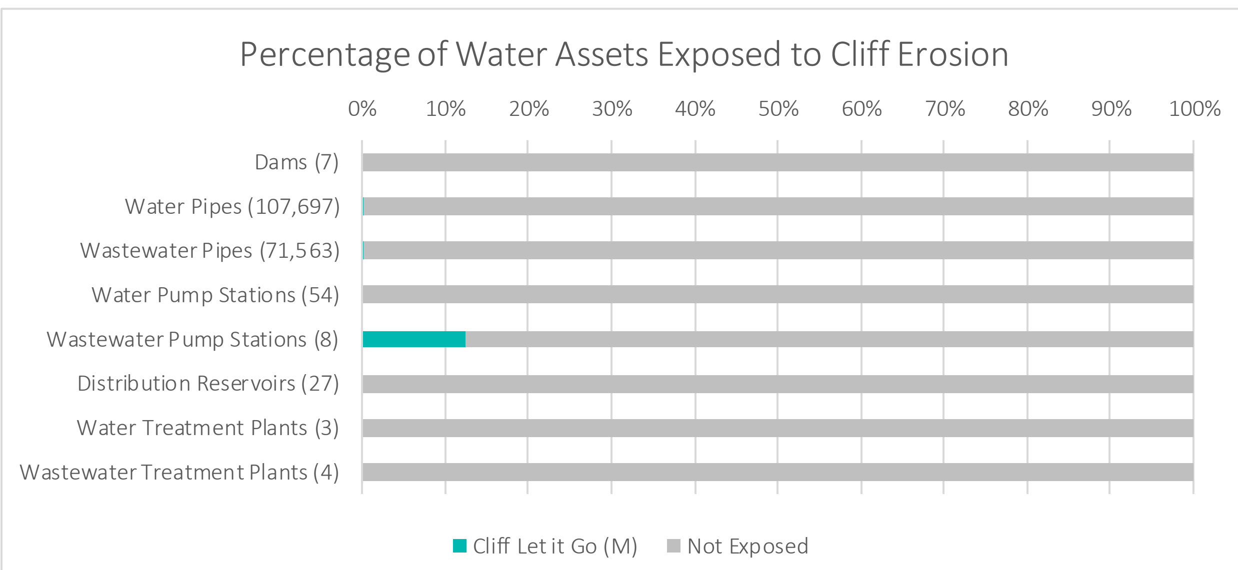

Figure 19. Water critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to erosion if the City does not implement coastal armoring and allows cliff retreat and erosion.

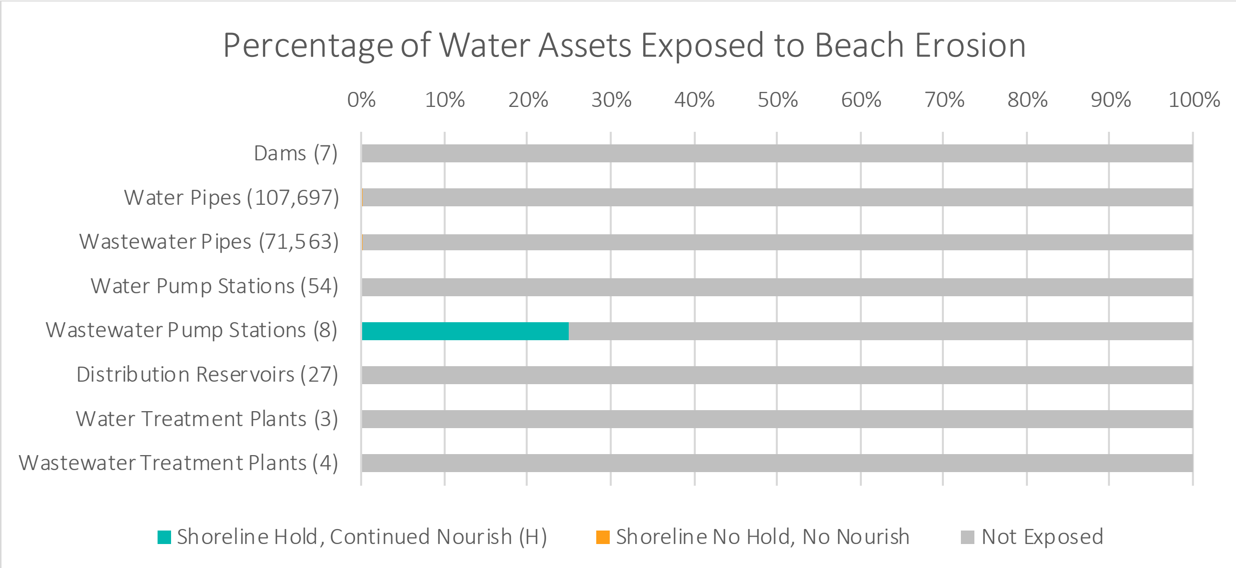

Figure 20. Water critical assets exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

Water Asset Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure assessment, the City reviewed the sensitivity and adaptive capacity of water pipes, wastewater pipes, wastewater pump stations, and wastewater treatment plants to coastal flooding and erosion. The results of this analysis are shown in Table 30.

Table 30. Sensitivity and Adaptive Capacity of Water Critical Asset Types to Coastal Hazards

Water Pipes	
SLR Sensitivity: Low Since pipes are buried underground, they will likely suffer little damage from flooding (ICLEI, 2017). However, chronic inundation could decrease accessibility of the pipes, and sitting in corrosive saltwater for extended periods of time could shorten pipes' useful life (Consultation with City of San Diego PUD, 2020).	*SLR Adaptive Capacity: High* Water pipes are a networked system, so redundancy overall is quite high (Consultation with City of San Diego PUD, 2019). A majority of the City's water pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes could be expensive; however PUD has planned within the department's Capital Improvements Program to rehabilitate and replace pipes as necessary (City of San Diego, 2019).
Storm Surge with SLR Sensitivity: Low Since pipes are buried underground, they will likely suffer minimal damage from flooding (ICLEI,	*Storm Surge with SLR Adaptive Capacity: High* Water pipes are a networked system, so redundancy overall is quite high (Consultation

2017).	with City of San Diego PUD, 2019). A majority of the City's water pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes could be expensive; however PUD has planned within the department's Capital Improvements Program to rehabilitate and replace pipes as necessary (City of San Diego, 2019).
Coastal Erosion Sensitivity: High Pipes are sensitive to erosion, as this hazard could compromise the functionality of the system (ICLEI, 2017).	*Coastal Erosion Adaptive Capacity: Low* Pipes have low adaptive capacity, as coastal erosion that impacts one location could have implications for the system overall (ICLEI, 2017). PUD is currently engaging in a study on coastal erosion at certain locations to further investigate the issue.
Wastewater Pipes	
SLR Sensitivity: Medium Since pipes are buried underground, they will likely suffer little damage from flooding (ICLEI, 2017). However, chronic inundation could decrease accessibility of the pipes, and sitting in corrosive saltwater for extended periods of time could shorten pipes' useful life. Additionally, the potential for seawater to inflow and infiltrate into wastewater pipes may increase flows to the wastewater treatment system (Consultation with City of San Diego PUD, 2020).	*SLR Adaptive Capacity: High* Wastewater pipes are not a networked system, so this system has less overall redundancy (Consultation with City of San Diego PUD, 2019). A majority of the City's wastewater pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes could be expensive; however PUD has planned within the department's Capital Improvements Program to rehabilitate and replace pipes as necessary (City of San Diego, 2019).
Storm Surge with SLR Sensitivity: Medium Since pipes are buried underground, they will likely suffer minimal damage from flooding (ICLEI, 2017). However, the potential for seawater to inflow and infiltrate into wastewater may increase flows to the wastewater treatment system (Consultation with City of San Diego PUD, 2020).	*Storm Surge with SLR Adaptive Capacity: High* Wastewater pipes are not a networked system, so this system has less overall redundancy (Consultation with City of San Diego PUD, 2019). A majority of the City's wastewater pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes could be expensive; however PUD has planned within the department's Capital Improvements Program to rehabilitate and

	replace pipes as necessary (City of San Diego, 2019).
Coastal Erosion Sensitivity: High Pipes are sensitive to erosion, as this hazard could compromise the functionality of the system (ICLEI, 2017).	*Coastal Erosion Adaptive Capacity: Low* Pipes have low adaptive capacity, as coastal erosion that impacts one location could have implications for the system overall (ICLEI, 2017). PUD is currently engaging in a study on coastal erosion at certain locations to further investigate the issue.
Wastewater Pump Stations	
SLR Sensitivity: Low Exposure to flooding would have little impact on pump stations (ICLEI, 2017).	*SLR Adaptive Capacity: High* Impaired components may be isolated for repair, if necessary, without significant disruption to the system (ICLEI, 2017). However, if an entire pump station were to be shut down, the risk for spills and damage to the environment would increase (Consultation with City of San Diego PUD, 2020). Each pump station has an operations plan and emergency plan in place (Consultation with City of San Diego PUD, 2019). All major pump stations have onsite backup power generation to maintain functionality in the event of an outage (Consultation with City of San Diego PUD, 2020).
Storm Surge with SLR Sensitivity: Low Exposure to flooding would have little impact on pump stations (ICLEI, 2017).	*Storm Surge with SLR Adaptive Capacity: High* Impaired components within a station may be isolated for repair, if necessary, without significant disruption to the system (ICLEI, 2017). However, if an entire pump station were to be shut down, the risk for spills and damage to the environment would increase (Consultation with City of San Diego PUD, 2020). Each pump station has an operations plan and emergency plan in place (Consultation with City of San Diego PUD, 2019). All major pump stations have onsite backup power generation to maintain functionality in the event of an outage (Consultation with City of San Diego PUD, 2020).
Coastal Erosion Sensitivity: High Erosion could severely impact the system and compromise its functionality (ICLEI, 2017).	*Coastal Erosion Adaptive Capacity: Low* While not currently in place, there are measures available that could protect pump stations from coastal erosion. These include natural structures that minimize wave energy and erosion (e.g.,

	living shorelines) as well as traditional engineered structures (e.g., rip rap, sea walls) (Consultation with City of San Diego PUD, 2020).
Wastewater Treatment Plants	
SLR Sensitivity: Medium Wastewater treatment plants are designed for contingencies such that the plant could stay functional even if some parts fail. Backup generators are always available in the event of an outage. Coastal plants (such as Point Loma) are designed for some coastal impacts, meaning that some equipment is marine rated (e.g., units are housed or coated to prevent corrosion), but coatings break down over time. Chronic inundation could pose a threat to access and plant longevity (Consultation with City of San Diego PUD, 2019).	*SLR Adaptive Capacity: Medium* The current design of the wastewater treatment plants and requirement of on-site backup generators means that these facilities are well-prepared for coastal impacts. However, if inundation becomes chronic, additional engineering solutions and site improvements will be evaluated. PUD is currently maximizing water reuse, which will reduce the volume of wastewater being treated at these plants into the future (Hummel, 2018).
Storm Surge with SLR Sensitivity: Low Wastewater treatment plants are designed for contingencies such that the plant could stay functional even if some parts fail. Backup generators are always available in the event of an outage. Coastal plants (such as Point Loma) are designed for some coastal impacts, meaning that some equipment is marine rated (e.g., units are housed or coated to prevent corrosion), but coatings break down over time (Consultation with City of San Diego PUD, 2019).	*Storm Surge with SLR Adaptive Capacity: High* The current design of wastewater treatment plants and requirement of on-site backup generators means that these facilities are well prepared for coastal storms (Consultation with City of San Diego PUD, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*

Water Asset Vulnerability to Precipitation-driven Flooding

The City found that all water critical asset types, except distribution reservoirs, wastewater treatment plants, and water treatment plants are vulnerable to precipitation-driven flooding. Distribution reservoirs and wastewater and water treatment plants are located outside of both the FEMA 100-year and 500-year floodplains, and therefore not considered vulnerable.

The results of the vulnerability assessment of water critical asset types to precipitation-driven flooding are shown in Table 31. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to precipitation-driven flooding. Table 32 provides the rationale for the sensitivity and adaptive capacity scores.

This assessment focused on precipitation-driven flooding, using the FEMA 100- and 500-year floodplains to estimate exposure. However, increases in the frequency and intensity of drought conditions is also anticipated. Drought is a region-wide issue that could affect both the locally collected water supply and imported water supply. Scientists in California are actively studying drought as a climate change related hazard (Pierce, 2018; California Energy Commission, 2020), and San Diego is pursuing projects such as the Pure Water Program, which contributes to a more resilient water supply. The Public Utilities Department also considered climate change in the development of its most recent long-term water sourcing plan (Consultation with City of San Diego PUD, 2020).

Table 31. Vulnerability of Water Critical Asset Types to Precipitation-driven Flooding

	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribution Reservoirs	Water Treatment Plants	Waste-water Treat-ment Plants
Exposure	High	High	High	Medium	High	Not exposed	Not exposed	Not exposed
Sensitivity	High	Low	Low	Medium	High	N/A	N/A	N/A
Adaptive Capacity	High	High	High	Medium	Medium	N/A	N/A	N/A
Vulnerability	High	Medium	Medium	Medium	High	N/A	N/A	N/A

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Water Asset Exposure to Precipitation-driven Flooding

Of the water critical asset types, dams, water and wastewater pipes, and water and wastewater pump stations face exposure to precipitation-driven flooding, as shown in Figure 21.

Dams are the asset type facing highest proportional exposure, as twenty-nine percent of dams face exposure to the 100-year precipitation-driven flooding event. Twenty-five percent of wastewater pump stations fall within the 100-year floodplain. Two percent of water pump stations are exposed to precipitation; all of these are in the 500-year floodplain. Roughly five percent of water pipes and wastewater pipes lie in a floodplain.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

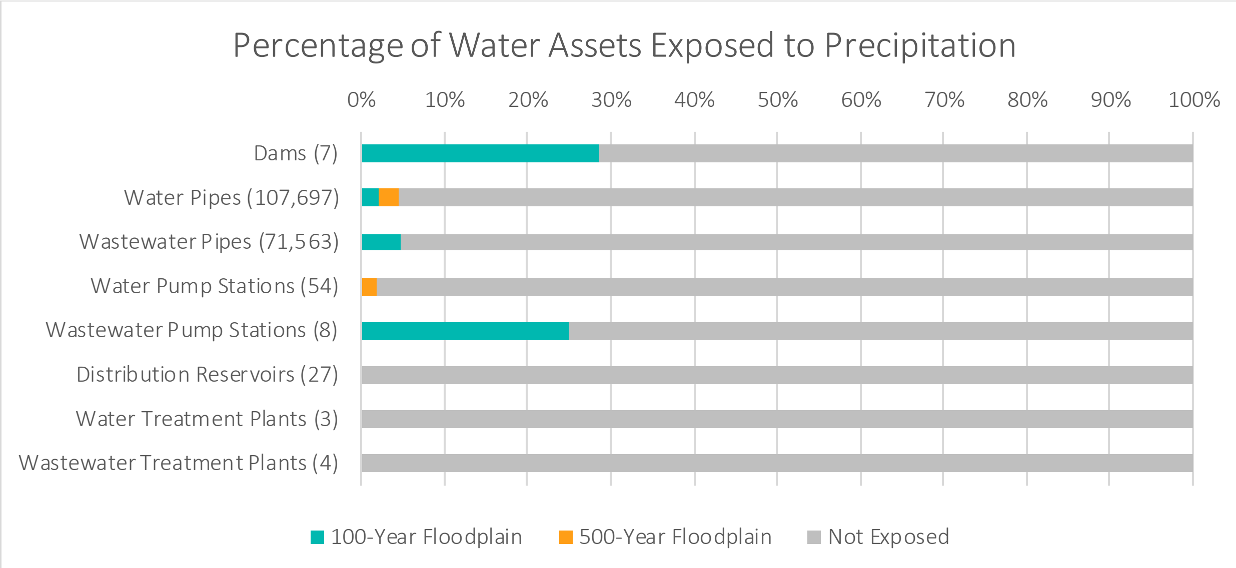

Figure 21. Water critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange-colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

Water Asset Sensitivity and Adaptive Capacity to Precipitation-driven Flooding

Based on the findings of the exposure assessment, the City included dams, both types of pipes and pump stations, and wastewater treatment plants in the sensitivity and adaptive capacity analysis. The results of this analysis are shown in Table 32.

Table 32. Sensitivity and Adaptive Capacity of Water Critical Asset Types to Precipitation-driven Flooding

Dams	
Precipitation Sensitivity Rating: High Extreme precipitation is often the cause for dam overtopping and/or failure across the United States (Association of State Dam Safety Officials, 2019; Smith & Schwartz, 2019). Higher precipitation may increase sediment load in water held by dams, which may benefit from dredging to restore reservoir capacity and function (Consultation with City of San Diego Parks and Recreation Department, 2019). However, many dams nationwide are also functional reservoirs, so they are sited in areas planned and expected to experience high precipitation (e.g., floodplains) in order to mitigate floods and capture water for treatment and use. As a result, dams are generally well-managed for high precipitation events.	*Precipitation Adaptive Capacity Rating: High* The City actively manages the raw water reservoir levels by keeping the water levels low throughout the rainy season, which reduces the risk for dam overtopping or failure (Consultation with City of San Diego PUD, 2019).

Water and Wastewater Pipes	
Precipitation Sensitivity Rating: Low Since pipes are buried underground, they will likely suffer little damage from being located within the floodplains (ICLEI, 2017). However, there is the potential for exposure when precipitation leads to washouts.	*Precipitation Adaptive Capacity Rating: High* Water pipes are a networked system, so redundancy overall is quite high. However, this is not the case for the wastewater system; this system has less overall redundancy (Consultation with City of San Diego PUD, 2019). A majority of the City's water and wastewater pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes could be expensive, but PUD has planned within the department's Capital Improvements Program to rehabilitate and replace pipes as necessary (City of San Diego, 2019).
Water Pump Stations	
Precipitation Sensitivity Rating: Medium Underground facilities can be susceptible to flooding. If storms result in power outages, any pump stations without emergency backup generators may be temporarily non-functional (USAID, 2014).	*Precipitation Adaptive Capacity Rating: Medium* Portable pumps could be moved to affected facilities if access roads are not also flooded (Consultation with City of San Diego PUD, 2019). Above grade pump stations can be protected against flooding through design/location of the pump station and/or through protection measures such as sandbags and sump pumps.
Wastewater Pump Stations	
Precipitation Sensitivity Rating: High Precipitation-based flooding is the main climate hazard of concern for wastewater pump stations. Heavy rainfall could lead to failure of pump stations or generator failure (Consultation with City of San Diego PUD, 2019).	*Precipitation Adaptive Capacity Rating: Medium* Portable pumps could be moved to affected facilities if access roads are not also flooded and thus preventing access. Pure Water can reduce the volume of wastewater being handled at some pump stations and at the WWTP. All major wastewater pump stations have back-up power options such as natural gas engines or additional generators to prevent interruptions during a power outage.

Water Asset Vulnerability to Heat

The City found that all water critical asset types are exposed to heat except water and wastewater pipes. Dams, wastewater pump stations, water treatment plants and wastewater treatment plants showed medium to low exposure, with assets sitting in UHI zones scoring up to eighty. Water pump stations and distribution reservoirs showed high exposure, with one asset in each asset type sitting in an 80-100 UHI zone. As water and wastewater pipes are underground, and ground temperature does not strongly correlate to ambient air temperature, these two asset types are considered not exposed, and therefore not vulnerable, to heat for this analysis.

The results of the vulnerability assessment of water critical asset types to heat are shown in Table 33. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to heat. Table 34 provides the rationale for the sensitivity and adaptive capacity scores.

Table 33. Vulnerability of Water Critical Asset Types to Heat

	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribution Reservoirs	Water Treatment Plants	Wastewater Treatment Plants
Exposure	Medium	Not exposed	Not exposed	High	Low	High	Medium	Medium
Sensitivity	Low	N/A	N/A	Low	Low	Low	Low	Medium
Adaptive Capacity	High	N/A	N/A	High	High	High	High	Medium
Vulnerability	Low	N/A	N/A	Medium	Low	Medium	Low	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10.

Water Asset Exposure to Extreme Heat

The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[29] A score of zero indicates that there is no difference in temperature

In San Diego, coastal areas are relatively cooler than inland areas due to the moderating impacts of the ocean and offshore winds. This coastal effect dominates the urban heat island effect in the City.

[29] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

over time between an urban Census tract and nearby upwind rural reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

Dams, water pump stations, distribution reservoirs, water treatment plants, and wastewater treatment plants have all their assets facing some level of heat exposure (Figure 22). Only thirteen percent of wastewater pump stations face some level of exposure to heat. As water and wastewater pipes are underground, and ground temperature does not strongly correlate to ambient air temperature, these two asset types are considered not exposed to heat.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the heat levels.

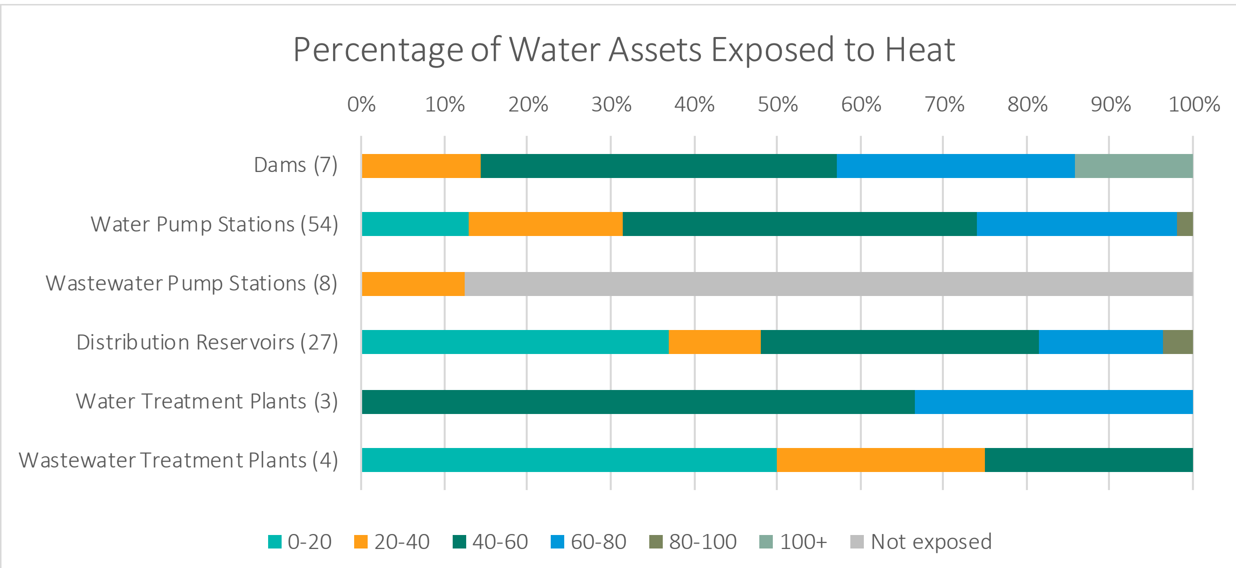

Figure 22. Water critical assets exposed to extreme heat. The value after each asset name indicates the asset count. The colored bars represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

Water Asset Sensitivity and Adaptive Capacity to Heat

Based on the exposure analysis, the City considered the sensitivity and adaptive capacity of all water critical asset types except water and wastewater pipes to heat. The results of this analysis are presented in Table 34 below.

Table 34. Sensitivity and Adaptive Capacity of Water Critical Asset Types to Heat

Dams	
Heat Sensitivity Rating: Low Higher heat may increase water loss due to increases in evaporation rates.	*Heat Adaptive Capacity Rating: High* Adaptation to heat is likely not necessary for dams.
Water and Wastewater Pump Stations	
Heat Sensitivity Rating: Low Higher heat may stress electrical equipment. In	*Heat Adaptive Capacity Rating: High* Portable pumps, backup pumps, and emergency

the event of blackouts or brownouts, water service may be interrupted, and water treatment may be disrupted (U.S. General Services Administration, 2015). However, pump stations that are underground are less sensitive to changes in ambient air temperature.	generators can be employed in the event of a power outage (Consultation with City of San Diego PUD, 2019). All major pump stations have onsite backup power generation to maintain functionality in the event of an outage (Consultation with City of San Diego PUD, 2020).
Distribution Reservoirs	
Heat Sensitivity Rating: Low San Diego's distribution reservoirs are covered, so the water contained within these resources would likely not evaporate. Additionally, reservoirs are designed with expandable joints and flexible coatings to prevent leakage or structural damage caused by temperature change (Consultation with City of San Diego PUD, 2019).	*Heat Adaptive Capacity Rating: High* Adaptation to heat is likely not necessary for distribution reservoirs outside of the existing operational strategies currently used, particularly those aimed at maintaining water quality, as heat degrades disinfectants. To address this, tanks are operated with daily volume turnover and provided with inlet/outlet systems designed to create internal tank mixing. Reservoir temperatures and disinfectant residuals are continuously monitored at potable reservoirs and action levels are in place to identify and resolve water quality problems (Consultation with City of San Diego PUD, 2020).
Water Treatment Plants	
Heat Sensitivity Rating: Low The U.S. Environmental Protection Agency (EPA) requirement to have backup generators at all treatment facilities reduces these facilities' sensitivity to blackouts and brownouts during extreme heat events (Consultation with City of San Diego PUD, 2019).	*Heat Adaptive Capacity Rating: High* All water treatment plants have emergency backup power or dual power sources in the event of an outage. In addition, the City has a contingency plan in place: if one plant is down, the City could switch to one of the other two water treatment facilities. As needed, the City could also purchase water from the County Water Authority (Consultation with City of San Diego PUD, 2019).
Wastewater Treatment Plants	
Heat Sensitivity Rating: Medium Increases in heat could damage equipment and wastewater treatment plants in several ways. Higher temperatures increase production of hydrogen sulfide, which corrodes infrastructure and equipment (ICLEI, 2012). Higher heat may stress and degrade electrical equipment. In addition, higher heat may lead to	*Heat Adaptive Capacity Rating: Medium* All wastewater treatment plants have emergency backup power or dual power sources in the event of an outage. Wastewater treatment plants include robust ventilation and cooling systems as part of their design. However, ambient design temperatures were put in place decades ago and may now be

lower water flows due to evaporation and drought, which could decrease treatment efficiency (USAID, 2014).	outdated. While the City plans on using projected temperatures to design treatment facilities moving forward, older facilities may have less ability to adapt to heat (Consultation with City of San Diego PUD, 2019).

Water Asset Vulnerability to Wildfires

The City found that all water critical asset types except water pipes, wastewater pipes, and wastewater pump stations face exposure to wildfire. In particular, water pump stations show high vulnerability: high exposure and high sensitivity are enough to rate them as highly vulnerable, despite medium adaptive capacity. While water pipes and wastewater pipes cross through areas within the different fire hazard zones, these asset types are underground and therefore were assumed to not be at risk of exposure to wildfire (and therefore not vulnerable for the sake of this analysis).

The results of the vulnerability assessment of water critical asset types to wildfire are shown in Table 35. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to wildfire. Table 36 provides the rationale for the sensitivity and adaptive capacity scores.

Table 35. Vulnerability of Water Critical Asset Types to Wildfire

	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Distribu-tion Reservoirs	Water Treatment Plants	Waste-water Treatment Plants
Exposure	High	Not exposed	Not exposed	High	Not exposed	High	Low	Medium
Sensitivity	Low	N/A	N/A	High	N/A	Low	High	High
Adaptive Capacity	High	N/A	N/A	Medium	N/A	High	High	Medium
Vulnerability	Medium	N/A	N/A	High	N/A	Medium	Medium	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Water Asset Exposure to Wildfire

All water critical asset types except water pipes, wastewater pipes, and wastewater pump stations may be exposed to wildfire (Figure 23). Water and wastewater pipes are underground and therefore were assumed to not be at risk of exposure to wildfire. All four wastewater treatment plants face exposure, with three facing medium exposure and one facing low exposure. There is one dam, thirty-two water pump stations, and fifteen distribution reservoirs facing high exposure to wildfire.

Wildfire Hazard Zones for San Diego

High: Native vegetation and 100-foot setback zones

Medium: 300-foot setback zone

Low: Fire hazard zone outside native vegetation zone and setbacks

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

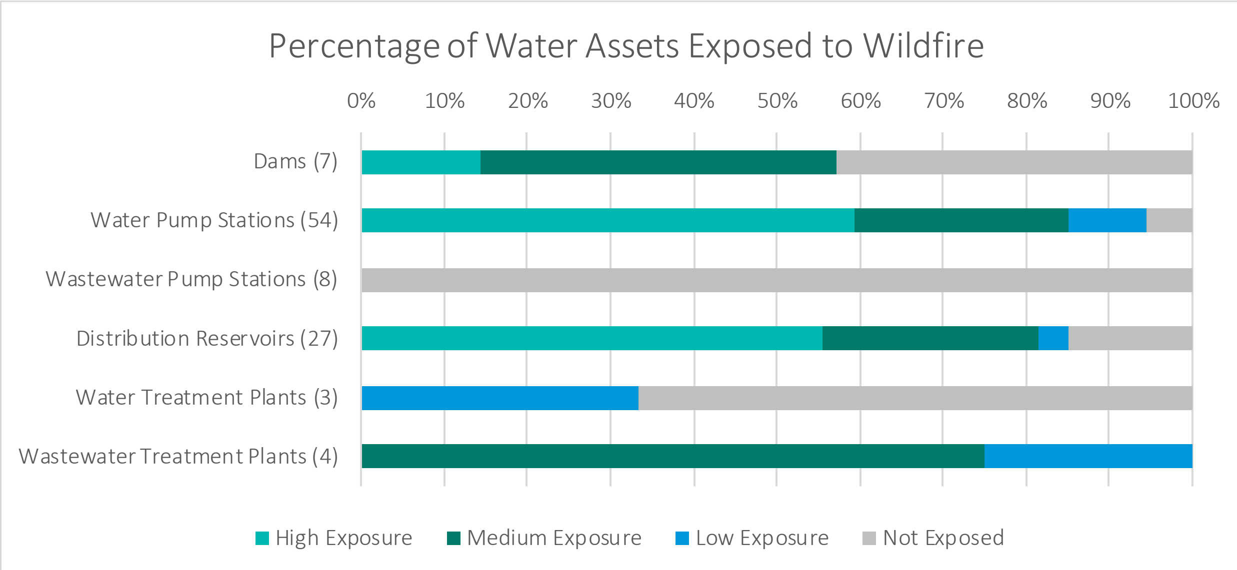

Figure 23. Water critical assets exposed to wildfire. The value after each asset name indicates the asset count.

Water Asset Sensitivity and Adaptive Capacity to Wildfire

Based on the exposure analysis, the City assessed the sensitivity and adaptive capacity of all critical water asset types except water pipes, wastewater pipes, and wastewater pump stations to wildfire. The results of this analysis are shown in Table 36.

Table 36. Sensitivity and Adaptive Capacity of Water Critical Asset Types to Wildfire

Dams	
Wildfire Sensitivity Rating: Low Because dams are always made of concrete or earth (materials that are not sensitive to fire), dams will not fail due to wildfire (Consultation with City of San Diego PUD, 2019).	*Wildfire Adaptive Capacity Rating: High* In general, there is defensible space around dams; City staff regularly clean the landscape (Consultation with City of San Diego PUD, 2019).
Water Pump Stations	
Wildfire Sensitivity Rating: High Most pump stations are above ground (Consultation with City of San Diego PUD, 2019), which renders them more susceptible to wildfire damage.	*Wildfire Adaptive Capacity Rating: Medium* Backup generators are available to keep pump stations running, assuming wildfire does not prevent access (City of San Diego, 2007). However, replacement costs of pump stations could be relatively high (e.g., Pump Station 81 required $245,705 in debris removal and repair after the October 2007 wildfires) (City of San Diego, 2007).
Distribution Reservoirs	

Wildfire Sensitivity Rating: Low Wildfires increase water demand, which could put pressure on the water supply.	*Wildfire Adaptive Capacity Rating: High* The potable water system is designed to operate with multiple fail-safes and operational mechanisms to address outages (Consultation with City of San Diego PUD, 2020).
Water Treatment Plants	
Wildfire Sensitivity Rating: High Wildfires could directly burn and damage water treatment plants. This could lead to a plant shutdown.	*Wildfire Adaptive Capacity Rating: High* The areas within the fence line of facilities are landscaped and maintained to comply with the fire code. Treatment plants are also typically within City limits and not in rural areas where there is a lot of vegetation. All water treatment plants have emergency backup power or dual power sources in the event of an outage. Additionally, control rooms and other sensitive areas have sprinklers. In addition, the City has a contingency plan in place: if one plant is down, the City switches to one of the other two treated water facilities. The City could also buy water from the County Water Authority if necessary (Consultation with City of San Diego PUD, 2019).
Wastewater Treatment Plants	
Wildfire Sensitivity Rating: High Wildfires could directly burn and damage wastewater treatment plants. This could lead to untreated wastewater being released, posing environmental and human health hazards. Fires could also cut off access to these plants. The greatest risk posed by fire, however, is the loss of electrical transformers or other electrical equipment at the plant, which are needed whether power is being sourced from a power utility or the plant's emergency generators (Consultation with City of San Diego PUD, 2020).	*Wildfire Adaptive Capacity Rating: Medium* The areas within the fence line of facilities are landscaped and maintained to comply with the fire code. Wastewater treatment plants are also typically within City limits and not in rural areas with plentiful fuel for wildfires. Some wastewater treatment plants are built with fire-retardant walls. If the level of sewage is "high," an alarm is sent to the City and the emergency plan is implemented. The plants also contain fire alarm systems, and some have sprinklers (Consultation with City of San Diego PUD, 2019).

Transportation and Storm Water Vulnerability Findings

Transportation and Storm Water assets include those managed by the City's Transportation and Storm Water department and Real Estate Assets Department.[30] The following asset types are considered critical and were evaluated for vulnerability: City-operated airports, bridges, major arterials, drain pump stations, storm water outfalls, and levees.[31] Not all assets in this list were found to be exposed to climate hazards.

This assessment includes the City-operated airports Brown Field Municipal Airport (KSDM) and Montgomery-Gibbs Executive Airport (KMYF) but does not include San Diego International Airport, which is owned by the San Diego Regional Airport Authority. These City-owned airports include sensitive habitats and open space areas that are considered and discussed under the "Open Space and Environment" section below.

Other Transportation Assets

The City of San Diego also considered the exposure of state (Caltrans) highways and freeways, as they are part of the transportation network in the City but not owned or managed by the City. This information is found in the "Non-City-Owned Resources" section near the end of this report.

The City did not include transit infrastructure in this vulnerability assessment, as SANDAG received a Caltrans grant to evaluate the resilience of the transit system.

Bridges often have mixed ownership between the City and State: there are 126 bridges in the City for which the City is responsible for maintenance of the bridge deck, railing, streetlights, and improvements above the superstructure of the bridge, while Caltrans is responsible for the maintenance of the superstructure and substructure of the bridge. Bridges and major arterials are broken down into roadway segments as defined in the City's asset management system.

The storm water outfalls, drain pump stations and levees are part of a larger storm water conveyance system that includes channels and underground pipes. While a significant portion of this assessment focuses on the aboveground assets, underground storm water infrastructure could be critically impacted by the changes in precipitation patterns and levels (i.e. inches of rainfall per year, plus duration and intensity of rainfall events).

The results of the vulnerability assessment for transportation and storm water asset types are shown in Table 37. "N/A" indicates that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were determined to not be vulnerable.

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[30] The Real Estate Assets Department (READ) manages the City-owned airports. All other transportation assets are managed by the Transportation and Storm Water Department (TSWD).

[31] The levees followed a different exposure analysis than the other assets in this vulnerability assessment. More information is provided in the sections below.

The City found that all transportation and storm water critical asset types face exposure to all hazards, except for airports, which only face exposure to heat and wildfire.

Coastal flooding, coastal erosion, and wildfire are priority hazards, as nearly all asset types are highly vulnerable to these hazards. All asset types besides airports show medium to high vulnerability to precipitation, and all asset types besides drain pump stations and levees show medium vulnerability to heat.

Table 37. Vulnerability of Transportation and Storm Water Critical Asset Types to Climate Change Hazards[32]

	Sea Level Rise (SLR)	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
Airports	N/A	N/A	N/A	**Low**	Medium	**High**
Bridges	**High**	Medium	**High**	Medium	Medium	**High**
Major Arterials	**High**	Medium	Medium	Medium	Medium	**High**
Drain Pump Stations	**High**	**High**	N/A	High	**Low**	**High**
Outfalls	**High**	**High**	**High**	**High**	Medium	Medium
Levees	**Low**	**Low**	N/A	Medium	**Low**	Medium

City-Managed Trees

While not a part of this current vulnerability assessment, the City also considers its urban trees to be critical assets. The City has approximately 200,000 street trees, 600,000 park trees, and an unknown number of trees on other public properties owned and managed by the City. These trees provide many benefits to the City's communities, including but not limited to reduction of storm water runoff, reduction in electricity use during the summer, mitigation against the urban heat island effect, and a reduction in airborne particulates. A recent inventory showed that approximately 70,000 trees stored over 12,800 tons of carbon worth $1.6 million. Under Strategy 5 of the City's CAP, the tree canopy cover is targeted to be increased to 15 percent by 2020 and 35 percent by 2035.

Trees are critical assets to the City's communities and could be affected by sea level rise, drought, heat, and wildfire. Increased sea levels could affect City trees in low coastal areas. This could affect existing trees as well as reduce areas for new trees to grow. Almost all tree species in the City are sensitive to salts (brackish water). Recent droughts have also shown that some trees are highly sensitive to changes in

[32] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections and localized modeling for the chosen climate hazard scenarios, and an assumption of asset type-level (general) of sensitivity and adaptive capacity based on literature reviews and high-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

temperature and changes in amounts of precipitation. Several years ago, a large grove of coastal redwoods died in Balboa Park after a long period without water. Changes in climate, in combination with recent droughts, have additionally made trees more susceptible to pests such as the shot hole borer, gold spotted borer and the South American palm weevil. All three pests have affected trees in San Diego, creating deteriorating tree conditions that increase risk to people and property.

Sudden impacts from precipitation events, drought, pests, or wildfire could greatly affect a large number of trees in a given area, creating a significant risk to public safety that often needs immediate action to address. The costs to remove and replace trees could be significant. A future, tree-specific, vulnerability assessment would provide more detailed analysis of the specific climate change driven impacts to trees.

Transportation and Storm Water Consequences

Transportation Consequences

Transportation systems are vital for economic vitality and societal functioning of San Diego. Disruptions could delay or inhibit the movement of goods and people, including delays for emergency vehicles and disruptions to daily life. The extent of damage would depend on the location and traffic load of the asset. The consequences would also depend on the level of redundancy within the system that allows travel to continue despite damage to one part of the system.

Illustrative examples of the consequences of transportation damage, disruption, and failure are presented in Table 38. This table is provided purely to illustrate potential impacts; it is not meant to imply that these impacts will definitively occur, nor is this list fully comprehensive of all potential consequences to all asset types.

Table 38. Illustrative Consequences of Transportation Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Airports	City Services Human Health Historical, Tribal Cultural, and Archaeological Resources Natural Resources and the Environment	Brown Field Municipal Airport (KSDM) and Montgomery-Gibbs Executive Airport (KMYF) are the airports owned and operated by the City of San Diego. Both City-owned airports provide critical services, such as law enforcement, air ambulance, and fire-rescue operations. Both also serve as reliever airports for San Diego International Airport and provide flight training and cargo services. Brown Field Municipal Airport contains historical, tribal cultural, and archaeological resources, including the Alta School site and several building facilities within the Auxiliary Naval Air Station Brown Field Historic District. Damage to these structures could impact their ability to convey historical and cultural information and value (Consultation with City of San Diego Historic Preservation Planning, 2020). These airports also contain open space, vernal pools, and endangered species.
Bridges	City Services Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources	Bridges often have less redundancy than other parts of the transportation system, since there are limited crossings over bodies of water. Thus, failure could result in collapse of all or some portion of the transportation system (FHWA, 2011). Disruptions or delays could affect people going about their daily lives and reduce mobility of goods, resulting in economic losses (Pregnolato, Ford, Wilkinson, & Dawson, 2017). This could disrupt emergency response services if the capacity of certain routes (e.g., evacuation routes) becomes compromised. The Coast Walk Trail and Devil's Slide Footbridge, the First Avenue Bridge, the Georgia Street Bridge, the Quince Street Footbridge, and the Spruce Street Suspension Bridge are City-owned designated historical resources. Additionally, other bridges that are not currently designated may be eligible for designation pending evaluation. Damage to these structures could impact their ability to convey historical and cultural information and value.
Roadway Network (Major Arterials)	City Services Human Health Social Equity	Disruptions or delays could affect people going about their daily lives and reduce mobility of goods, resulting in economic losses (Pregnolato, Ford, Wilkinson, & Dawson, 2017). Also, roadway disruptions could disrupt emergency response services if the capacity of certain routes (e.g., evacuation routes) becomes compromised. There could be a risk of injury, depending on the type of damages. Communities of concern may have fewer mobility options to reach critical service, so they may be disproportionately affected by disruptions.

Storm Water Consequences

Storm water systems play a key role in reducing the risk of flooding. Because of this, impacts to this infrastructure could exacerbate damages due to climate change-related hazards. For example, flooding could be exacerbated if storm water systems become overwhelmed or blocked by debris. Damage, disruption, or failure of storm water systems would impact City services through responses to manage flood risk. Corrosion and pipe deterioration may occur faster under pipes exposed to more frequent and larger storm events.

Illustrative examples of the consequences of storm water system damage, disruption, and failure are presented in Table 39.

Table 39. Illustrative Consequences of Storm Water Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Drain Pump Stations	City Services Human Health Social Equity	Pump stations remove storm water from areas that cannot be drained by gravity. Flooding could be exacerbated if the pumps fail, potentially resulting in significant damages. For example, road safety could be threatened if roads become flooded. Other transportation disruptions and potential traffic accidents could occur. Communities of concern may have fewer mobility options to reach critical service, so they may be disproportionately affected by disruptions.
Outfalls	City Services Human Health Natural Resources and Environment	If outfalls are inhibited, storm water could back up and exacerbate flooding. Reduced discharge capacity could cause flooding of adjoining areas and disrupt access to homes, jobs, and recreation areas (BCDC, 2019). This would require additional maintenance and response. Depending on the source and destination of the outfall, damage or failure could negatively affect water quality of surface waters. Water contamination has implications for human health and the environment.
Levees	City Services	The city's levees, which provide crucial floodwater protection,

	Human Health	are situated along the San Diego River south of Mission Bay and along the Tijuana River.[33] If they were to be compromised by climate hazards, then the area surrounding the levees may experience flooding. This could disrupt transportation, business, and pose a health and safety risk to the public.

Transportation and Storm Water Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day under each sea level rise scenario. Storm surge flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm under each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

The City found that all transportation and storm water critical asset types except airports, which are not exposed, and levees, which received a low vulnerability score, are highly vulnerable to sea level rise and have medium to high vulnerability to storm surge with sea level rise. Bridges, major arterials, and outfalls show vulnerability to coastal erosion. All erosion scenarios assume 2.0 meters of sea level rise (which is the upper range for 2100).

The results of the vulnerability assessment of transportation and storm water critical asset types to coastal hazards are shown in Table 40, Table 41, and Table 42.

The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to coastal hazards. Table 44 provides the rationale for the sensitivity and adaptive capacity scores.

Table 40. Vulnerability of Transportation and Storm Water Critical Asset Types to Sea Level Rise

Sea Level Rise (SLR)	Airports[34]	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	N/A	High	High	High	High	Low
Sensitivity	N/A	High	High	High	High	Medium
Adaptive Capacity	N/A	Medium	Medium	Low	Low	Medium
Vulnerability	N/A	High	High	High	High	Low

[33] At this time, analysis was only completed for the San Diego River Levee. The Tijuana River levee was not evaluated as part of the exposure assessment. However, the sensitivity and adaptive capacity narratives for the San Diego River levees would also apply to the Tijuana River levees.
[34] The Real Estate Assets Department (READ) manages the City-owned airports. All other transportation assets are managed by the Transportation and Storm Water Department (TSWD).

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scorin g methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 41. Vulnerability of Transportation and Storm Water Critical Asset Types to Storm Surge with Sea Level Rise (One Hundred-Year storm)

Storm Surge with SLR	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	Not exposed	High	High	High	High	Low
Sensitivity	N/A	Medium	Medium	Medium	Medium	Low
Adaptive Capacity	N/A	Medium	Medium	Low	Low	Medium
Vulnerability	**N/A**	**Medium**	**Medium**	**High**	**High**	**Low**

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scorin g methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 42. Vulnerability of Transportation and Storm Water Critical Asset Types to Coastal Erosion at Medium-High Risk Aversion Scenario of 2m of Sea Level Rise

Coastal Erosion	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	Not exposed	High	Medium	Not exposed	High	Not exposed
Sensitivity	N/A	High	High	N/A	High	N/A
Adaptive Capacity	N/A	Low	Medium	N/A	Low	N/A
Vulnerability	**N/A**	**High**	**Medium**	**N/A**	**High**	**N/A**

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scorin g methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Transportation and Storm Water Exposure to Coastal Hazards

> **Sea Level Rise Projections for San Diego**
>
> 2030: 0.25 m SLR
>
> 2050: 0.5 to 0.75 m SLR
>
> 2100: 1.0 to 2.0 m SLR

A small portion of the critical transportation assets may be exposed to sea level rise and storm surge with sea level rise, whereas a large percentage of storm water assets face exposure to coastal hazards (Figure 25, Figure 26). This exposure analysis was conducted by comparing the locations of assets, such as bridge approaches, to projected flooding with different levels of sea level rise and storm surge with sea level rise, to determine the assets' potential exposure. Information on the elevation of assets (such as bridges) would be necessary to determine whether they would be underwater given a certain height of sea level rise or storm surge.

Across all transportation assets, less than five percent may be exposed to sea level rise; however, there is local exposure in some coastal neighborhoods (Figure 25). According to institutional knowledge within the Transportation and Storm Water Department, only eight road locations have historically been subject to repeat tidal flooding. Of the transportation elements analyzed, major arterial segments showed the greatest exposure in the near term (thirty-two segments at .25 m in 2030). Over time, more significant portions of the major arterial network—up to 213 segments at 1.0 to 2.0 m (2100)—may be exposed to sea level rise. With .25 m sea level rise (2030), four bridges would face exposure to sea level rise; up to seven more becoming exposed by the end of the century (2.0 m sea level rise). Compared with transportation assets, a much larger proportion of storm water assets may be exposed to sea level rise. Seven percent of drain pump stations may be exposed starting at 0.25 m sea level rise (2030), and thirty-six to fifty-seven percent of drain pump stations may be exposed by 2100 (1.0 to 2.0 m sea level rise). Twenty-seven percent of outfalls may be exposed starting at 0.25 m sea level rise (2030), and thirty-nine to fifty-one percent of outfalls may be exposed by 2100 (1.0 to 2.0 m sea level rise).

With storm surge and sea level rise scenarios, where sea level rise vulnerability is compounded by storm surge, assets become exposed across a broader spectrum of sea level rise ranges. Under these scenarios a few additional transportation assets face flooding but the proportion still stays below 5 percent, with a total of up to 323 major arterial road segments potentially exposed to a storm surge event in 2100 (2.0 m sea level rise) (Figure 26). Major arterial segments would be the most exposed with the addition of storm surge to sea level rise: 44 segments face projected exposure in 2030, increasing to 123 - 323 segments by 2100.

Figure 24. A coastal storm water outfall in San Diego.

More storm water assets may also become exposed to inundation during a storm surge. Thirty-six percent of stations may be exposed starting at 0.25 meters (2030), and between forty-three and eighty-six percent of drain pump stations may face flooding from storm surge with sea level rise in 2100. Similar to drain pump stations, thirty-six percent of outfalls may be exposed to storm surge with sea level rise starting at 0.25 meters of sea level rise (2030), and fifty to fifty-nine percent may be exposed by 2100.

Among the transportation assets, bridges are not exposed to cliff erosion, and there is a single major arterial segment that may be exposed (Figure 27). Among the storm water assets, outfalls may be more exposed than drain pump stations to cliff erosion: fifteen percent of outfalls face exposure. As Figure 28 shows, a single bridge and major arterial segment face exposure to beach erosion. Similar to cliff erosion, outfalls face the greatest proportion exposure to beach erosion at eight percent. No drain pump stations are expected to be exposed to erosion.

While the City-owned airports (Brown Field Municipal Airport and Montgomery-Gibbs Executive Airport) are inland and therefore not exposed to coastal hazards, both airports serve as reliever airports for smaller aircraft that would otherwise be served by San Diego International Airport, which is coastal. Impacts to San Diego International Airport could have cascading effects, such as potential rerouting of aircraft to City-owned airports (Consultation with City of San Diego Real Estate Assets Department, 2019). San Diego International Airport has prepared its own Climate Resilience Plan, which focuses on sea level rise, precipitation patterns, and extreme heat (San Diego International Airport, 2019).

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

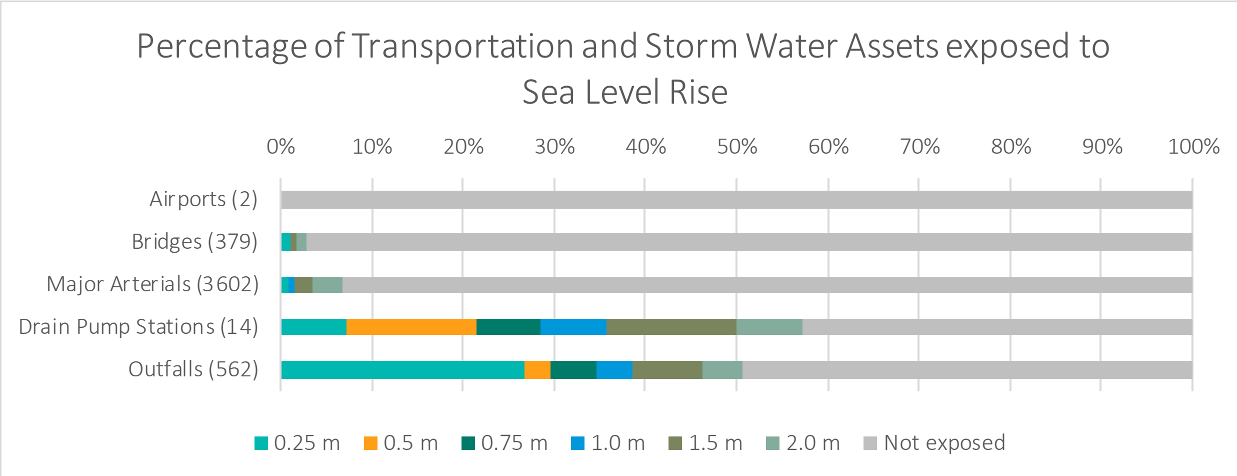

Figure 25. Transportation and storm water critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

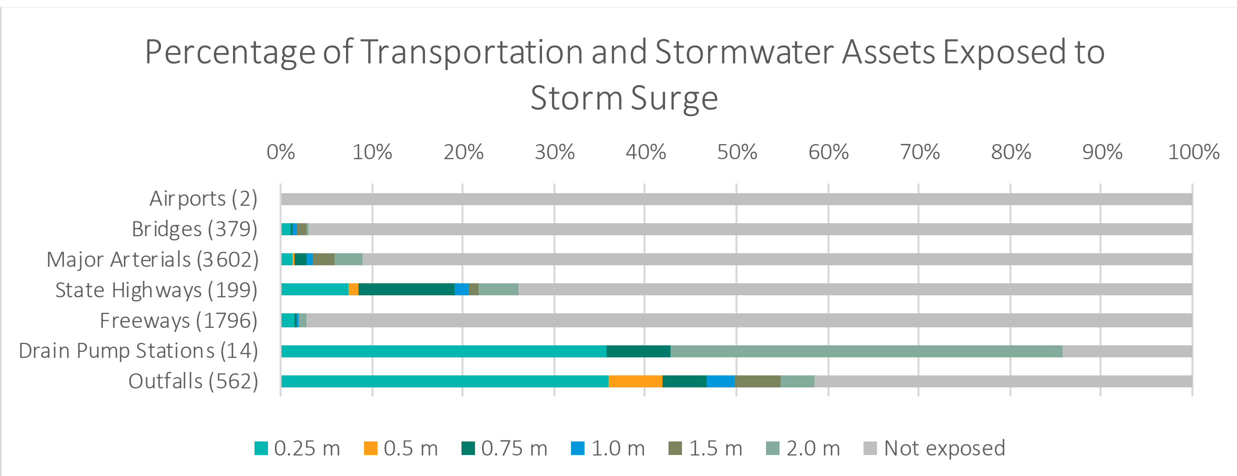

Figure 26. Transportation and storm water critical assets exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average daily flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

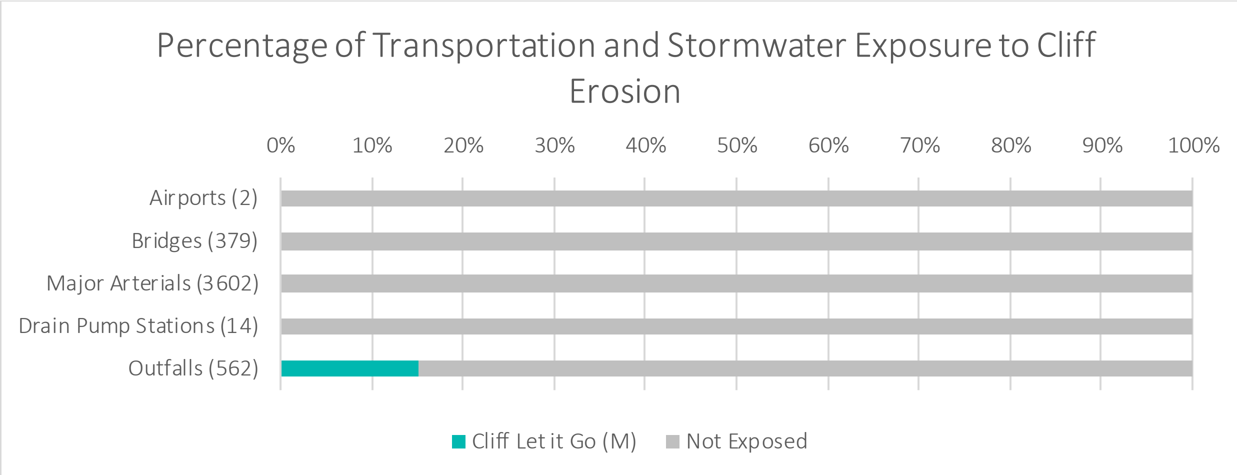

Figure 27. Transportation and storm water critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

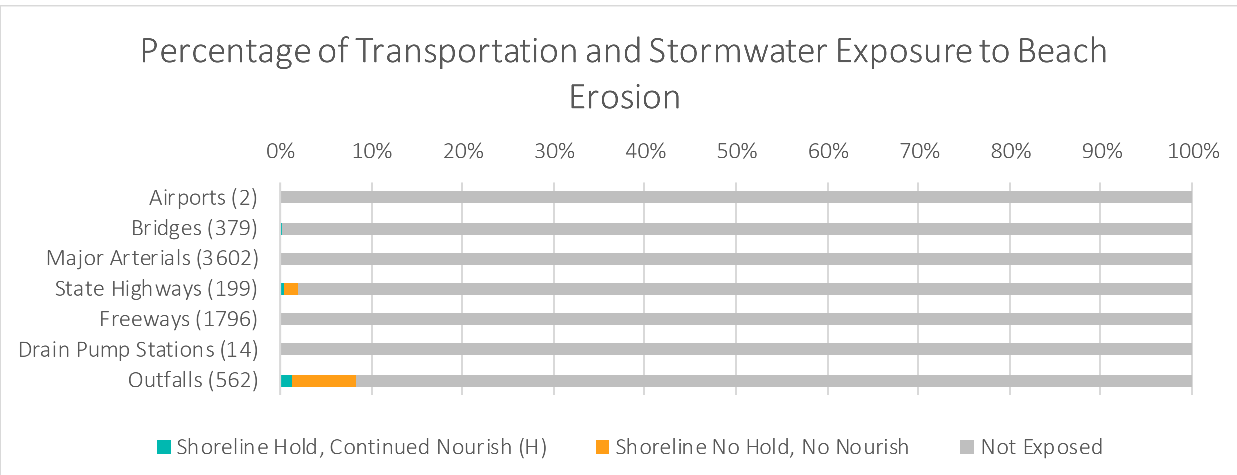

Figure 28. Transportation and storm water critical assets exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

Levee Exposure to Coastal Hazards

Estimates of levee exposure to sea level rise were based on the City's internal calculations and scoring, which employ a different methodology from that used for the other asset types in this vulnerability assessment. The City determined the minimum elevation of each levee, then compared this elevation to projected sea level rise. The levees were determined to be exposed to sea level rise when the projected sea level exceeded the minimum levee elevation. The City incorporated storm surge projections by adding the historical National Oceanic and Atmospheric Administration's (NOAA) Annual Exceedance Probability Curves for San Diego Bay (0.73 meters [2.40 feet] above Mean Higher High Water for the 100-year storm) to projected sea levels (Table 43).[35]

Table 43. Exposure of City of San Diego Levees to Sea Level Rise in 2030, 2050, and 2100 based on low, medium-high, and extreme risk scenarios. All units are feet.

Year	Present-Day Tidal Datum		Sea Level Rise Scenario			Levee Elevation Relative to Sea Level Rise			Levee Elevation Relative to Storm Surge with SLR		
	Levee Elevation	Mean Higher High-Water Elevation above MSL	Low	Medium - High	Extreme	Low	Medium - High	Extreme	Low	Medium - High	Extreme
2030	9.8	2.8	0.8	1.1	1.5	6.2	5.9	5.5	3.8	3.5	3.1
2030	11.6	2.8	0.8	1.1	1.5	8.0	7.7	7.3	5.6	5.3	4.9
2050	9.8	2.8	1.2	2.0	2.8	5.8	5.0	4.2	3.4	2.6	1.8
2050	11.6	2.8	1.2	2.0	2.8	7.6	6.8	6.0	5.2	4.4	3.6
2100	9.8	2.8	3.6	7.0	10.2	3.4	0.0	**-3.2**	1.0	**-2.4**	**-5.6**
2100	11.6	2.8	3.6	7.0	10.2	5.2	1.8	**-1.4**	2.8	**-.06**	**-3.8**

The minimum elevations for the three City levees along the San Diego River are 9.8 feet, 11.6 feet, and 11.6 feet.

None of the three City levees along the San Diego River would experience overtopping until 10.2 feet of sea level rise (which the California Coastal Commission has categorized as an extreme risk aversion scenario for 2100) (Consultation with City of San Diego Transportation and Storm Water Department, 2020). Exposure at 10.2 feet (3.1 meters) of sea level rise corresponds to the vulnerability assessment's low exposure score since it is not projected to occur until late in the century.

Using 2.4 feet of storm surge based on NOAA's tidal datum, the levees are projected to be exposed to sea level rise with storm surge—beginning with the medium-high risk aversion projection for 2100, which equates to 7 feet (or 2.1 meters), which also results in a low exposure score.

It is possible that sea level rise inundation could flow from the non-river side, and the City should consider how sea level rise might impact the area surrounding the levees. This is a potential area for future modeling and research.

[35] https://tidesandcurrents.noaa.gov/est/curves.shtml?stnid=9410170

Transportation and Storm Water Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure analysis, the City assessed the sensitivity and adaptive capacity of all transportation and storm water critical asset types except airports to coastal hazards. The results of this analysis are shown in Table 44 below.

Table 44. Sensitivity and Adaptive Capacity of Transportation and Storm Water Critical Asset Types to Coastal Hazards

Bridges	
SLR Sensitivity: High Daily inundation could cause structural damage to assets and cut off access from flooded routes.	*SLR Adaptive Capacity: Medium* There is relatively low redundancy in the bridge network. Daily flooding could require the creation of alternate routes outside of inundation zones. Currently there is no routine maintenance performed on bridges, and no routine funds allocated for maintenance and repair. However, if it is a priority repair/safety related, the City addresses those needs. State funds could be applied for to address issues that Caltrans finds during its inspections and are categorized as Capital Improvement Plan work. Currently, there is no State or Federal grant program for routine bridge maintenance. (Consultation with City of San Diego Transportation and Storm Water Department (TSWD), 2019).
Storm Surge with SLR Sensitivity: Medium Sea level rise is projected to increase the frequency and baseline water level of extreme storms, which may exceed design standards for bridges. Storm surge could stress bridges via erosion and scour, and by washing debris into bridges (FHWA, 2014). Typically, bridge and roadway drainage design standards are for the historical 100-year storm. For bridges that cross over a channel or river rather than a roadway, the design standard may change to suit needs (e.g., West Mission Bay Drive is designed to withstand a 500-year tsunami). A majority of bridges in San Diego have gone through major rehabilitation improvements and have been seismically retrofitted (City of San Diego, 2019).	*Storm Surge with SLR Adaptive Capacity: Medium* There is limited redundancy in the bridge network. Currently there is no routine maintenance performed on bridges, and no routine funds allocated for maintenance and repair. However, if it is a priority repair, safety related, the City addresses those needs. State funds could be applied for to address issues that Caltrans finds during its inspections and are categorized as Capital Improvement Plan work, though this is a limited pool that may only cover one to two bridges every few years (Consultation with City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: High Roads and bridges are highly sensitive to erosion.	*Coastal Erosion Adaptive Capacity: Low* There is limited redundancy in the bridge

If major routes become eroded, new routes should be created (ICLEI, 2017) (Consultation with City of San Diego TSWD, 2019).	network. Currently there is no routine maintenance performed on bridges, and no routine funds allocated for maintenance and repair. However, if it is a priority repair, safety related, the City addresses those needs. State funds could be applied for to address issues that Caltrans finds during its inspections and are categorized as Capital Improvement Plan work, though this is a limited pool that may only cover one to two bridges every few years (Consultation with City of San Diego TSWD, 2019).
Major Arterials	
SLR Sensitivity: High Daily inundation could cause structural damage to the road subgrade and cut off access from flooded routes.	*SLR Adaptive Capacity:* Medium The roadway network in the coastal zone has high redundancy; however, policy and planning decisions are needed for long-term solutions (Consultation with City of San Diego TSWD, 2019).
Storm Surge with SLR Sensitivity: Medium Periodic flooding of major arterials could cause significant disruptions in the transportation system and could damage roads in the long term, especially damaging the subgrade layers (City of San Diego, 2019).	*Storm Surge with SLR Adaptive Capacity:* Medium There is significant redundancy in the roadway network and the Transportation and Storm Water Department could prepare for periodic flooding by setting up pumps, building berms, and closing flood gates, as well as providing anticipated areas of road closures (Consultation with City of San Diego TSWD, 2019). Longer-term adaptation is more difficult. For example, porous pavement is not an option for major roads (Consultation with City of San Diego TSWD, 2019). Repairs resulting from previous storms have been relatively low-cost (FEMA, 2017; City of San Diego, 2017b).
Coastal Erosion Sensitivity: High Roads are highly sensitive to erosion and have already begun to suffer the impacts. If major routes become eroded, new routes should be created (ICLEI, 2017).	*Coastal Erosion Adaptive Capacity:* Medium Permanent impacts from erosion pose a more significant challenge for adaptation (ICLEI, 2017). However, there is significant redundancy in the roadway network. Rerouting traffic through a detour or temporarily limiting service on affected roads would affect fewer travelers than on state-owned routes (e.g., state highways and freeways).
Drain Pump Stations	

SLR Sensitivity: High Storm water assets may become inundated from sea level rise and higher groundwater levels. Inundation of the system could cause the pumps to continuously run without making progress, resulting in pump failure and burnout.	*SLR Adaptive Capacity: Low* It is relatively difficult to adapt drain pump stations (by increasing elevation, adding backflow valves, and/or installing additional pumps). There are spatial and topographical constraints to elevating drain pump stations, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of a station. As of 2019, the cost to replace one drain pump station could be between $4.5 and $6 million (Consultation with City of San Diego TSWD, 2019). Pumps may have to be reconfigured for a greater strength or capacity.
Storm Surge with SLR Sensitivity: Medium Storm water assets may become inundated from floods and higher groundwater levels. Periodic flooding from storm surge, however, would be less detrimental than chronic inundation.	*Storm Surge with SLR Adaptive Capacity: Low* It is relatively difficult to adapt drain pump stations (by increasing elevation, adding backflow valves, and/or installing additional pumps). There are spatial and topographical constraints to elevating drain pump stations, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of a station (Consultation with City of San Diego TSWD, 2019). As of 2019, the cost to replace one drain pump station could be between $4.5 and $6 million (Consultation with City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*
Outfalls	
SLR Sensitivity: High There are outfalls with elevation that would be chronically inundated/submerged, resulting in poor drainage and/or backflow of water. The storm water system may become inundated from floods and higher groundwater levels, and a redesign would be necessary to accommodate changing sea level elevations (e.g., outfall elevation).	*SLR Adaptive Capacity: Low* It is relatively difficult to adapt outfalls (by increasing elevation and/or adding backflow valves). There are spatial and topographical constraints to elevating outfall pipes, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (Consultation with City of San Diego TSWD, 2019). As of 2019, the cost to replace one storm water

	outfall could be between $1.35 and $2 million (Consultation with City of San Diego TSWD, 2019).
Storm Surge with SLR Sensitivity: Medium Storm surge may temporarily impede the effectiveness of the storm water system/outfalls by preventing storm water drainage, especially for gravity-fed portions of the system.	*Storm Surge with SLR Adaptive Capacity: Low* It is relatively difficult to adapt outfalls (by increasing elevation and/or adding backflow valves). There are spatial and topographical constraints to elevating outfall pipes, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (Consultation with City of San Diego TSWD, 2019). As of 2019, the cost to replace one storm water outfall could be between $1.35 and $2 million (Consultation with City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: High Erosion could compromise the functionality of the system.	*Coastal Erosion Adaptive Capacity: Low* It is relatively difficult to adapt outfalls as there are the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (Consultation with City of San Diego TSWD, 2019). As of 2019, the cost to replace one storm water outfall could be between $1.35 and $2 million (Consultation with City of San Diego TSWD, 2019).
Levees	
SLR Sensitivity: Medium By their nature, levees are meant to endure daily exposure to water and are designed with flooding in mind. However, daily overtopping would render the levees ineffective.	*SLR Adaptive Capacity: Medium* Increasing the height of the levees is an option; however, doing so generally requires federal approval and significant resources.
Storm Surge with SLR Sensitivity: Low By their nature, levees are meant to endure daily exposure to water and are designed with flooding in mind.	*Storm Surge with SLR Adaptive Capacity: Medium* Increasing the height of the levees is an option; however, doing so generally requires federal approval and significant funding.
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*

Transportation and Storm Water Vulnerability to Precipitation-driven Flooding

The City found that all transportation and storm water critical asset types except airports show medium to high vulnerability to precipitation-driven flooding. Those showing high vulnerability include drain pump stations and outfalls. The high outfall vulnerability indicates a broader vulnerability of the storm water system, which also includes storm water conveyance pipes and channels. These pipes and channels were not formally assessed, but are considered as part of the storm water system when discussing sensitivity and adaptive capacity in Table 46 below (see the outfalls portions of the table). When considering updates to the storm water system to address climate change vulnerabilities, the complete storm water system needs to be taken into consideration. For the system to function, the entire interconnected system must be resilient.

The results of the vulnerability assessment of transportation and storm water critical asset types to precipitation-driven flooding are shown in Table 45. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to precipitation-driven flooding. Table 46 provides the rationale for the sensitivity and adaptive capacity scores.

Table 45. Vulnerability of Transportation and Storm Water Critical Asset Types to Precipitation-driven Flooding

	Airports [36]	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	Low	High	High	High	High	High
Sensitivity	Medium	Medium	Medium	Medium	High	Low
Adaptive Capacity	Medium	Medium	Medium	Low	Medium	Medium
Vulnerability	Low	Medium	Medium	High	High	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scorin g methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Transportation and Storm Water Exposure to Precipitation-driven Flooding

All transportation asset types except airports have assets within the 100- and 500-year floodplains, though these exposed assets represent a relatively small proportion of total transportation assets. Storm water assets face greater proportional exposure to precipitation-driven flooding than do transportation assets (Figure 31). About twelve percent of major arterial segments may be exposed to precipitation-driven flooding, and about half of these lie in the 100-year floodplain. Bridges may be less exposed to

[36] The Real Estate Assets Department (READ) manages the City-owned airports. All other transportation assets are managed by the Transportation and Storm Water Department (TSWD).

precipitation-driven flooding, but most of the assets that are exposed lie in the 100-year floodplain (which carries a higher exposure score).

According to institutional knowledge of the Transportation and Storm Water Department, forty road locations have historically been subject to precipitation-driven flooding.[37] These locations are largely local roads, including roads in downtown San Diego (Figure 29) and near Mission Bay (Figure 30). Under a climate change scenario, the quantity of locations subject to future flooding is likely to increase.

[37] The locations where roadways experience repeated flooding were identified based on the knowledge and expertise of the transportation department. While this testimony is critical institutional knowledge, no easily accessible documentation is available to support this information. This could mean that certain locations are more memorable, and some sites may be missed, or the damages could be misrepresented. Incident reports or other documentation of damages would help corroborate the findings and provide more robust data on the frequency or duration of flooding.

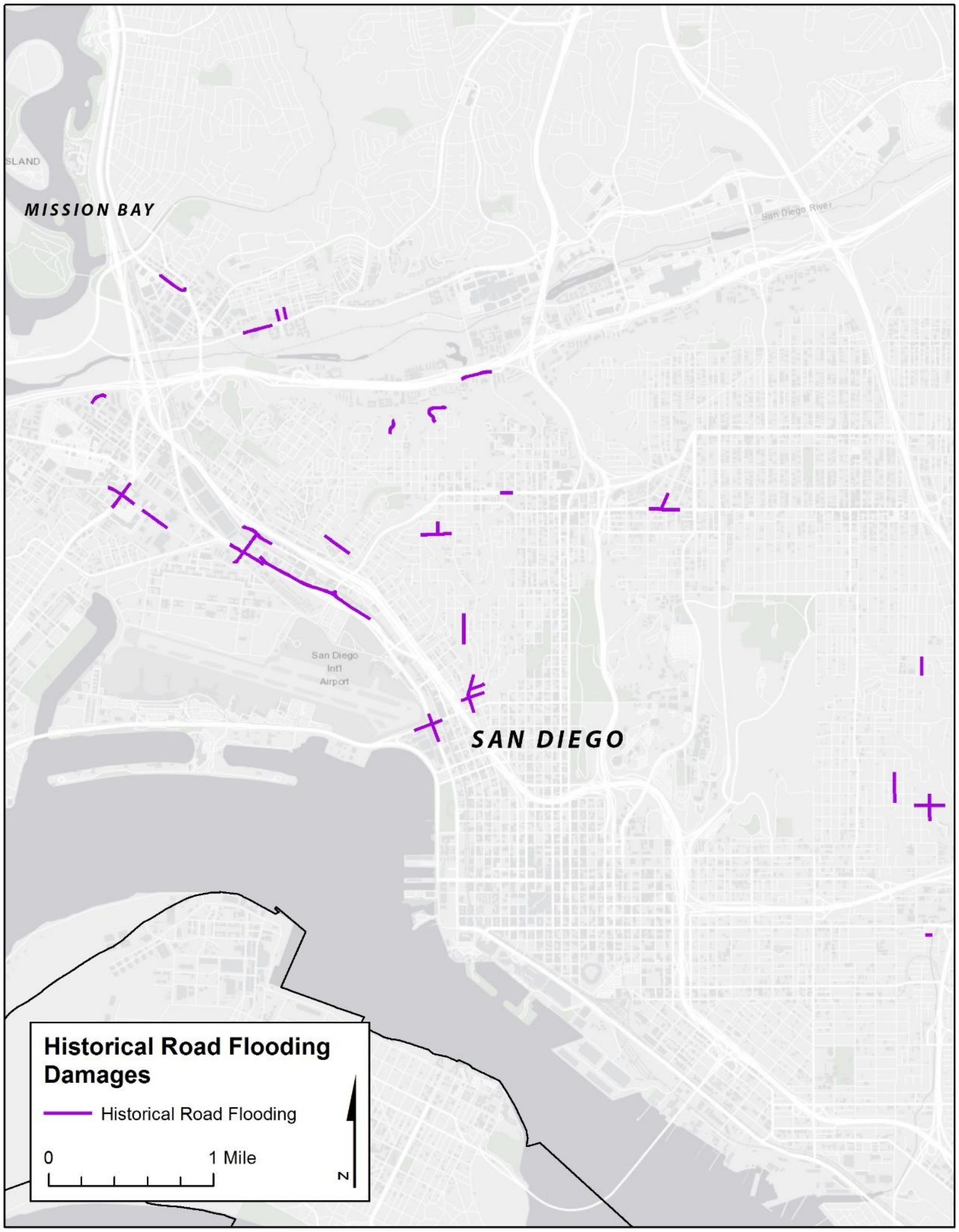

Figure 29. Areas of historical road flooding damages in downtown San Diego. Data courtesy of Street Division.

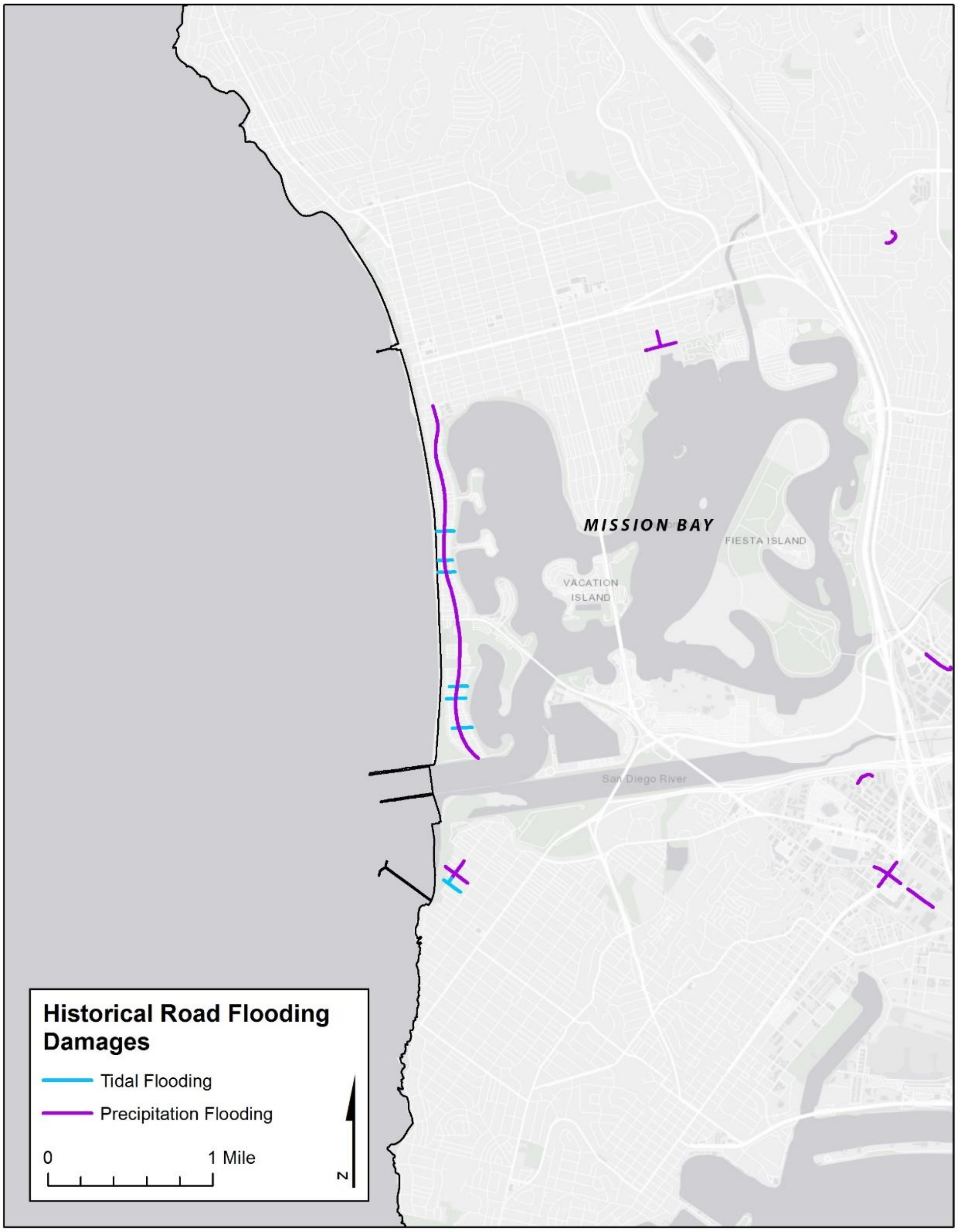

Figure 30. Locations of historical road flooding damage in the City of San Diego Mission Bay area. Data courtesy of Street Division.

One location that has historically flooded is along Aero Drive near the Montgomery-Gibbs Executive Airport; however, the airport itself is not exposed to the 100- or 500-year floodplains. As Aero Drive is the only route available to reach the main entrance to Montgomery-Gibbs Executive Airport, flooding of this road would cut off access to portions of the airport. Historical flooding in this area could be attributed to the hard pan surface of the soil underneath the airport, which has previously resulted in flooding and the formation of vernal pools during heavy rain events.[38] Additionally, institutional knowledge from the airport team within the Real Estate Assets Department (READ) indicates that the City airports have experienced pooling during particularly heavy rain years, which could lead to complications for aviation equipment. As such, airports were included as "exposed" for this vulnerability assessment, although they are not represented as such in Figure 31 below.

Both storm water asset types—drain pump stations and outfalls—have about thirty-five percent of their assets lying in the 100-year floodplain. Drain pump stations have roughly an additional ten percent of assets lying in the 500-year floodplain, while outfalls have an additional fifteen percent in the 500-year floodplain.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

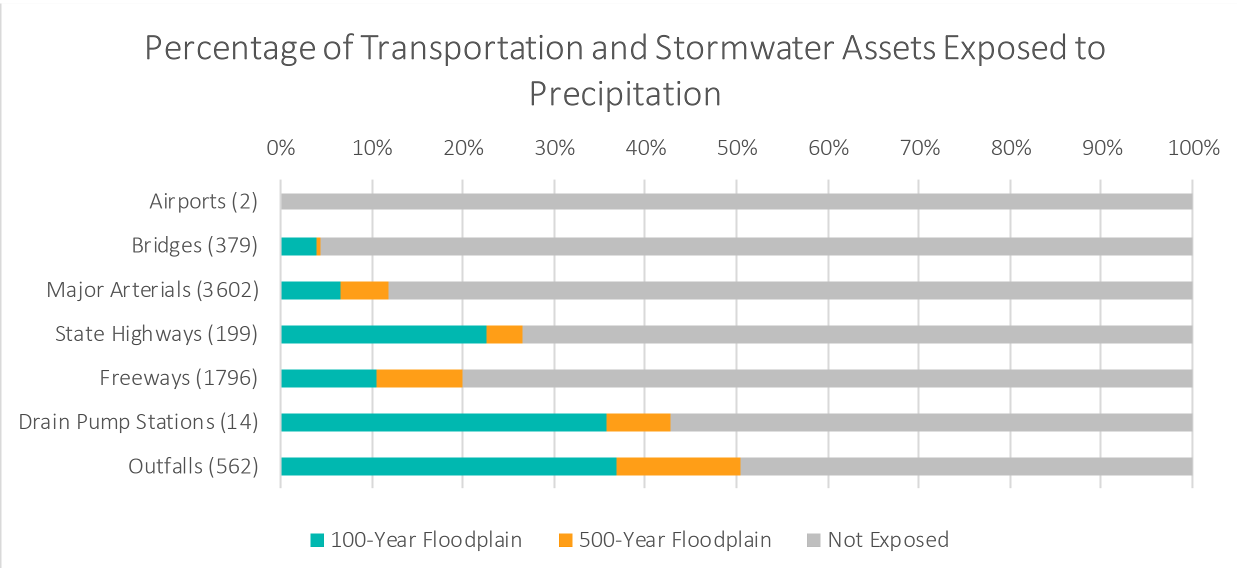

Figure 31. Transportation and storm water critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

Levee Exposure to Precipitation-driven Flooding

The southern bank of the San Diego River levee system is not vulnerable to precipitation-driven flooding, as infrastructure developed after the levees were put in place (including Caltrans-built Interstate 8) was

[38] A vernal pool, sometimes called an "ephemeral pool" due to its impermanence, is a small pond or lake formed by seasonal rains. These areas may fill up or dry out multiple times over the course of a season, depending on precipitation and drought patterns.

built higher than the FEMA floodplain level (Consultation with City of San Diego Transportation and Storm Water Department, 2020).

The northern bank is at a lower elevation and may be exposed to potential precipitation-driven overtopping as storm events increase in intensity and as sea levels rise.

Transportation and Storm Water Sensitivity and Adaptive Capacity to Precipitation

Based on the exposure analysis, the City assessed the sensitivity and adaptive capacity of all transportation and storm water critical asset types to precipitation. The results of this analysis are shown in Table 46 below.

Table 46. Sensitivity and Adaptive Capacity of Transportation and Storm Water Critical Asset Types to Precipitation-driven Flooding

Airports	
Precipitation Sensitivity Rating: Medium The soil underneath the airport is a hard pan, which does not allow for typical water absorption. This could result in vernal pool formation. In previous heavy rain events, pools have caused problems with aviation equipment (e.g., radar technology that bounces off the ground experiences interference from pooling; standing water may make it unsafe to operate aircraft). Heavy precipitation and flooding could also lead to erosion, potholes, and sink holes on taxiways. When rain causes flooding, the airports have to close off access to unpaved areas such as the perimeter road to avoid impacts to environmental resources. Flooding could also prevent emergency access to the area. In addition, mowing crews may not be able to properly maintain airfields during wet conditions (Consultation with City of San Diego Real Estate Assets Department, 2019).	*Precipitation Adaptive Capacity Rating: Medium* Airport staff could take some preemptive measures to prepare for certain impacts of precipitation-based flooding (e.g., mowing in advance of a forecasted storm). Airports could also implement runway grooving techniques, which provides skid resistance and prevents hydroplaning during wet weather (FAA, 2007). The airports have an asphalt rehabilitation program and schedule in place to help maintain taxiways and mitigate long-term damage. Green infrastructure measures that are well-suited to catching and holding storm water (and therefore mitigating flooding) are less suitable to airports, as bird populations should be discouraged from establishing at airports or else they are at risk of being struck by planes and possibly interrupting flight operations and/or damaging equipment.
Bridges	
Precipitation Sensitivity Rating: Medium Increased precipitation could lead to flooding and scour and could wash debris into bridges, potentially resulting in failure (FHWA, 2012). A majority of bridges in San Diego have gone through major rehabilitation improvements and have been seismically retrofitted. (City of San	*Precipitation Adaptive Capacity Rating: Medium* There is limited redundancy in the bridge network. Currently there is no routine maintenance performed on bridges, and no routine funds allocated for maintenance and repair. However, if it is a priority repair, safety related, the City addresses those needs (Consultation with City of San Diego TSWD, 2019). Before every storm, the City prepares for recovery by

Diego, 2019). Typically, bridge and roadway drainage design standards are for a 100-year storm. For bridges that cross over a channel or river rather than a roadway, the design standard may change to suit needs (e.g., West Mission Bay Drive is designed to withstand a 500-year tsunami).	organizing a fleet of vehicles essential to performing tasks such as clearing logjams, etc. The City removes logs and debris using cranes after flooding/storm events.
Major Arterials	
Precipitation Sensitivity Rating: Medium Periodic flooding of major arterials could cause significant disruptions in the transportation system and could damage roads in the long term, especially damaging the subgrade layers (City of San Diego, 2019).	*Precipitation Adaptive Capacity Rating: Medium* There is significant redundancy in the roadway network and the Transportation and Storm Water Department could prepare for periodic flooding by setting up pumps, building berms, and closing flood gates, as well as providing anticipated areas of road closures (Consultation with City of San Diego TSWD, 2019). Longer-term adaptation is more difficult. For example, porous pavement is not an option for major roads (Consultation with City of San Diego TSWD, 2019). Repairs resulting from previous storms have been relatively low-cost (FEMA, 2017; City of San Diego, 2017b).
Drain Pump Stations	
Precipitation Sensitivity Rating: Medium Drain pump stations may become overwhelmed if the volume of precipitation exceeds their capacity. However, the last time that significant damage occurred due to a pump station being underwater, multiple factors converged to cause the damage, such as debris, rain, and high tide (Consultation with City of San Diego TSWD, 2019).	*Precipitation Adaptive Capacity Rating: Low* It is relatively difficult to adapt drain pump stations (by increasing elevation, adding backflow valves, and/or installing additional pumps). There are spatial and topographical constraints to elevating drain pump stations, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of a station (Consultation with City of San Diego TSWD, 2019). As of 2019, the cost to replace one drain pump station could be between $4.5 and $6 million (Consultation with City of San Diego TSWD, 2019).
Outfalls	

Precipitation Sensitivity Rating: High The intensity and duration of the rain determines the amount of damage experienced. Storm water systems (which include outfalls as well as pipes and channels) are typically able to keep up with rain events, but rapid high-volume peak flows could quickly overwhelm the drainage system. In general, storm drain conveyance systems are designed for 100-year storms per the Drainage Design Manual. This means that these systems are equipped to handle current 100-year storms but may need to be upgraded if the 100-year storm is projected to become more intense or if the systems are within the 500-year floodplain (Consultation with City of San Diego TSWD, 2019). The age of the overall storm drain system may require system upgrades to address increased precipitation (Consultation with City of San Diego TSWD, 2019).	*Precipitation Adaptive Capacity Rating: Medium* Adding capacity (e.g., to deal with more intense storms and higher volumes of precipitation) is difficult when the asset in question would require additional area in a location constrained by existing structures and/or easement widths. As of 2019, the cost to replace one storm water outfall could be between $1.35 and $2 million. This cost does not include updates to the connected storm water conveyance system (e.g., pipes and channels). Storm water pipes and channels are necessary for overall system functioning and would also be in need of resilience upgrades to deal with more intense storms and higher volumes of storm water (Consultation with City of San Diego TSWD, 2019).
Levees	
Precipitation Sensitivity Rating: Low By their nature, levees are meant to endure daily exposure to water and are designed with flooding in mind.	*Precipitation Adaptive Capacity Rating: Medium* Increasing the height of the levees is an option; however, doing so generally requires federal approval and significant funding.

Transportation and Storm Water Vulnerability to Heat

The City found that all transportation and storm water critical asset types face exposure to heat, though drain pump stations' and levees' low exposure indicates nearly negligible vulnerability as areas with low urban heat island scores are expected to experience extreme heat events less frequently than areas with higher scores.

The results of the vulnerability assessment of transportation and storm water critical asset types to heat are shown in Table 47. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to heat. Table 48 provides the rationale for the sensitivity and adaptive capacity scores.

Table 47. Vulnerability of Transportation and Storm Water Critical Asset Types to Heat

	Airports [39]	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	Medium	High	High	Low	High	Low
Sensitivity	Medium	Low	Low	Low	Low	Low
Adaptive Capacity	Medium	Medium	High	High	High	High
Vulnerability	Medium	Medium	Medium	Low	Medium	Low

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Transportation and Storm Water Exposure to Heat

The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[40] A score of zero indicates that there is no difference in temperature over time between an urban Census tract and nearby upwind rural reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

In San Diego, coastal areas are relatively cooler than inland areas due to the moderating impacts of the ocean and offshore winds. This coastal effect dominates the urban heat island effect in the City.

Many transportation and storm water critical assets face low exposure to extreme heat (Figure 32).

Major arterial segments face the highest relative exposure to the higher set of potential temperatures compared to other transportation asset types, including over ten percent of major arterials that may be exposed at the 100+ heat index range.[41] Over half of bridges may be exposed at the 20+ heat index range. Both Montgomery-Gibb's Executive Airport and Brown Field Municipal Airport face exposure to heat, with Montgomery-Gibbs Executive Airport falling in the 40 to 60

[39] The Real Estate Assets Department (READ) manages the City-owned airports. All other transportation assets are managed by the Transportation and Storm Water Department (TSWD).

[40] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

[41] The major arterial asset type was assessed at the County level for exposure to heat, which included a total of 8,089 major arterial segments (exposed and un-exposed together). There are 3,602 major arterial segments in the City; only these segments were analyzed for the other hazards as the spatial analysis for other hazards was limited to the City boundary.

heat index range and Brown Field Municipal Airport falling in the 20 to 40 heat index range. For all asset types, assets exposed to the 0 to 20 heat index range (relatively low exposure) make up the largest portion of exposed assets.

Most storm water assets may be exposed to heat ranges which do not denote frequent high temperatures; all drain pump stations may be exposed to heat at the 0 to 20 heat index range. Most (over seventy percent) outfalls may be exposed to heat at the 0 to 20 heat level range. Only one outfall may be exposed at the 80 to 100 range.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the heat levels.

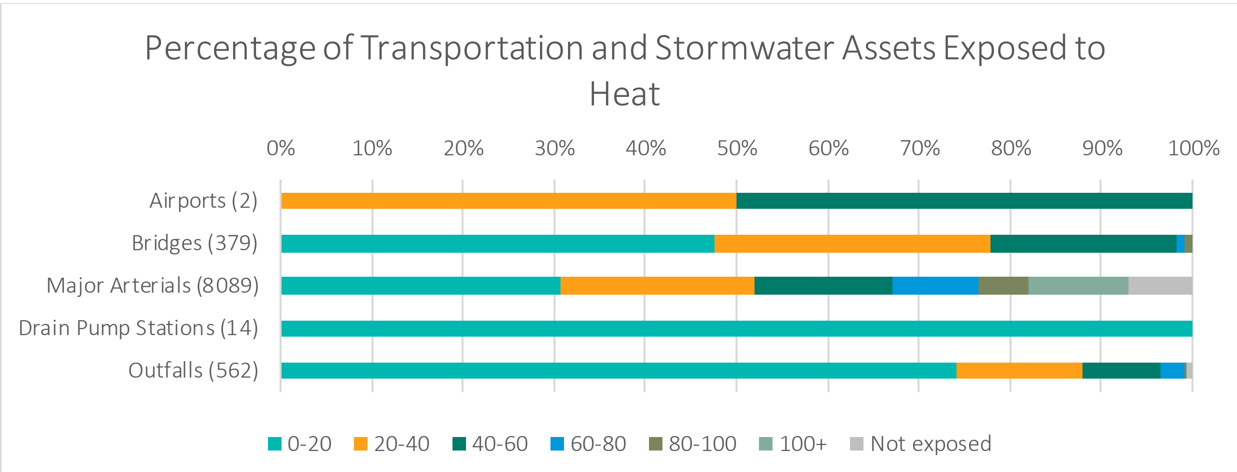

Figure 32. Transportation and storm water critical assets exposed to extreme heat. The value after each asset name indicates the asset count. The colored bars represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

Levee Exposure to Heat

The San Diego River south bank levee is within the 0 to 20 UHI zone, with the westernmost portion (coastal) having a 5.8 degree-hour day and the easternmost portion (inland) having a 14.1 degree-hour day.

Transportation and Storm Water Sensitivity and Adaptive Capacity to Heat

Based on the exposure analysis, the City assessed the sensitivity and adaptive capacity of all transportation and storm water critical asset types to heat. The results of this analysis are presented in Table 48.

Table 48. Sensitivity and Adaptive Capacity of Transportation and Storm Water Critical Asset Types to Heat

Airports	
Heat Sensitivity Rating: Medium	*Heat Adaptive Capacity Rating: Medium*
Airport runways may experience road softening or buckling from high temperatures, which could affect planes' ability to take off and land.	Airports could implement high heat day rules (e.g., starting outdoor work earlier and rotating shifts) to protect crews while ensuring that

Additionally, crews may not be able to maintain airfields (e.g., by mowing) during high heat conditions, as outdoor physical labor in high heat can lead to heat illness. This has potential implications for the efficiency of air transportation. Hot air is less dense, which lowers an aircraft's ability to generate lift. In extreme heat conditions, some aircraft may lose the ability to take off or land until temperatures decrease (Federal Aviation Administration, 2008).	outdoor work could be accomplished. In addition, airports could issue extreme heat advisories to pilots and recommend they fly earlier or later in the day.
Bridges	
Heat Sensitivity Rating: Low Bridges may experience pavement thermal expansion, which could increase rates of deterioration (NRC, 2008).	*Heat Adaptive Capacity Rating:* Medium There is limited redundancy in the bridge system. Currently there is no routine maintenance performed on bridges, and no routine funds allocated for maintenance and repair. However, if it is a priority repair, safety related, the City addresses those needs (Consultation with City of San Diego TSWD, 2019).
Major Arterials	
Heat Sensitivity Rating: Low Asphalt pavement may crack, warp, soften, and/or buckle. Asphalt may bleed from old pavements (Mills & Andrey, 2002). Concrete may heave at joints (Heitzman, 2010).	*Heat Adaptive Capacity Rating:* High Asphalt is milled and replaced on a relatively frequent cycle (about twenty years), which allows for pavement mixes that are less susceptible to heat impacts to be used in the future (U.S. DOT, 2018).
Drain Pump Stations	
Heat Sensitivity Rating: Low Heat is not expected to significantly impact drain pump stations, unless extreme heat leads to power outages. In such a case, service could be temporarily interrupted.	*Heat Adaptive Capacity Rating:* High Backup (diesel) pumps can be moved to affected facilities in the event of a power outage (City of San Diego, PUD 2019).
Outfalls	
Heat Sensitivity Rating: Low Outfalls are not anticipated to be sensitive to heat.	*Heat Adaptive Capacity Rating:* High Adaptation of outfalls to heat is likely not necessary.
Levees	
Heat Sensitivity Rating: Low Generally, there is little impact that heat could pose to earthen levees.	*Heat Adaptive Capacity Rating:* High Adaptation of levees to heat is likely not

	necessary.

Transportation and Storm Water Vulnerability to Wildfires

The City found that all transportation and storm water critical asset types are highly vulnerable to wildfire except for outfalls and levees, which show medium vulnerability to wildfire.

The results of the vulnerability assessment of transportation and storm water critical asset types to wildfire are shown in Table 49. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to wildfire. Table 50 provides the rationale for the sensitivity and adaptive capacity scores.

Table 49. Vulnerability of Transportation and Storm Water Critical Asset Types to Wildfire

	Airports[42]	Bridges	Major Arterials	Drain Pump Stations	Outfalls	Levees
Exposure	High	High	High	High	High	High
Sensitivity	High	High	High	High	Medium	Medium
Adaptive Capacity	Medium	High	High	Medium	Medium	High
Vulnerability	High	High	High	High	Medium	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Transportation and Storm Water Exposure to Wildfire

All transportation and storm water critical asset types face exposure to wildfire (Figure 33). Of the exposed assets, most face high exposure; this includes 1 of the airports, 186 bridges, 1,048 major arterial segments, 3 storm water drain pump stations, and 163 storm water outfalls.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

Wildfire Hazard Zones for San Diego

High: Native vegetation and 100-foot setback zones

Medium: 300-foot setback zone

Low: Fire hazard zone outside native vegetation zone and setbacks

[42] The Real Estate Assets Department (READ) manages the City-owned airports. All other transportation assets are managed by the Transportation and Storm Water Department (TSWD).

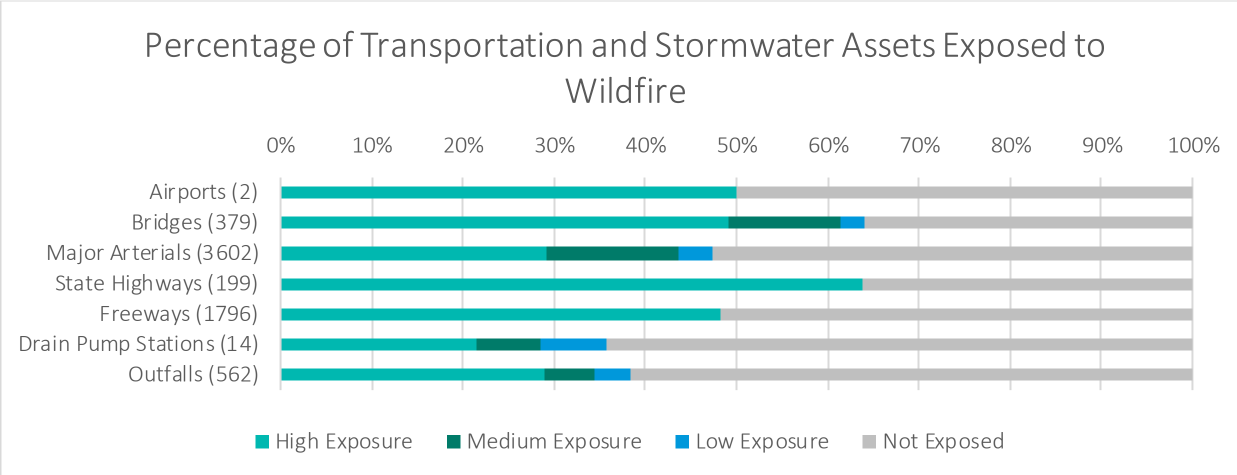

Figure 33. Transportation and storm water critical assets exposed to wildfire. The value after each asset name indicates the asset count.

Levee Exposure

The levees directly overlap with the 100-foot setback from the native vegetation hazard zone (see Figure 34), which confers a high exposure score, and the river area generally contains vegetation that is relatively dry in summer months.

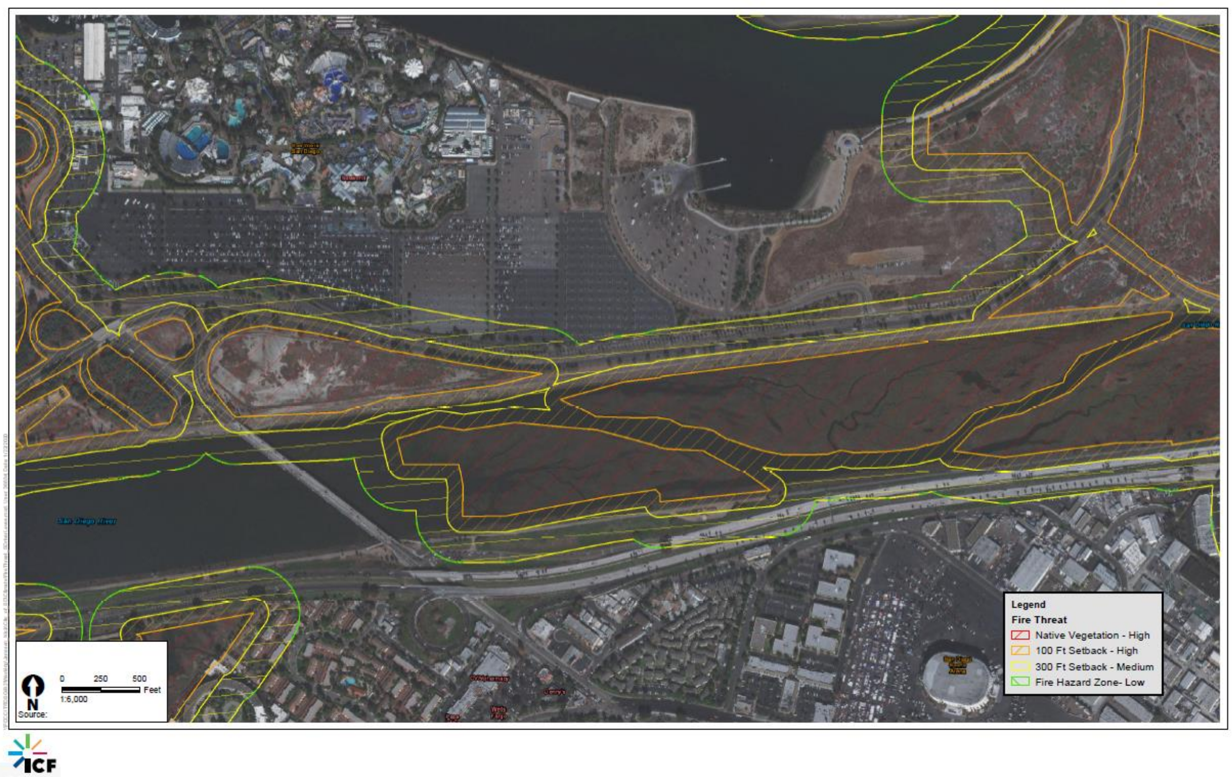

Figure 34. Levee exposure to the 100-foot setback fire hazard zone. Fire hazard zone data obtained from the City of San Diego. Map created 2020.

Transportation and Storm Water Sensitivity and Adaptive Capacity to Wildfire

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of all transportation and storm water critical asset types to wildfire. The results of this analysis are presented in Table 50.

Table 50. Sensitivity and Adaptive Capacity of Transportation and Storm Water Critical Asset Types to Wildfire

Airports	
Wildfire Sensitivity Rating: High Wildfire could cause damage to airport facilities and airplanes. Additionally, smoke from wildfires could limit the ability of planes to safely take off and land, and general wildfire hazards (fire, debris, smoke) could limit access to the airports.	*Wildfire Adaptive Capacity Rating: Medium* Airports have defensible space to protect against burning. In addition, only Montgomery-Gibbs Executive Airport faces potential exposure to wildfire, so there is redundancy in Brown Field Municipal Airport (not exposed) as well as in the major commercial airports, such as San Diego International Airport (Consultation with City of San Diego READ, 2019).
Bridges	
Wildfire Sensitivity Rating: High Burned bridges should be replaced after wildfires (City of San Diego, 2007). The cost to replace bridges is relatively high (City of San Diego, 2019).	*Wildfire Adaptive Capacity Rating: High* The City has budgeted for proactive tree pruning and removes dead trees within the developed right-of-way. Other brush management is conducted based on Fire Marshall requests, which prioritize areas near habitable structures (Consultation with City of San Diego TSWD, 2019).
Major Arterials	
Wildfire Sensitivity Rating: High Wildfire could damage roads in several ways. Unsafe conditions and damage could lead to road closures. Typical asphalt mixtures could ignite or melt/excessively soften. Debris from fires and subsequent landslides could block roads (Carvel & Torero, 2006; Cannon & DeGraff, 2009; Jofré, Romero, & Rueda, 2010).	*Wildfire Adaptive Capacity Rating: High* Most major roads have sidewalks that create a small defensible space as well as development of the surrounding areas. The City has budgeted for proactive tree pruning and removes dead trees within the developed right-of-way. Other brush management is conducted based on Fire Marshall requests, which prioritize areas near habitable structures (Consultation with City of San Diego TSWD, 2019).
Drain Pump Stations	
Wildfire Sensitivity Rating: High Wildfires could burn and damage drain pump stations. Wildfires could also alter hydrology by changing vegetation, increasing runoff and resulting in	*Wildfire Adaptive Capacity Rating: Medium* The City has a brush management program in place to reduce wildfire risk around critical assets. As of 2019, the cost to replace one drain pump station could be between $4.5 and $6 million

more sediment that could block drainage and damage structures (U.S. DOT, 2018).	(Consultation with City of San Diego TSWD, 2019).
Outfalls	
Wildfire Sensitivity Rating: Medium Wildfires could alter hydrology by changing vegetation, increasing runoff and resulting in more sediment that could block drainage and damage structures (U.S. DOT, 2018). This impact would be caused by upstream factors; wildfires are unlikely to directly burn and/or damage outfalls themselves due to construction materials and placement near bodies of water.	*Wildfire Adaptive Capacity Rating: Medium* The City has a brush management program in place to reduce wildfire risk around critical assets. As of 2019, the cost to replace one storm water outfall could be between $1.35 and $2 million (Consultation with City of San Diego TSWD, 2019).
Levees	
Wildfire Sensitivity Rating: Medium Fire might have an impact on the structure of earthen levees themselves, essentially "baking" the soil and making them more hydrophobic. The larger impact, however, would be the potential for wildfires to increase peak flows during post-fire floods due to the impact of the wildfire on the watershed. According to the USDA, "hydrophobic conditions, bare soils, and litter and plant cover loss will cause flood peaks to arrive faster and at higher levels" (USDA, 2005). However, since the San Diego area is largely urbanized, this specific risk is lessened.	*Wildfire Adaptive Capacity Rating: High* The City has an existing fire management program to mitigate the possibility for vegetation around assets to catch and spread fires. The levees are in an urbanized area, which increases the availability of firefighting resources.

Open Space and Environment Vulnerability Findings

Open Space and Environment assets include those managed by the City's Parks and Recreation Department, Environmental Services Department (ESD), Public Utilities Department (PUD), and Real Estate Assets Department (READ). The following asset types are considered critical: conservation areas/open space/source water land, community parks, the Miramar landfill, the City's CNG fueling station, and beaches. Not all assets in this list were found to be exposed to climate hazards.

Conservation areas/open space/source water land assets include open space parks (those that do not serve a human/recreational purpose), Multi-Habitat Planning Area (MHPA) land owned and managed by the PUD, and vernal pools conserved under the Vernal Pool Habitat Conservation Plan (VPHCP). MHPA land and VPHCP land are both managed for the purpose of conservation and habitat protection, while land managed by the PUD serves the primary role of source water and watershed protection. Community Parks include developed parks that serve an active recreational purpose. While recreation centers are often associated with parks, these buildings were treated as a separate asset class and are included in the

"Additional Asset Vulnerability Findings" section below. The Miramar Landfill and CNG Fueling Station are managed by the ESD. Beaches are managed by the Parks and Recreation Department.

The results of the vulnerability assessment for open space and environment are shown in Table 51. "N/A" indicates that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were deemed not vulnerable.

Of the open space and environment critical asset types considered, conservation areas/open space/source water land, community parks, and beaches may be exposed to all climate change hazards. The Miramar Landfill and CNG Fueling Station face exposure only to heat and wildfire, hazards to which all open space and environment critical asset types face exposure.

Table 51. Vulnerability of Open Space and Environment Critical Asset Types to Climate Change Hazards[43]

	Sea Level Rise (SLR)	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
Conservation Areas/Open Space/Source Water Land	High	High	High	High	High	High
Community Parks	High	Medium	High	Medium	Medium	High
Miramar Landfill	N/A	N/A	N/A	N/A	Low	Medium
CNG Fueling Station	N/A	N/A	N/A	N/A	Low	Low
Beaches	High	Medium	High	Medium	Low	Medium

Open Space and Environment Consequences

City parks and natural areas provide a variety of recreational opportunities, ecosystem services, and habitat value. Ecosystem services are those provided by nature that contribute to human and environmental wellbeing; they include provisioning services (e.g., providing food and water), regulating services (e.g., climate control and flood prevention), supporting services (e.g., nutrient cycling), and cultural services (e.g., recreation and heritage) (Buttke, 2014). Damage to these areas could have

[43] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections and localized modeling for the chosen climate hazard scenarios, and an assumption of asset type-level (general) of sensitivity and adaptive capacity based on literature reviews and high-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

significant consequences for City services, natural resources and environment, human health, and social equity. For example, habitat loss could be detrimental to many threatened and endangered species.

Open space and environment assets also include built infrastructure, such as the Miramar landfill and CNG fueling station. Damage to these assets could have significant consequences for City services, human health, and social equity. For example, mulch and composting reserves and processing from the landfill would be depleted if there was a fire.

Illustrative examples of the consequences of open space and environmental damage, disruption, and failure are presented in Table 52. This table is provided purely to illustrate potential impacts; it is not meant to imply that these impacts will definitively occur, nor is this list fully comprehensive of all potential consequences to all asset types.

Table 52. Illustrative Consequences of Open Space and Environmental Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Conservation Areas/Open Space/Source Water Land	City Services Human Health Historical, Tribal Cultural, and Archaeological Resources Natural Resources and Environment	Conservation areas and open space in the City of San Diego provide crucial ecosystem services such as the provisioning of clean air and water and climate regulation. If conservation areas are damaged, endangered species could be at increased risk species survival. If habitats of sensitive MHPA and VPHCP-covered species are subject to frequent disturbance or destruction, resources may be needed to adequately conserve these species. In addition, in the event of damage, more insects, pests, or invasive species could move in and out-compete native species. This land includes PUD watershed land managed primarily for the purpose of source water capture. If this land is impacted, then the City's water supply and water quality could be impacted. Conservation areas and open space can include a variety of historical, tribal cultural, and archaeological resources, including the Coronado Belt Line, Piedras Pintados, and various archaeological sites, all of which are City-owned designated historical resources, as well as sites that are covered under the Native American Heritage Commission Sacred Lands File. Additionally, other historical, tribal cultural, and archaeological resources within City-owned conservation and open space areas that are not currently designated may be eligible for designation pending evaluation. Damage to these resources could impact their ability to convey

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
		historical and cultural information and value.
Community Parks	Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources Natural Resources and Environment	Community parks serve a variety of functions in the City of San Diego. They are used for recreation, exercise, as gathering spaces, and sites of natural, historical, tribal cultural, and archaeological resources. Loss of or damage to community parks would interfere with their ability to serve these various functions.
Miramar Landfill	City Services Human Health	This landfill, which is the only City-run landfill, accepts around 3,900 tons of trash per day (City of San Diego, 2019e). If this facility is damaged, trash would need to be put elsewhere to maintain this service. Mulch and composting reserves and processing would be depleted if there was a fire. If the landfill's gas facilities are damaged, the Metropolitan Biosolids Center's energy supply may need a non-renewable backup energy supply, which could increase its greenhouse gas emissions. In the event of a natural disaster, landfills are crucial mitigation hubs: • Water trucks, bulldozers, and other on-site equipment act as key resources for fire suppression and recovery. Damage to this equipment could hinder disaster mitigation efforts. • Local enforcement agencies will allow exceptions to materials that would be typically accepted for trash collection to aid in the cleanup effort. Occupational Safety and Health Administration (OSHA) standards require monitoring workers for risk of heat-related illness and shortening work periods and increasing rest periods as temperature rises. In the case of a wildfire, and destruction of the landfill gas collection system equipment, methane emissions from the landfill could affect surrounding or downwind neighborhoods, disproportionately affecting communities until repairs to the gas collection system are made.

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
CNG Fueling Station	City Services	The CNG fueling station serves the City's fleet, which includes vehicles from a variety of departments. If the CNG fueling station is compromised by climate-related hazards, the fleet would have to look to other sources (privately-owned fueling stations) to maintain normal operations.
Beaches	City Services Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources Natural Resources and Environment	Like community parks, beaches in the City serve a variety of functions, including tourism, recreation, habitat, and as sites for historical, tribal cultural, and archaeological resources. Beaches can also help the public stay cooler during heat events, as the coastline in San Diego is generally cooler than areas further inland and provides access to the ocean. The beach also provides a buffer between the ocean and the built infrastructure of the City, helping to absorb coastal flooding. If beaches were to be impacted by climate hazards, they could lose the ability to provide these key amenities.

Open Space and Environment Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day under each sea level rise scenario. Storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm under each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

The City found that community parks, conservation areas/open space/source water land, and beaches are vulnerable to both coastal flooding and erosion. All erosion scenarios assume 2.0 meters of sea level rise (which is the upper range for 2100).

The results of the vulnerability assessment of open space and environment critical asset types to coastal hazards are shown in Table 53, Table 54, and Table 55. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to coastal hazards. Table 56 provides the rationale for the sensitivity and adaptive capacity scores.

Table 53. Vulnerability of Open Space and Environment Critical Asset Types to Sea Level Rise

SLR	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	Not	Not	High

			exposed	exposed	
Sensitivity	High	High	N/A	N/A	High
Adaptive Capacity	Medium	Low	N/A	N/A	Medium
Vulnerability	High	High	N/A	N/A	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 54. Vulnerability of Open Space and Environment Critical Asset Types to Storm Surge with Sea Level Rise (One Hundred-Year storm)

Storm Surge with SLR	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	Not exposed	Not exposed	High
Sensitivity	High	Medium	N/A	N/A	Medium
Adaptive Capacity	Medium	High	N/A	N/A	Medium
Vulnerability	High	Medium	N/A	N/A	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 55. Vulnerability of Open Space and Environment Critical Asset Types to Coastal Erosion at Medium-High Risk Aversion Scenario of 2m of Sea Level Rise

Coastal Erosion	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	Not exposed	Not exposed	High
Sensitivity	High	High	N/A	N/A	High
Adaptive Capacity	Medium	Medium	N/A	N/A	Medium
Vulnerability	High	High	N/A	N/A	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Open Space and Environment Exposure to Coastal Hazards

A specific subset of open space and environment critical assets may be exposed to coastal hazards (Figure 35).[44] The landfill and CNG fueling station are not exposed.

Beaches face the highest proportional exposure from sea level rise: thirty-nine percent of San Diego's beach area is projected to be exposed to sea level rise by 2030, and up to seventy-one percent is projected to be exposed to sea level rise by 2100 (Figure 35). Community parks and conservation areas/open space/source water land also face high exposure to sea level rise, but a much smaller portion of the assets are projected to be exposed.

Sea Level Rise Projections for San Diego

2030: 0.25 m

2050: 0.5 to 0.75 m

2100: 1.0 to 2.0 m

The number of assets and acres brought into flooding zones under storm surge with sea level rise does not increase significantly; however, assets are exposed earlier in time to storm surges than they are to sea level rise alone (Figure 36). Sixty percent of beach areas become flooded under storm surge conditions with 0.25 meters of sea level rise (2030). Community parks and conservation areas/open space/source water land still face very little exposure to storm surge with sea level rise flooding.

Different assets may become exposed to cliff erosion by 2100, but beaches face the greatest proportional exposure to cliff erosion (Figure 37). Fifteen percent of beach area may be exposed if no adaptive action is taken. This is beach area that currently abuts cliffs, such as along Torrey Pines or Sunset Cliffs Natural Park.

As with cliff erosion, beaches face the greatest exposure to beach erosion: up to twenty percent of beach area may be exposed (Figure 38).

See <u>Appendix C: Exposure Data</u> for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

[44] Due to project constraints, the project team was unable to analyze the exposure of the 30,321 acres of conservation areas/open space/source water land outside the City of San Diego boundary to coastal hazards. This inflates the portion of this asset type that is reported as not exposed to coastal hazards; however, much of this land is inland and would not be exposed.

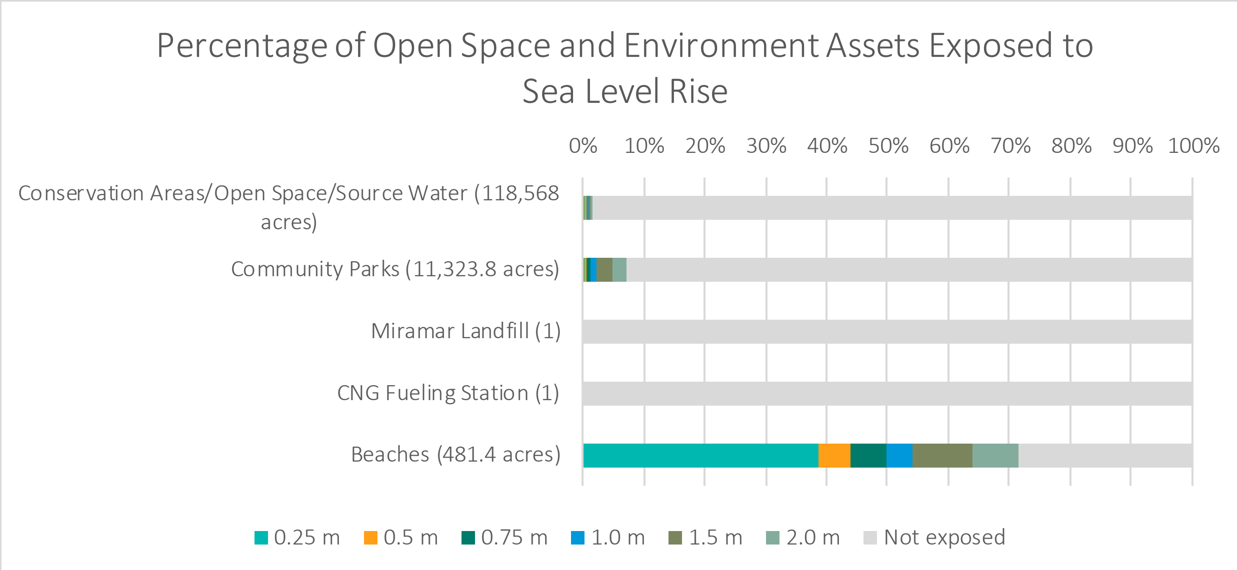

Figure 35. Open space and environment critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

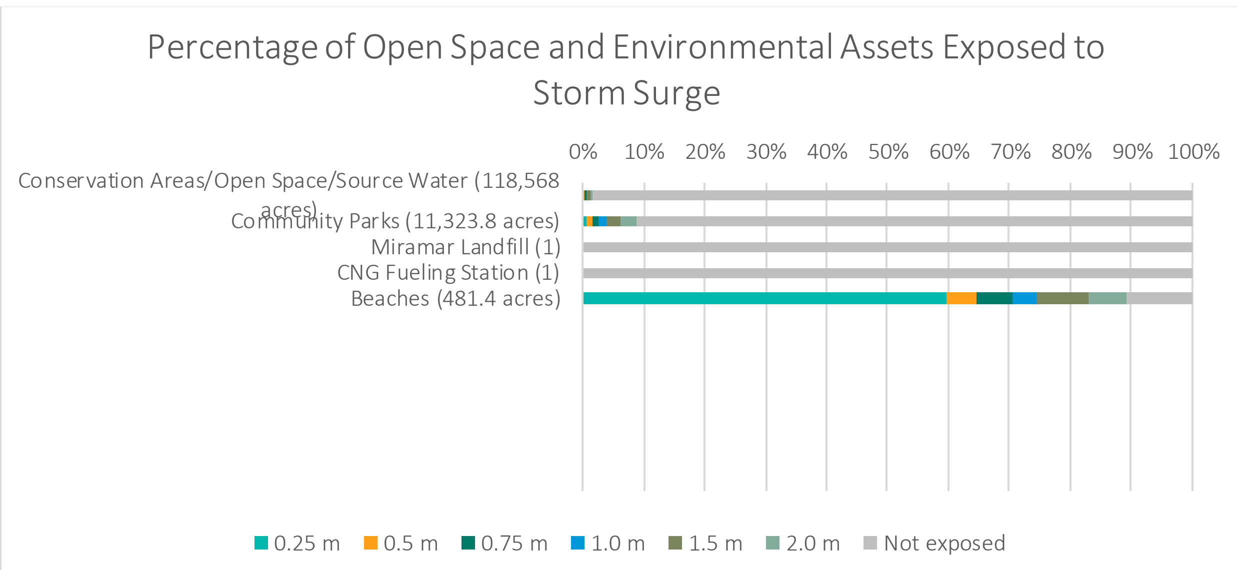

Figure 36. Open space and environment critical assets exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average daily flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

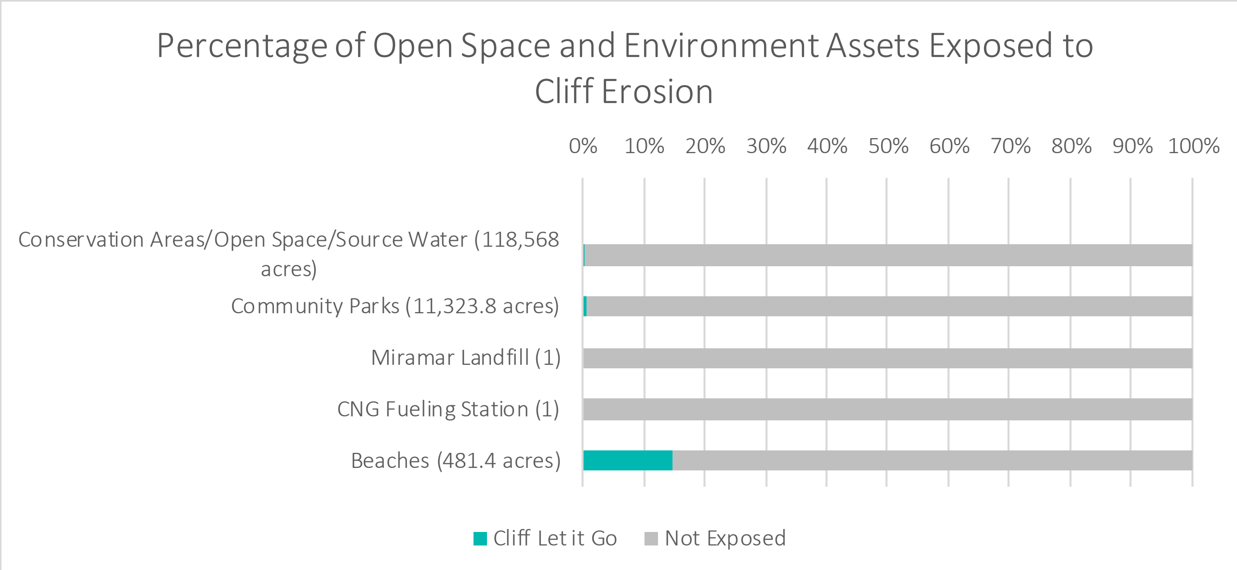

Figure 37. Open space and environment assets critical exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

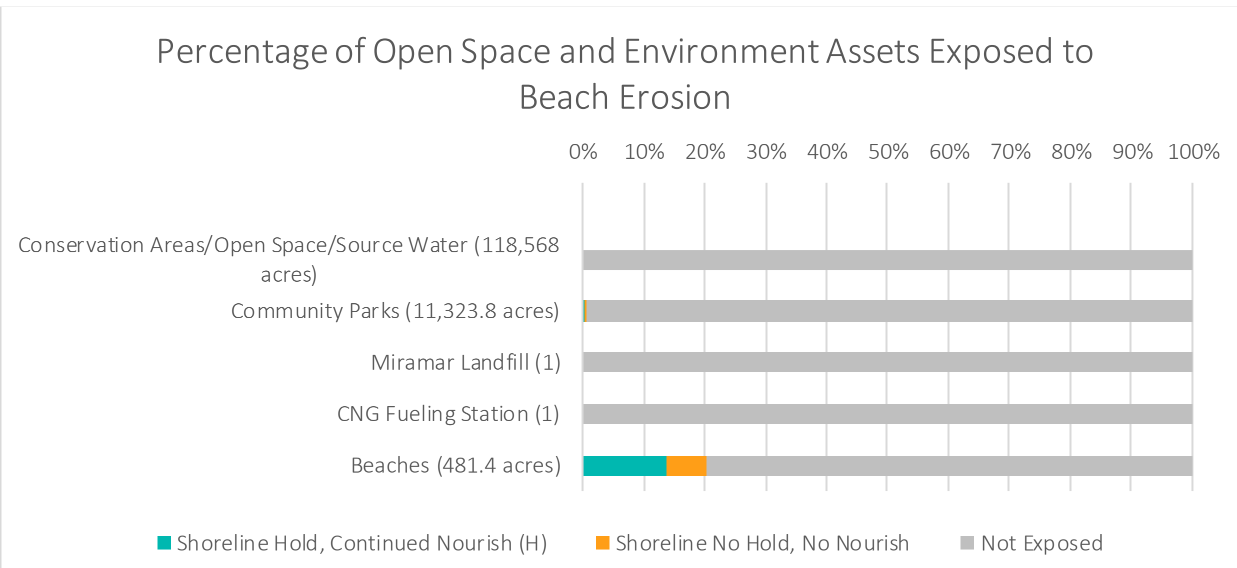

Figure 38. Open space and environment assets critical exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

Open Space and Environment Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of conservation areas/open space/source water land, community parks, and beaches to coastal hazards. The results of this analysis are presented in Table 56.

Table 56. Sensitivity and Adaptive Capacity of Open Space and Environment Critical Asset Types to Coastal Hazards

Conservation Areas/Open Space/Source Water Land	
SLR Sensitivity: High Conservation areas could experience damage or significant alteration if exposed to chronic flooding. The changes to ecosystems that come with sea level rise impacts—changes in sediment, nutrient availability, and salinity—could lead to shifts in habitat locations and may cause certain habitats to shrink or disappear (ICLEI, 2017). Species (including endangered species) may become locally extirpated if certain habitats in conservation areas and parks are lost (Consultation with City of San Diego Parks and Recreation Department, 2019).	*SLR Adaptive Capacity: Medium* If there is sufficient available space and the areas do not abut human or natural barriers, some habitats may be able to migrate inland to reduce exposure to chronic flooding. However, not all habitat types or species would be able to keep pace with sea level rise. Sensitive plant species that have limited distribution and rely on specific habitats within these areas may require assisted relocation. Banking seed from sensitive plant species now (while they are still here) could help ensure the future persistence of these species and is a strategy currently in place at the San Diego Zoo (Davitt, 2018).
Storm Surge with SLR Sensitivity: High Flooding from storms may temporarily disrupt conservation areas, but water could likely be absorbed into the ground. However, the Rare Plant Working Group has identified several rare species that are a high priority for regional conservation and are threatened by more frequent storm surges. As storm surges push salinity farther upstream into traditionally freshwater areas, freshwater species further inland may be threatened and habitat areas may shift (Consultation with City of San Diego Parks and Recreation Department, 2019).	*Storm Surge with SLR Adaptive Capacity: Medium* Most natural areas are able to recover from periodic flooding. Certain species may not be able to adapt to shifting storm surge regimes and/or greater salinity being pushed farther upstream and inland; this includes some rare species identified by the Rare Plant Working Group (Consultation with City of San Diego Parks and Recreation Department, 2019).
Coastal Erosion Sensitivity: High Erosion could erase or significantly alter habitable land within conservation areas. The changes to ecosystems that come with sea level rise impacts—changes in sediment, nutrient availability, and salinity—could lead to shifts in habitat locations and may cause certain habitats to shrink or disappear (ICLEI, 2017). Coastal bluffs such as those at Point Loma and La Jolla are home to sensitive species that might be impacted if there is more coastal erosion. The	*Coastal Erosion Adaptive Capacity: Medium* Inland migration might be possible, though most of these habitats abut human or natural barriers. Sensitive plant species that have limited distribution and rely on specific habitats within these areas may require assisted relocation. Banking seed from sensitive plant species now (while they are still here) could help ensure the future persistence of these species and is a strategy currently in place at the San Diego Zoo

Torrey Pines Bluffs are another conserved sensitive area that could be affected by erosion (Consultation with City of San Diego Parks and Recreation Department, 2019).	(Davitt, 2018).
Community Parks	
SLR Sensitivity: High Chronic flooding could limit access to and use of parks and fundamentally change habitat types. Chronic flooding could also pose a threat to public safety.	*SLR Adaptive Capacity: Low* The City has a beach maintenance program in place that could be updated to account for SLR impacts.
Storm Surge with SLR Sensitivity: Medium Periodic flooding may temporarily limit access to parks, but once flood waters recede the park should be usable again with limited clean up (Consultation with City of San Diego Parks and Recreation Department, 2019).	*Storm Surge with SLR Adaptive Capacity: High* Parks could be modified to mitigate flooding (e.g., increase use of porous materials on trails, parking lots, and playgrounds; high use of natural infrastructure; flood walls).
Coastal Erosion Sensitivity: High Erosion could render the recreational functions of parks useless and pose a threat to public safety.	*Coastal Erosion Adaptive Capacity: Medium* The City of San Diego has some measures in place currently to deal with coastal erosion. For example, the Parks and Recreation Department annually stockpiles sand and kelp to build winter storm berms and to repair erosion caused by high tides and surf (Consultation with City of San Diego Parks and Recreation Department, 2019). In addition, the City recently updated its Coastal Erosion Assessment (2018), which helps pinpoint areas for erosion mitigation efforts.
Beaches	
SLR Sensitivity: High Narrowing sandy areas could limit a beach's ability to provide valuable recreational and ecological services. Current beaches may shrink as sea levels rise.	*SLR Adaptive Capacity: Medium* If allowed, beaches will move landward as sea levels rise. If constrained by coastal protection structures or by natural coastal, beaches will erode as sea levels rise (Spiegel, 2016). In San Diego, most beaches abut an area of urban development and therefore have limited space for inland migration as sea levels rise. Beach nourishment is a common and available approach to combating erosion and has been widely used in San Diego (Brennan, 2018). Beach nourishment provides an additional buffer to beach erosion in the short term.

Storm Surge with SLR Sensitivity: *Medium* Periodic flooding has the potential to limit access to beaches and wash away sand. Once floods recede, the beach could generally resume functionality—albeit with reduced long-term functionality as sea levels rise.	*Storm Surge with SLR Adaptive Capacity:* *Medium* The adaptive capacity of beaches to storm surge and sea level rise is enhanced by beach nourishment that provides an additional buffer to beach erosion. There are measures the City could take to mitigate flood damage to beaches from storm surge (e.g., living shorelines, beach nourishment). However, long-term sea level rise would lead to long-term changes in the shoreline over time as sea levels rise and storm surge impacts reach farther inland (Spiegel, 2016).
Coastal Erosion Sensitivity: *High* By definition, coastal erosion is the inland migration of the shoreline as beaches and cliffs are eroded into the ocean. Thus, beaches could be highly impacted by coastal erosion.	*Coastal Erosion Adaptive Capacity:* *Medium* Beach nourishment is a common and available approach to combating erosion and has been widely used in San Diego (Brennan, 2018). Nourishment provides an additional buffer to beach erosion in the short term. Common hard infrastructure protection such as sea walls and bulkheads could increase rates of erosion at the infrastructure's edge (Spiegel, 2016).

Open Space and Environment Vulnerability to Precipitation Changes

The City found that all open space and environment critical asset types except the Miramar Landfill and CNG Fueling Station are vulnerable to precipitation-driven flooding and changes in precipitation.

The results of the vulnerability assessment of open space and environment asset types to precipitation-driven flooding are shown in Table 57. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to precipitation impacts. Table 58 provides the rationale for the sensitivity and adaptive capacity scores.

Table 57. Vulnerability of Open Space and Environment Critical Asset Types to Precipitation-driven Flooding

	Conservation Areas/Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	Not exposed	Not exposed	High
Sensitivity	High	Medium	N/A	N/A	Medium
Adaptive Capacity	Medium	High	N/A	N/A	High
Vulnerability	**High**	**Medium**	**N/A**	**N/A**	**Medium**

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Open Space and Environment Exposure to Precipitation-driven Flooding

Only two open space and environmental critical asset types are *not* exposed to precipitation impacts: the landfill and CNG fueling station (Figure 39).

Eight percent of community parks, eleven percent of conservation areas/open space/source water land area, and thirty-two percent of beach area lie in floodplains. Most of these open space and environment assets already face exposure under the 100-year floodplain; with a smaller proportion potentially becoming exposed under the 500-year flood scenario.[45]

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

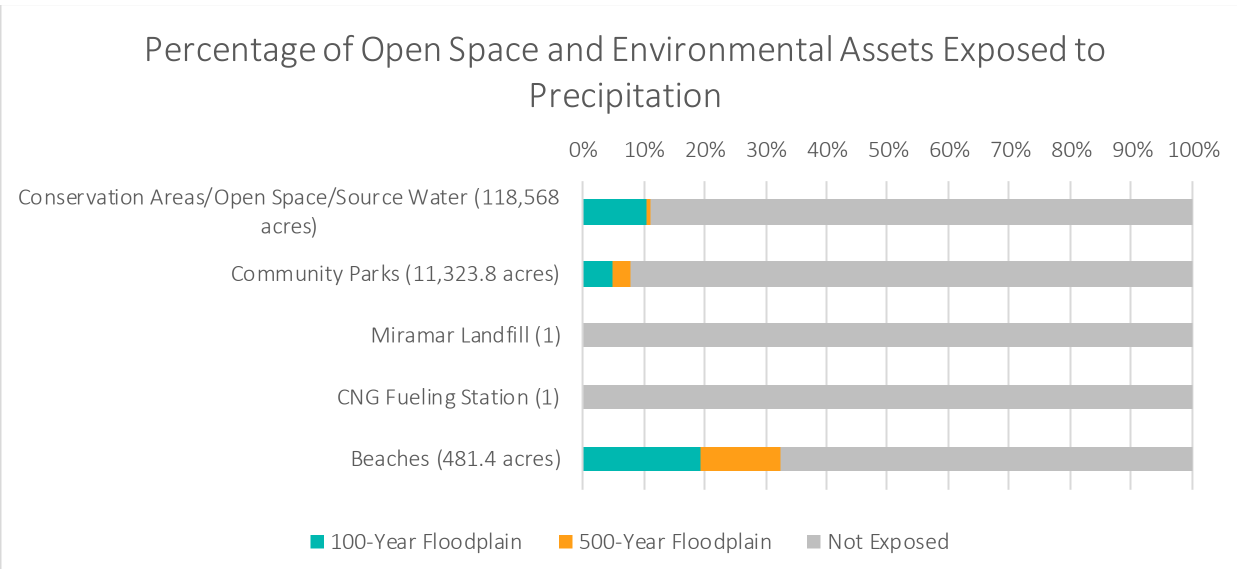

Figure 39. Open space and environment critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

[45] Due to project constraints, the project team was unable to analyze the exposure of the 30,321 acres of conservation areas/open space/source water land outside the City of San Diego boundary to coastal hazards. This inflates the portion of this asset type that is reported as not exposed to precipitation-driven flooding.

Open Space and Environment Sensitivity and Adaptive Capacity to Precipitation-driven Flooding

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of conservation areas/open space/source water land, community parks, and beaches to precipitation. The results of this assessment are shown in Table 58.

Table 58. Sensitivity and Adaptive Capacity of Open Space and Environment Critical Asset Types to Precipitation-driven Flooding

Conservation Areas/Open Space/Source Water Land	
Precipitation Sensitivity Rating: High	*Precipitation Adaptive Capacity Rating: Medium*
Flash flooding has the potential to impact habitats. Increased precipitation patterns could encourage the growth of invasive species, which increases the risk of habitat type conversion (especially for sensitive, rare native habitat types such as coastal scrub and maritime chaparral communities) to exotic grasslands. In addition, flooding in watersheds could impact water quality by bringing more nutrients and total dissolved solids into the water supply. This could also increase eutrophication (Consultation with City of San Diego Parks and Recreation Department, 2019). Studies show that sensitive native habitats are facing difficulty when faced with long-term drought in Southern California and may not be able to adapt to climate-induced changes in drought regimes (Consultation with City of San Diego Parks and Recreation Department, 2019).	If precipitation encourages the growth of invasive species, land management to prevent type conversion would become more intensive and require funding. If the region is experiencing drought, resilience measures such as controlling and managing invasive pests, planting tolerant and diverse plant species assemblages, and assisting migration could be undertaken to restore habitats. Notably, these measures require significant budgets and may be limited by available funding.
Community Parks	
Precipitation Sensitivity Rating: Medium	*Precipitation Adaptive Capacity Rating: High*
Storm events could cause erosion on trails. Past events have blown down trees, which could be costly to remove (FEMA disaster 1731 and February 2017 IDE). Trails could close for two or more days after rain events due to flooding, erosion, and unsafe conditions (City of San Diego Parks and Recreation Department, 2011). Periodic flooding may temporarily limit access to parks, but once flood waters recede the park should be usable again with limited clean up (Consultation with City of San Diego Parks and	Parks could be modified to mitigate flooding (e.g., increase use of porous materials on trails, parking lots, and playgrounds; high use of natural infrastructure.) However, it might be difficult to fully protect trails without limiting the public's access to some features of parks.

Recreation Department, 2019).	
Beaches	
Precipitation Sensitivity: Medium Beaches are not very sensitive to rain-driven flooding. However, runoff from urbanized inland areas could cause localized beach erosion around drainage outfalls and has the potential to carry pollutants to the beach and coastal waters. (EPA, 2016).	*Precipitation Adaptive Capacity: High* Beaches naturally absorb periodic rainwater flooding and will allow the water to filter or run off into the ocean. There is localized reduction in adaptive capacity when drainage outfalls discharge onto beaches, as this increases the volume of storm water the beaches experience. Runoff pollution from further inland could be mitigated through increased groundwater infiltration (e.g., increased green spaces).

Open Space and Environment Vulnerability to Heat

The City found that all open space and environment critical asset types face exposure to heat. However, beaches and CNG fueling stations' low exposures indicates nearly negligible vulnerability for these types of asset, as areas with low urban heat island scores are expected to experience extreme heat events less frequently than areas with higher scores.

While the precipitation section above focused on vulnerability to increases in precipitation and precipitation-based flooding events, vulnerability to heat discussed in this section could be accentuated by a heightened risk of drought, which could particularly affect open space and environmental assets.

The results of the vulnerability assessment of open space and environment critical asset types to heat are shown in Table 59. Cells that are shaded in green indicate asset types that should be prioritized for further attention toward the development of adaptation strategies based on their vulnerability scores. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to heat. Table 60 provides the rationale for the sensitivity and adaptive capacity scores.

Table 59. Vulnerability of Open Space and Environment Critical Asset Types to Heat

	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	Medium	Low	Low
Sensitivity	High	Low	Low	Low	Low
Adaptive Capacity	Medium	High	Medium	High	High
Vulnerability	High	Medium	Low	Low	Low

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Open Space and Environment Exposure to Heat

The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[46] A score of zero indicates that there is no difference in temperature over time between an urban Census tract and nearby upwind rural reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

> In San Diego, coastal areas are relatively cooler than inland areas due to the moderating impacts of the ocean and offshore winds. This coastal effect dominates the urban heat island effect in the City.

Most open space and environment critical assets face exposure to heat mainly at the lower levels (0 to 20, 20 to 40, and 40 to 60 heat index range) (Figure 40).[47] For example, the Miramar landfill faces exposure at the 40 to 60 index range, while the CNG fueling station faces exposure at the 20 to 40 range. Beaches have all of their potentially exposed acres exposed at the 0 to 20 heat level range.

[46] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

[47] The project team was able to assess the exposure of all 118,568 acres of conservation areas/open space/source water land to heat, including the 30,321 acres outside of the City boundary.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the heat levels.

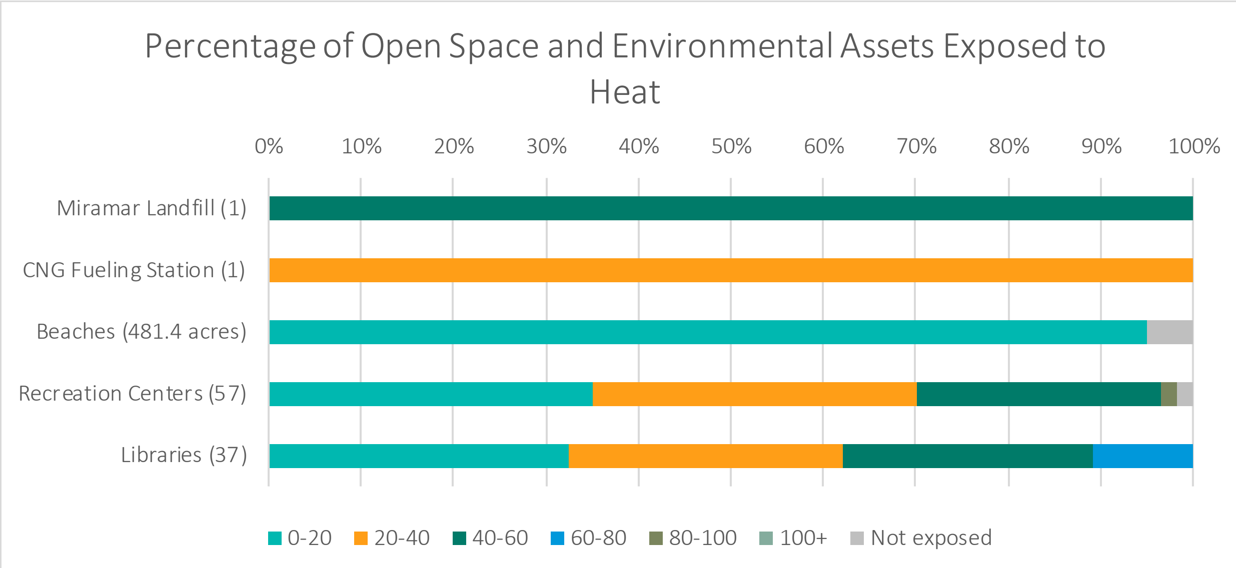

Figure 40. Open space and environment critical assets exposed to extreme heat. The value after each asset name indicates the asset count. The colored bars represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

Open Space and Environment Sensitivity and Adaptive Capacity to Heat

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of all critical open space and environment asset types to heat. The results of this analysis are presented in Table 60.

Table 60. Sensitivity and Adaptive Capacity of Open Space and Environment Critical Asset Types to Heat

<table>
<tr><th colspan="2">Conservation Areas/Open Space/Source Water Land</th></tr>
<tr><td>Heat Sensitivity Rating: High

Increased heat may lead to species shifting their ranges northward and to higher elevations. This could result in new species interactions or desynchronization of current interactions. Increased heat could also negatively affect reproductive and survival rates of sensitive species (Jennings M. K., 2018).

In watersheds, higher heat could increase rates of evaporation, such that more precipitation is needed to saturate dry creek beds before flows occur that could convey water to distribution reservoirs (Consultation with City of San Diego PUD, 2019).</td><td>Heat Adaptive Capacity Rating: Medium

If the region is experiencing intense heat, resilience measures such as controlling and managing invasive pests, planting tolerant and diverse plant species assemblages, and assisting migration could be undertaken to restore habitats. These measures require significant budgets and may be limited by available funding.</td></tr>
<tr><th colspan="2">Community Parks</th></tr>
<tr><td>Heat Sensitivity Rating: Low</td><td>Heat Adaptive Capacity Rating: High</td></tr>
</table>

Playgrounds are typically made of steel and plastic components. Plastic components have a low sensitivity to heat, though steel is somewhat more susceptible to heating up. Green space in parks is naturally cooler than built/urban landscapes. However, ongoing heat/drought events could be harmful to wildlife and greenery in parks.	Shade is an important concept in San Diego's playground design and has been incorporated where possible. Most parks have drinking fountains. The Parks and Recreation Department may experience an increased need to water the green space in community parks, which would increase routine maintenance costs.
Miramar Landfill	
Heat Sensitivity Rating: Low	*Heat Adaptive Capacity Rating: Medium*
High temperatures exacerbate the risk of fire in some landfill facility components, including combustible mulch and compost. Collection trucks could be diverted to other facilities in case of a fire (Consultation with City of San Diego ESD, 2020). High temperatures have the potential to create stress for landfill staff, particularly those who work outdoors.	Indoor air-conditioned areas and outdoor shaded areas may help landfill staff cool down and avoid adverse heat-induced health impacts. The City's landfill operation and gas collection processes are designed to prevent heat-driven fires at landfills. The city has monitoring systems that track leachate and methane gas production.
CNG Fueling Station	
Heat Sensitivity Rating: Low	*Heat Adaptive Capacity Rating: High*
Most trucks fuel overnight so there would be limited to no operational issues.	There is not a need for high heat day protocols, since most trucks fuel overnight.
Beaches	
Heat Sensitivity Rating: Low	*Heat Adaptive Capacity Rating: High*
Given their proximity to the coastal zone, beaches are cooler areas within the City and are more likely to serve as refuges from extreme heat than suffer its impacts.	There is not a need for beaches to adapt to extreme heat, as these areas are not projected to experience the same levels of high heat as inland areas.

Open Space and Environment Vulnerability to Wildfire

The City found that all open space and environment critical asset types are exposed to wildfire.

The results of the vulnerability assessment of open space and environment critical asset types to wildfire are shown in Table 61. The sections below provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to wildfire. Table 62 provides the rationale for the sensitivity and adaptive capacity scores.

Table 61. Vulnerability of Open Space and Environment Critical Asset Types to Wildfire

	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches

	Conservation Areas/ Open Space/Source Water Land	Community Parks	Miramar Landfill	CNG Fueling Station	Beaches
Exposure	High	High	High	Low	High
Sensitivity	High	High	Low	Medium	Low
Adaptive Capacity	Low	Medium	High	High	High
Vulnerability	High	High	Medium	Low	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Open Space and Environment Exposure to Wildfire

All open space and environment critical asset types may be exposed to wildfire, as shown in Figure 41. Over sixty percent of conservation areas/open space/source water land and community parks face exposure to wildfire.[48] The Miramar landfill is also within the high fire hazard zone. The CNG fueling station faces low exposure to wildfire. About a third of beach acreage faces exposure to wildfire, with most of this facing high exposure.

Wildfire Hazard Zones for San Diego

High: Native vegetation and 100-foot setback zones

Medium: 300-foot setback zone

Low: Fire hazard zone outside native vegetation zone and setbacks

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

[48] Due to project constraints, the project team was unable to analyze the exposure of the 30,321 acres of conservation areas/open space/source water land outside the City of San Diego boundary to coastal hazards. This inflates the portion of this asset type that is reported as not exposed to wildfire.

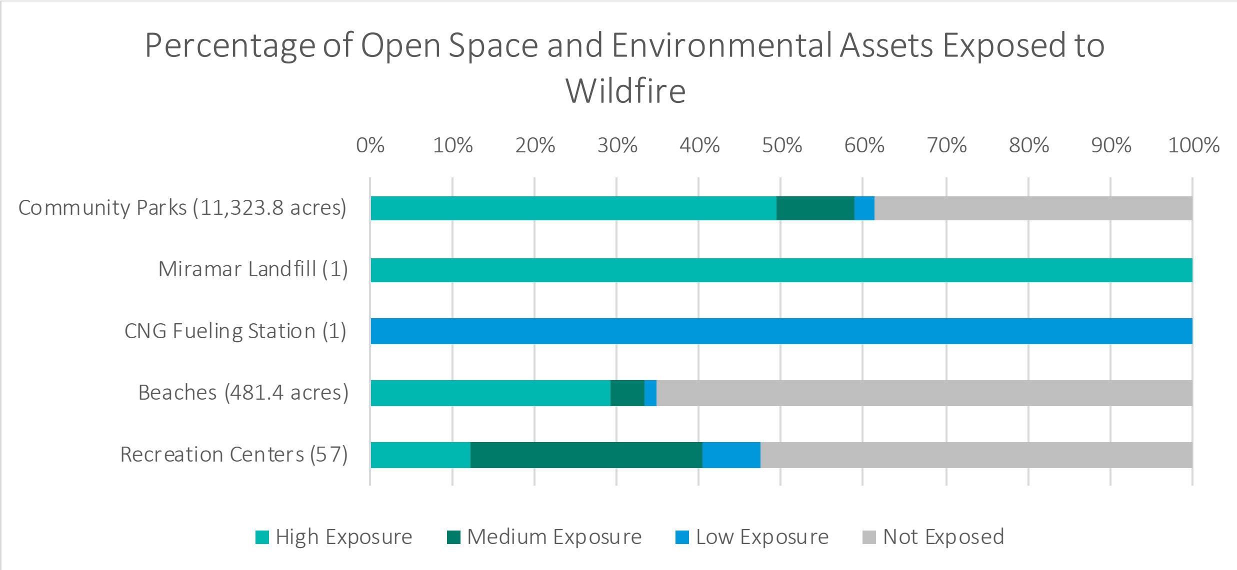

Figure 41. Open space and environment critical assets exposed to wildfire. The value after each asset name indicates the asset count.

Open Space and Environment Sensitivity and Adaptive Capacity to Wildfire

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of all open space and environment critical asset types to wildfire. The results of this analysis are presented in Table 62.

Table 62. Sensitivity and Adaptive Capacity of Open Space and Environment Critical Asset Types to Wildfire

Conservation Areas/Open Space/Source Water Land	
Wildfire Sensitivity Rating: High	*Wildfire Adaptive Capacity Rating: Low*
Wildfires could destroy critical habitats. This may lead to local extirpation of species, including endangered species. For example, California gnatcatchers are not fully recolonizing burned areas (Consultation with City of San Diego MSCP, 2019). Additionally, changing wildfire regimes may change the type of habitats present in the area from shrubland ecosystems to non-native annual grasslands (Jennings M. K., 2018). These native habitats are often home to critical and endangered species. Fires in watersheds could increase erosion and lead to toxic burned materials as well as higher volumes of pollutants and nutrients entering the water supply (Consultation with City of San Diego	Small reserves represent crucial habitat for many species, including endangered species, and there are typically no backup areas (Consultation with City of San Diego Parks and Recreation Department, 2019). Smaller reserves are often near development and are less likely to catch fire or are closer to resources for fire extinguishment. Larger conservation areas that are farther from development are more likely to burn longer, as the response time for fire extinguishment resources is greater (Consultation with City of San Diego Parks and Recreation Department, 2020). Some habitats within these reserves, such as coastal sage scrub, are resilient to fire when it occurs in infrequent intervals (roughly every twenty to thirty years). However, increased fire frequency may impede habitat recovery, resulting in a positive feedback loop and necessitating

PUD, 2019).	human intervention in the form of restoration and/or fire prevention (Consultation with City of San Diego Parks and Recreation Department, 2020). PUD is currently in the process of implementing erosion control and habitat restoration projects post-fire, which will help protect source water quality (Consultation with City of San Diego PUD, 2019).
Community Parks	
Wildfire Sensitivity Rating: High The damage to parks from wildfires depends on a park's location and arrangement of amenities within the park. If a playground were to be destroyed, it could take up to three years to replace (Consultation with City of San Diego Parks and Recreation Department, 2019).	*Wildfire Adaptive Capacity Rating: Medium* City departments have brush management plans in place to reduce risk of wildfire spreading; however, parks that are largely open space may accept some level of burning risk.
Miramar Landfill	
Wildfire Sensitivity Rating: Low Wildfires surrounding the landfill have the potential to disrupt access to the landfill and temporarily impact the City's ability to dispose of refuse. Wildfires that reach the landfill may burn above-ground structures such as gas lines but would not impact the landfill's ability to function (Consultation with City of San Diego Environmental Services Department (ESD), 2019).	*Wildfire Adaptive Capacity Rating: High* Surrounding closed sections of the landfill, highways, and Marine Corps Air Station runway areas may serve as fire breaks to the east and south. Surrounding vegetation is maintained pursuant to the brush management requirements of the Land Development Code and specifications of the General Development Plan for the landfill (Consultation with City of San Diego ESD, 2019). The landfill has an emergency plan in case of wildfire and fire suppression assets such as water tanks on-site. Trash can be diverted to other landfills or transfer stations in the case of a wildfire (Consultation with City of San Diego ESD, 2020). As the Environmental Service Department is a part of the Emergency Operations Center, interagency coordination and communication improves with each disaster event.
CNG Fueling Station	
Wildfire Sensitivity Rating: Medium If the fueling station was exposed, it would	*Wildfire Adaptive Capacity Rating: High* The fueling station has defensible space and

require repair before being available for use. The fueling station is not expected to be damaged beyond repair or further use.	SDG&E has a fueling station nearby, if needed (Consultation with City of San Diego ESD, 2019).
Beaches	
Wildfire Sensitivity Rating: Low Beaches themselves would not burn during a wildfire. The vegetation on beaches might burn. Additionally, wildfire could degrade water quality by damaging sewage infrastructure and increasing the amount of runoff into the ocean (Fry, 2019).	*Wildfire Adaptive Capacity Rating: High* There is little risk of fire spreading into the beach and therefore little need for adaptation.

Additional Asset Vulnerability Findings

Additional assets include those managed by the Real Estate Assets (READ), Parks and Recreation, Library, Fleet Services, and Public Utilities departments, along with the Commission for Arts and Culture and the Parking Organization. The following asset types are considered critical: recreation centers, libraries, City buildings, and historical, tribal cultural, and archaeological resources. While recreation centers are often associated with community parks, the two asset types were treated separately in this analysis. Community parks are included in the "Open Space and Environment Vulnerability Findings" section above. Not all assets in this list were found to be exposed to climate hazards.

The results of the vulnerability assessment for additional asset types are shown in Table 63. "N/A" indicates that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were deemed not vulnerable.

The City found that historical, tribal cultural, and archaeological resources are highly vulnerable to all hazards except heat. This is due to their high sensitivity and low adaptive capacity: these assets could suffer severe damage from hazards, are irreplaceable when destroyed, and their historic and cultural nature requires more thought, consideration, and oversight when implementing protective measures. Note that historical resources could be restored and preserved when damage is not irreparable: in the past, repairs-in-kind have been performed on resources damaged by climate hazards. However, in general these assets carry the potential for high sensitivity and low adaptive capacity, which warranted the higher vulnerability scores. As such, these scores are a conservative estimate. Vulnerability and resilience to climate hazards vary across individual assets, particularly given the variety of forms represented by historical, tribal cultural, and archaeological resources.

The exposure assessment is based on the 2018 spatial data on assets listed under the City's Historical Resources Register; 2018 was the most recent vintage of data available at the time of analysis.[49] The number of resources on this register is dynamic and subject to change periodically. As of the end of calendar year 2019, there were 1,324 individually significant resources listed on the City's Register of Designated Historical Resources (Historic Register), including seventeen archaeological and/or tribal cultural resources. In addition, the Historic Register includes twenty-five designated historical districts that contain approximately 2,000 contributing resources, for a total of more than 3,300 historical buildings, structures, objects, districts, landscapes, tribal cultural resources, and archaeological resources listed on the Historic Register alone, with more added every month. This does not include resources listed on or determined eligible for listing on the State or National Registers that are not listed on the City's Historic Register. While the vast majority of these resources are privately owned, the City of San Diego owns more than 100 of these resources.

Table 63. Vulnerability of Additional Critical Asset Types to Climate Change Hazards[50]

	SLR	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
Recreation centers	High	Low	N/A	Medium	Medium	Medium
Libraries	N/A	N/A	N/A	N/A	Low	Medium
City buildings	N/A	N/A	N/A	N/A	Low	Medium
Historical, Tribal Cultural, and Archaeological Resources	High	High	High	High	Medium	High

Additional Asset Consequences

City critical asset types not included in the other sectors analyzed in this assessment (collectively referred to as "additional assets") are vulnerable to climate-related hazards. Damages to these assets could have consequences, particularly to City services or directly to historical and cultural resources.

Illustrative examples of the consequences of other City asset damage, disruption, and failure are presented in Table 64. This table is provided purely to illustrate potential impacts; it is not meant to imply that these impacts will definitively occur, nor is this list fully comprehensive of all potential consequences to all asset types.

[49] The use of these data was based on information available from the City of San Diego's GIS department. It does not represent a comprehensive analysis of all historical, tribal cultural, and archaeological assets within in the city, as it includes mostly built environment points included on the Register. A closer consideration of other assets including archaeological and tribal sites could be an area of future analysis.

[50] Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 64. Illustrative Consequences of Additional Asset Damage, Disruption, or Failure

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
Recreation Centers	City Services Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources	Recreation centers serve as community centers, which are important for after-school programs, community activities, and exercise. Use of these facilities could promote a sense of neighborhood social cohesion and could improve mental health (Perez, et al., 2015). Human health and social equity could be compromised if these centers are damaged. These centers also serve as critical facilities during emergencies, such as serving as cooling centers during heat waves (San Diego Gas and Electric (SDG&E), 2018). Damages could compromise their performance as an emergency facility, which could result in additional risks to human health. Elderly and low-income residents could experience disproportionate impacts due to damages to these facilities. The La Jolla Adult Recreation Center Club and the La Jolla Recreation Center are City-owned designated historical resources. Additionally, other recreation centers that are not currently designated may be eligible for designation pending evaluation. Damage to these buildings and associated facilities could impact their ability to convey historical and cultural information and value.
Libraries	City Services Human Health Social Equity Historical, Tribal Cultural, and Archaeological Resources	Libraries play an important role in community cohesion, acting as a meeting and social gathering space. They provide services to citizens and serve as learning centers, and employment resources. In addition, public libraries serve diverse communities by providing a place for children to go after school or resources for immigrants (e.g., English courses, citizen classes, immigration legal clinics) (City of San Diego, 2019a). Social equity could be compromised if libraries are damaged. Libraries are also used as cooling centers during extreme heat events (San Diego Gas and Electric (SDG&E), 2018; County of San Diego HHSA, 2019). Human health may be affected if these locations are not available to provide refuge. The La Jolla Public Library, the San Ysidro Free Public Library, the Ocean Beach Library, and the San Diego City Library are City-owned designated historical resources. Additionally, other libraries that are not currently designated may be eligible for designation pending evaluation. Damage to these buildings could impact their ability to convey historical and cultural information and value. Additionally, since libraries protect books and historical archives

Critical Asset	Relevant Consequence Categories	Illustrative Consequences
		and some libraries are themselves historic resources, damage to libraries could result in losses of historical and cultural resources.
City Buildings	City Services Historical, Tribal Cultural, and Archaeological Resources	City buildings include facilities where City staff work as well as where the public can interface with the City government. Impacts to these buildings could cause disruptions in the ability of City staff to carry out their day-to-day duties. There are portions of the Civic Administration site such as the plaza and surrounding buildings that have been evaluated for historic registration designation and found to be potentially eligible, though no designations have yet been made. Damage to these structures could impact their ability to convey historical and cultural information and value.
Historical, Tribal Cultural, and Archaeological Resources	Historical, Tribal Cultural, and Archaeological Resources	San Diego is home to a variety of historical, tribal cultural, and archaeological resources, including buildings, structures, objects, districts, archaeological sites and artifacts, traditional cultural properties and tribal cultural resources, historic documents, and historical or cultural landscapes (City of San Diego, 2019d). Loss or damage of these resources could result in permanent loss of historical and cultural resources that may be integral to the identity of San Diego.

Additional Asset Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day assuming various sea level rise scenarios. Storm surge flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm assuming each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

The City found that recreation centers and historical, tribal cultural, and archaeological resources may be exposed to coastal hazards. Historical, tribal cultural, and archaeological resources are highly vulnerable to both coastal flooding and erosion, given their exposure to these hazards starting at just 0.25 m of sea level rise (projected to occur by 2030) and their high sensitivity to impacts. Sea level rise and storm events could damage or destroy built assets, permanently inundate coastal assets, and increase erosion of assets. Because these assets are critical for their historical and cultural value, they are not easily replaced (and in some cases irreplaceable) and repairs could be difficult and/or costly. Recreation centers face high vulnerability to chronic inundation with sea level rise, low vulnerability to periodic inundation with storm surge, and are not exposed to coastal erosion. All erosion scenarios assume 2.0 meters of sea level rise (which is the upper range for 2100).

The results of the vulnerability assessment of additional critical asset types to coastal hazards are shown in Table 65, Table 66, and Table 67.

The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to coastal hazards. In particular, Table 68 provides the rationale for the sensitivity and adaptive capacity scores.

Table 65. Vulnerability of Additional Critical Asset Types to Sea Level Rise

SLR	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	Low	Not exposed	Not exposed	High
Sensitivity	High	N/A	N/A	High
Adaptive Capacity	Low	N/A	N/A	Low
Vulnerability	High	N/A	N/A	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 66. Vulnerability of Additional Critical Asset Types to Storm Surge with Sea Level Rise (One Hundred-Year storm)

Storm Surge with SLR	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	Low	Not exposed	Not exposed	High
Sensitivity	Medium	N/A	N/A	High
Adaptive Capacity	Medium	N/A	N/A	Medium
Vulnerability	Low	N/A	N/A	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Table 67. Vulnerability of Additional Critical Asset Types to Coastal Erosion at Medium-High Risk Aversion Scenario of 2m of Sea Level Rise

Coastal Erosion	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	Not Exposed	Not exposed	Not exposed	Medium
Sensitivity	N/A	N/A	N/A	High
Adaptive Capacity	N/A	N/A	N/A	Low
Vulnerability	N/A	N/A	N/A	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Additional Asset Exposure to Coastal Hazards

Sea Level Rise Projections for San Diego

2030: 0.25 m

2050: 0.5 to 0.75 m

2100: 1.0 to 2.0 m

Of the additional critical asset types, only recreation centers and historical, tribal cultural, and archaeological resources may be exposed to sea level rise and storm surge with sea level rise, as shown in Figure 42 and Figure 43. Seven historical, tribal cultural, and archaeological resources may become exposed to sea level rise starting at 0.25 meters of sea level rise (approximately 2030), and seventeen total historical, tribal cultural, and archaeological resources may become exposed under 2 meters of sea level rise, which is the high-end estimate for 2100. Only one recreation center (out of fifty-seven total) faces exposure from sea level rise, beginning with 1.5 meters of sea level rise (approximately 2100).

Storm surge with sea level rise brings eleven historical, tribal cultural, and archaeological resources into flooding zones at 0.25 meters of sea level rise (2030) and an upper end of twenty-five resources into flooding zones in 2100 (Figure 43). Eight of these twenty-five resources only face exposure to storm surge with sea level rise at the highest scenario (2 meters) of sea level rise.

Recreation centers, libraries, and City buildings are not exposed to shoreline erosion. There are six historical and cultural resources that face exposure to cliff erosion and seven that face exposure to beach erosion (assuming no beach nourishment or seawall improvements) (Figure 45).

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

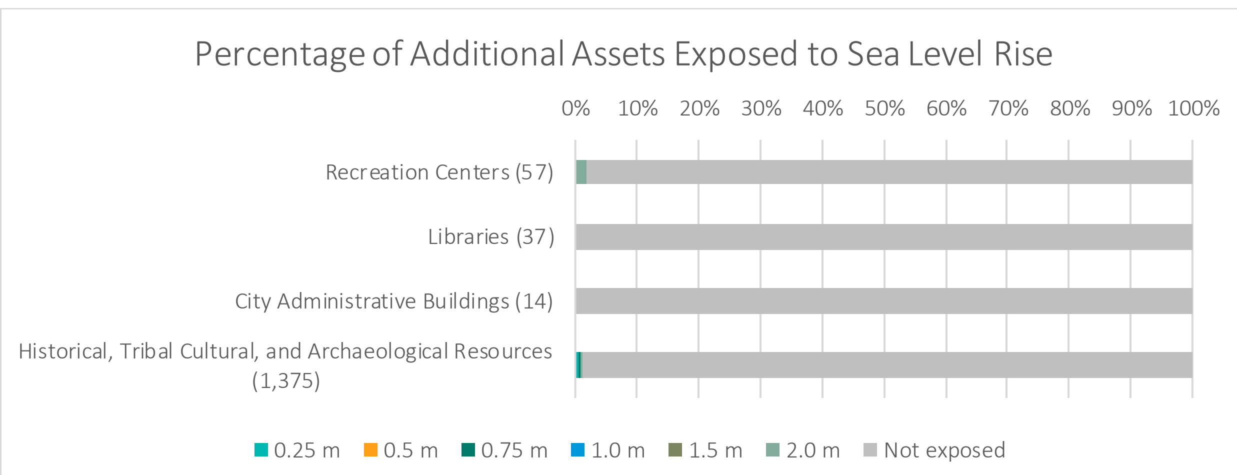

Figure 42. Additional critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

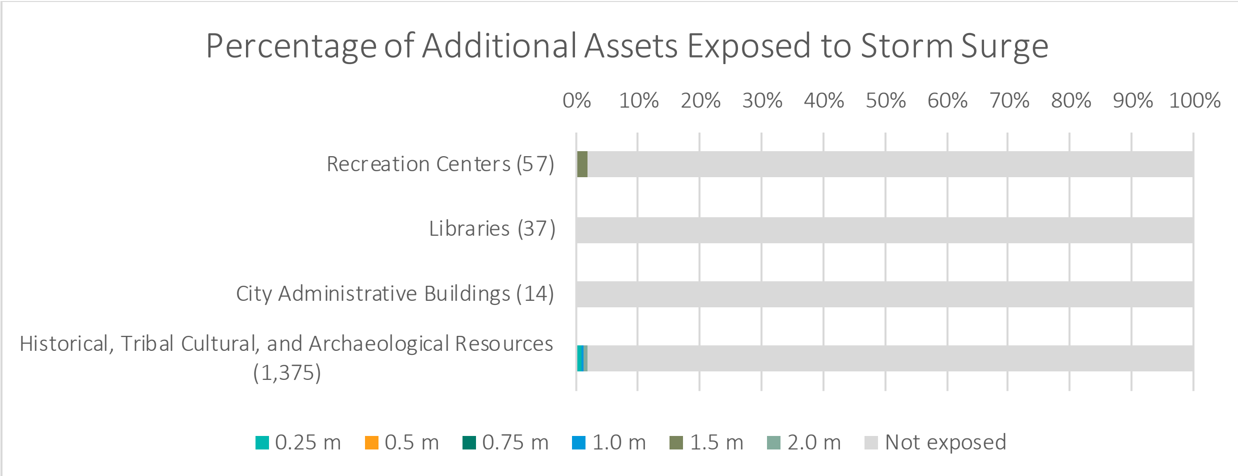

Figure 43. Additional critical assets exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average daily flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

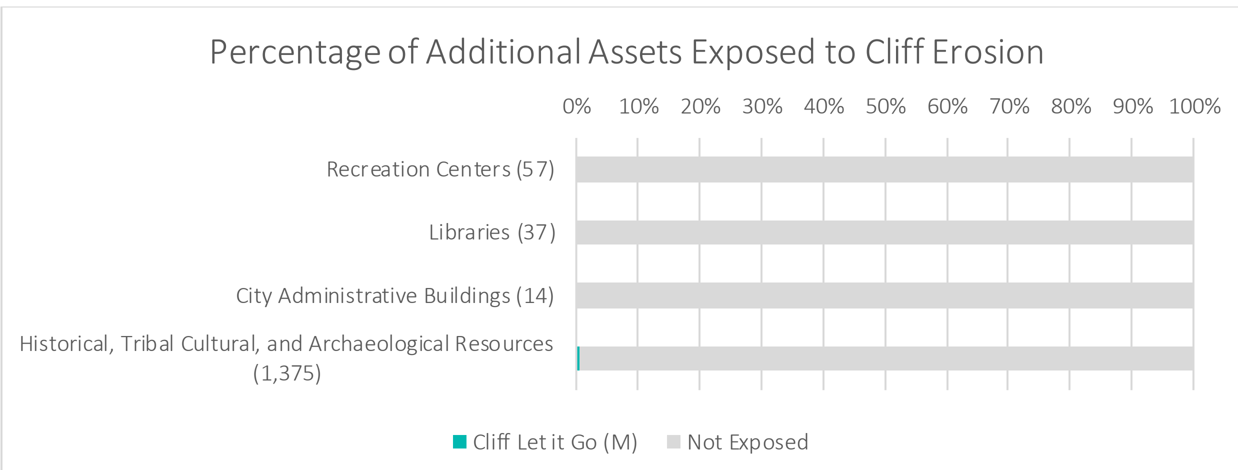

Figure 44. Additional critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

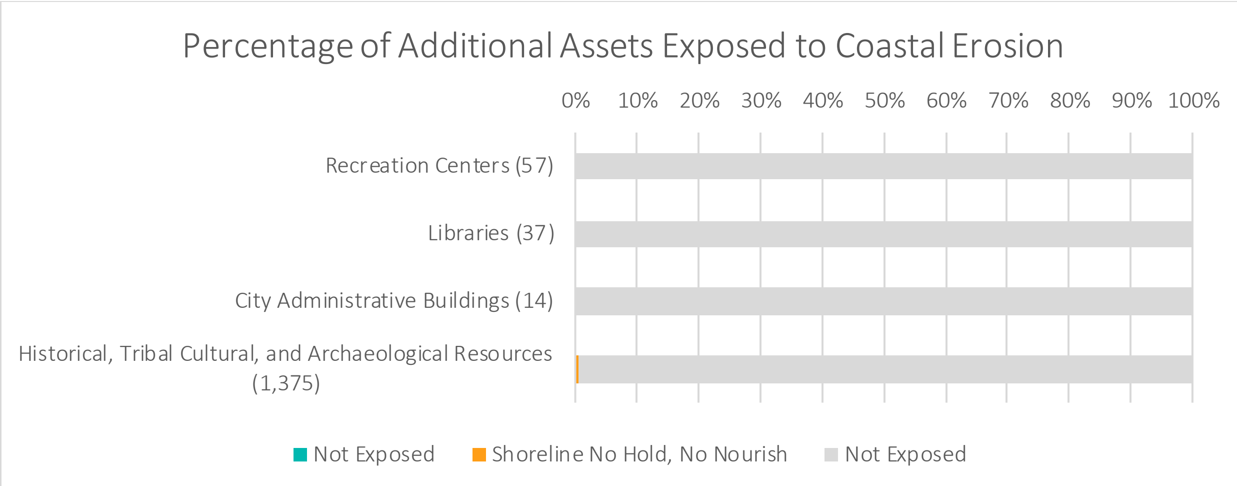

Figure 45. Additional critical assets exposed to coastal erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

Additional Asset Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of recreation centers and historical, tribal cultural, and archaeological resources to coastal hazards. The results of this analysis are presented in Table 68.

Table 68. Sensitivity and Adaptive Capacity of Additional Asset Types to Coastal Hazards

Recreation Centers	
SLR Sensitivity: High Sea level rise could permanently inundate buildings within the projected sea level rise zone, could increase the erosion of structures, and could damage or destroy buildings and equipment (USAID 2014).	*SLR Adaptive Capacity: Low* Longer-term adaptation may be necessary if chronic flooding within the coastal zone becomes a highly likely scenario. In some areas, this may occur as soon as 2030 (with 0 to 0.25 m of sea level rise); other areas may start to experience chronic flooding around 2050 (0.5 to 0.75 m sea level rise) or 2100 (1 to 2 m sea level rise).
Storm Surge with SLR Sensitivity: Medium Recreation centers might have to be temporarily closed in the event of a flood, and flood damages would have to be repaired before the facilities could be fully functional again.	*Storm Surge with SLR Adaptive Capacity: Medium* Short-term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation is more difficult.
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*

Historical, Tribal Cultural, and Archaeological Resources	
SLR Sensitivity: High Chronic flooding could limit access to, damage, or destroy historical, tribal cultural, and archaeological resources.	*SLR Adaptive Capacity: Low* Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable), and repairs could be difficult and/or costly.
Storm Surge with SLR Sensitivity: High Periodic flooding from storms could damage or destroy these resources.	*Storm Surge with SLR Adaptive Capacity: Medium* Protective measures against storm-based damage and flooding should be in place, though individual asset managers and maintenance staff are directly responsible for these measures. In the past, the City has been able to perform repairs-in-kind or rebuilds to flood-damaged assets (e.g., adobes) (Consultation with City of San Diego Historic Preservation Planning, 2019). Historical structures could be retrofitted or upgraded in accordance with Secretary of the Interior's Standards for the Treatment of Historic Properties.
Coastal Erosion Sensitivity: High Coastal erosion could threaten the ability of historical, tribal cultural, or archaeological resource to remain in-situ, which could result in relocation or loss of the asset.	*Coastal Erosion Adaptive Capacity: Low* Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable), and repairs could be difficult and/or costly. Moving an asset is not always possible for assets that are part of the physical landscape and would have particularly negative impacts on resources that have place-based significance.

Additional Asset Vulnerability to Precipitation-driven Flooding

The City found that, within the additional asset category, only recreation centers and historical, tribal cultural, and archaeological resources face exposure to precipitation-driven flooding. Historic, tribal cultural, and archaeological resources were found to be highly vulnerable. This is due to these assets' high exposure (eight are within the 100-year floodplain) and high sensitivity (flooding could damage or destroy resources) to precipitation. However, even though libraries and City buildings were not found to be located within the FEMA floodplains, City staff indicated that many City-owned facilities are susceptible to water intrusion and damage from rain events (Consultation with City of San Diego Planning Department, 2019).

The results of the vulnerability assessment of additional asset types to precipitation-driven flooding are shown in Table 69. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to precipitation-driven flooding. Table 70 provides the rationale for the sensitivity and adaptive capacity scores.

Table 69. Vulnerability of Additional Critical Asset Types to Precipitation-driven Flooding

	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	Medium	Not exposed	Not exposed	High
Sensitivity	Medium	N/A	N/A	High
Adaptive Capacity	Medium	N/A	N/A	Medium
Vulnerability	Medium	**N/A**	**N/A**	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Additional Asset Exposure to Precipitation

No libraries or City buildings lie in the FEMA floodplains; recreation centers and historical, tribal cultural, and archaeological resources may be exposed to precipitation-driven flooding (Figure 46). There are nineteen historical, tribal cultural, and/or archaeological resources that face exposure from precipitation-driven flooding. Eight of these resources lie in the 100-year floodplain, while eleven resources lie in the 500-year floodplain.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

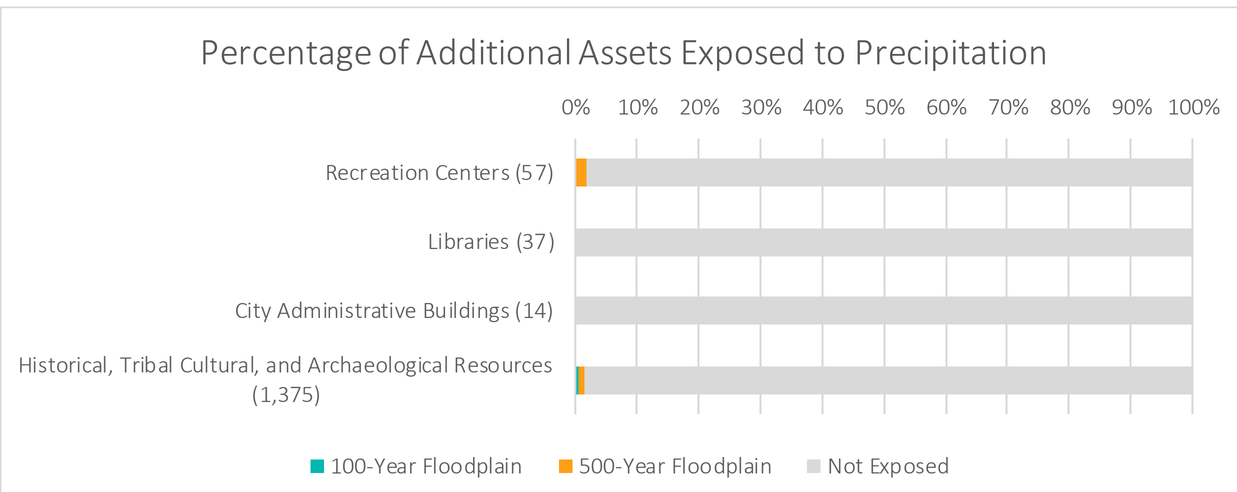

Figure 46. Additional critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

Additional Asset Sensitivity and Adaptive Capacity to Precipitation-driven Flooding

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of recreation centers and historical, tribal cultural, and archaeological resources to precipitation. The results of this analysis are presented in Table 70.

Table 70. Sensitivity and Adaptive Capacity of Additional Critical Asset Types to Precipitation-driven Flooding

Recreation Centers	
Precipitation Sensitivity Rating: Medium Roofs have leaked at recreation centers in previous storm events (City of San Diego, 2019f; City of San Diego, 2017c). Flooding in buildings could lead to costly damage (e.g., flooding at the MLK Recreation Center and racquetball court in the February 2017 storms cost $150,000) (City of San Diego, 2017b).	*Precipitation Adaptive Capacity Rating: Medium* Short-term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation is more difficult.
Historical, Tribal Cultural, and Archaeological Resources	
Precipitation Sensitivity Rating: High Flooding could damage or destroy irreplaceable resources.	*Precipitation Adaptive Capacity Rating: Medium* Protective measures against precipitation-based damage and flooding should be in place, though individual asset managers and maintenance staff are directly responsible for these measures. In the past, the City has been able to perform repairs-in-kind or rebuilds to flood-damaged assets (e.g., adobes) (Consultation with City of San Diego Historic Preservation Planning, 2019). Historical structures could be retrofitted or upgraded in accordance with Secretary of the Interior's Standards for the Treatment of Historic Properties.

Additional Asset Vulnerability to Heat

The City found that all additional critical asset types face some level of exposure to heat, with recreation centers and historical, tribal cultural, and archaeological resources showing medium vulnerability.

The results of the vulnerability assessment of additional critical asset types to heat are shown in Table 71. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to heat. Table 72 provides the rationale for the sensitivity and adaptive capacity scores.

Table 71. Vulnerability of Additional Critical Asset Types to Heat

	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	High	Medium	Medium	High
Sensitivity	Low	Low	Low	Medium
Adaptive Capacity	High	High	High	Medium
Vulnerability	Medium	Low	Low	Medium

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Additional Asset Exposure to Heat

The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[51] A score of zero indicates that there is no difference in temperature over time between an urban Census tract and nearby upwind rural reference points. A score of 100 indicates that there is a difference of 7.5 degrees Fahrenheit (approx. 4.2 degrees Celsius) between these tracts over 24 hours.

In San Diego, coastal areas are relatively cooler than inland areas due to the moderating impacts of the ocean and offshore winds. This coastal effect dominates the urban heat island effect in the City.

Almost all individual additional critical assets may face some level of exposure to heat, as shown in Figure 47. One recreation center and nineteen historical, tribal cultural, and archaeological resources do not face exposure to extreme heat. Most assets face exposure at the lower heat ratings, in urban heat island index zones scoring between 0 and 40.

Historical, tribal cultural, and archaeological resources contain five assets potentially exposed to extreme heat at the 80 to 100 heat index range. There is one recreation center also exposed at this high level. Over ten percent of libraries are potentially exposed to extreme heat at the 60 to 80 heat index range.

[51] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period. To estimate the total number of degrees Fahrenheit per day, divide the Index by 24 hours and multiply by 1.8 degrees. Higher scores denote hotter areas.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the heat levels.

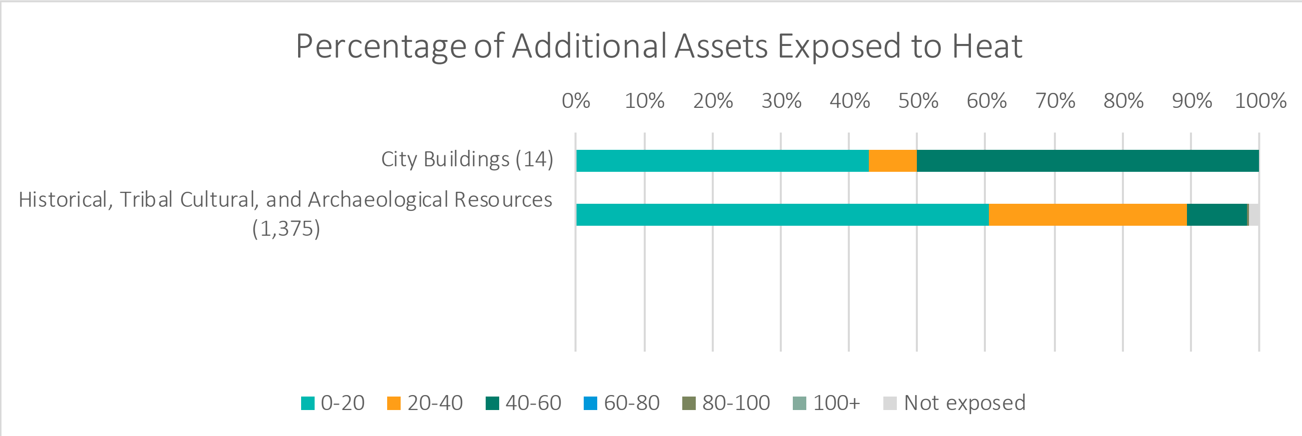

Figure 47. Additional critical assets exposed to extreme heat. The value after each asset name indicates the asset count. The colored bars represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

Additional Asset Sensitivity and Adaptive Capacity to Heat

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of all additional critical asset types to heat. The results of this analysis are presented in Table 72.

Table 72. Sensitivity and Adaptive Capacity of Additional Critical Asset Types to Heat

Recreation Centers	
Heat Sensitivity Rating: Low Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	*Heat Adaptive Capacity Rating: High* Tree plantings are an option with multiple co-benefits (Consultation with City of San Diego Sustainability Department, 2019) While several newer recreation centers have air conditioning and are energy efficient, most do not have air conditioning or energy efficient systems (Consultation with City of San Diego Parks and Recreation Department, 2019).
Libraries	
Heat Sensitivity Rating: Low Thermal stress could cause wear on building materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	*Heat Adaptive Capacity Rating: High* Almost all libraries have air conditioning, and most are energy efficient (Consultation with City of San Diego Facilities, 2019).
City buildings	
Heat Sensitivity Rating: Low Thermal stress could cause wear on building	*Heat Adaptive Capacity Rating: High* New buildings (built within the last five to eight

materials and place an increased load on mechanical and cooling equipment, leading to higher energy costs and potentially damaging electrical equipment (USAID, 2014; USGBC, 2011).	years) are guaranteed to be energy efficient. New City design standards require all buildings to either be LEED certified or energy efficient. All buildings built before this standard would likely not be energy efficient (Consultation with City of San Diego Facilities, 2019).
Historical, Tribal Cultural, and Archaeological Resources	
Heat Sensitivity Rating: Medium Warmer temperatures and higher humidity have the potential to damage historic structures and materials (USAID, 2014).	*Heat Adaptive Capacity Rating: Medium* Historical, tribal cultural, and archaeological resources may be difficult and/or costly to repair, replace, or move. However, historical structures could be retrofitted or upgraded in accordance with Secretary of the Interior's Standards for the Treatment of Historic Properties.

Additional Asset Vulnerability to Wildfire

The City found that all additional critical asset types show medium to high vulnerability to wildfire. All include assets within the City's brush management zone (the highest potential exposure level). Recreation centers, libraries, and City buildings show medium sensitivity to wildfire, as many of these buildings are built with fire-resistant materials. Historical, tribal cultural, and archaeological resources show high sensitivity to wildfire, since many of these resources are not fire-resistant and could be lost if severely damaged.

The results of the vulnerability assessment of additional critical asset types to wildfire are shown in Table 73. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these asset types to wildfire. Table 74 provides the rationale for the sensitivity and adaptive capacity scores.

Table 73. Vulnerability of Additional Critical Asset Types to Wildfire

	Rec Centers	Libraries	City Buildings	Historical, Tribal Cultural, and Archaeological Resources
Exposure	High	High	High	High
Sensitivity	Medium	Medium	Medium	High
Adaptive Capacity	High	High	High	Low
Vulnerability	Medium	Medium	Medium	High

Note: Exposure scores are based on the best available climate science, the interpretation of this science in the context of the timeframes when impacts may occur, risk management considerations, and asset location data to identify spatial overlap between critical City assets and climate hazards within the City limits. Sensitivity and adaptive capacity scores are based on information from literature reviews and interviews with City department staff and represent generalizations for asset types, rather than individual assets. More information on the scoring methodology can be found in Table 8, Table 9, and Table 10. Green shaded cells in the table indicate good candidates for consideration of adaptation strategies.

Additional Asset Exposure to Wildfire

All additional asset types may be exposed to wildfire (Figure 48); however, less than half of all assets within each asset type

Wildfire Hazard Zones for San Diego

High: Native vegetation and 100-foot setback zones

Medium: 300-foot setback zone

Low: Fire hazard zone outside native vegetation zone and setbacks may be exposed to wildfire. Of exposed assets, twelve to sixteen percent face high exposure to wildfire, five to twenty-eight percent face medium exposure, and seven to nine percent face low exposure.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

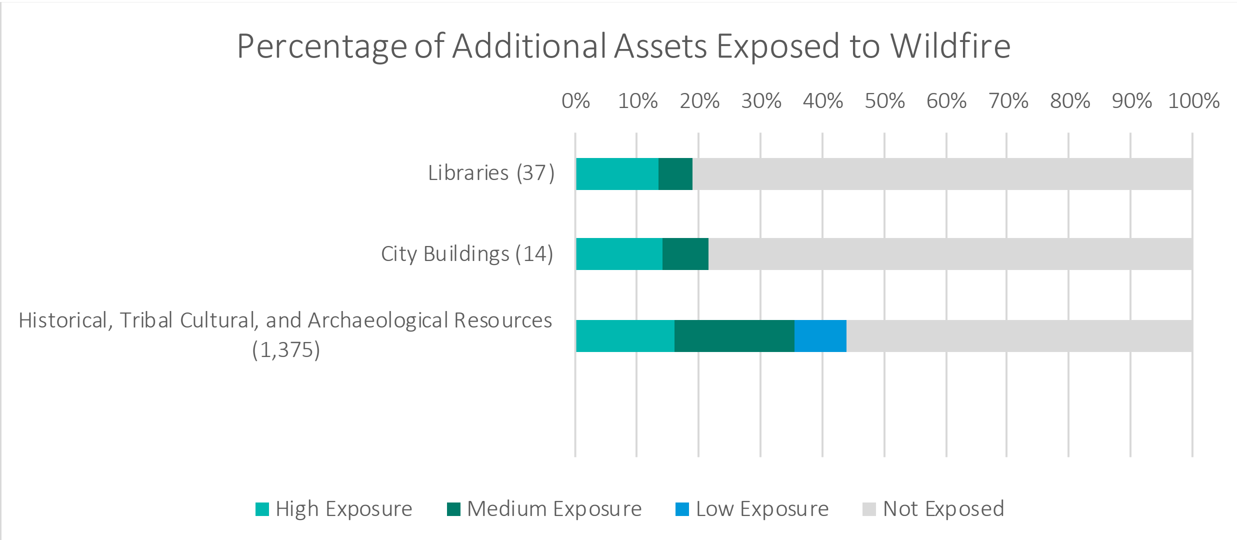

Figure 48. Additional critical assets exposed to wildfire. The value after each asset name indicates the asset count.

Additional Asset Sensitivity and Adaptive Capacity to Wildfire

Based on the exposure assessment, the City analyzed the sensitivity and adaptive capacity of all additional critical asset types to wildfire. The results of this analysis are presented in Table 74.

Table 74. Sensitivity and Adaptive Capacity of Additional Critical Asset Types to Wildfire

Recreation Centers	
Wildfire Sensitivity Rating: Medium Wildfires could directly damage buildings and increase deterioration via increased particulate matter and smoke (USAID, 2014). Most recreation centers are of masonry construction with fire-resistant roofs (Consultation with City of San Diego Parks and Recreation Department, 2019).	*Wildfire Adaptive Capacity Rating: High* Most recreation centers have defensible space.
Libraries	
Wildfire Sensitivity Rating: Medium Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014). However, only one library—Logan Heights—is made with fire-susceptible material (City of San Diego Facilities, 2019).	*Wildfire Adaptive Capacity Rating: High* All buildings have defensible space (City of San Diego Facilities, 2019).

City buildings	
Wildfire Sensitivity Rating: Medium Wildfires could directly damage buildings and could accelerate building material deterioration due to increased smoke and particulate matter (USAID, 2014). However, no City buildings are made with fire-susceptible material.	*Wildfire Adaptive Capacity Rating: High* All buildings have defensible space (City of San Diego Facilities, 2019).

Historical, Tribal Cultural, and Archaeological Resources	
Wildfire Sensitivity Rating: High Historical resources include assets that are constructed with flammable materials. Many historical resources have a wooden exterior, which makes them more susceptible to fire. Wildfires, efforts to extinguish them, and their aftermath (e.g., runoff and erosion) could damage or destroy irreplaceable historical, tribal cultural, and archaeological resources. In previous events, this has been costly, but may be covered by insurance, allowing for repair when possible (City of San Diego, 2007).	*Wildfire Adaptive Capacity Rating: Low* Wildfire threat could be mitigated to some extent through use of defensible space and other interventions such as planting low-fuel native vegetation around above-ground archaeological resources, fire sprinklers in buildings, and materials could be replaced in-kind when damage is not extensive. Some but not all historical, tribal cultural, and archaeological resources have defensible space (Consultation with City of San Diego Historic Preservation Planning, 2019). Destruction of a historical resource by wildfire would result in an irreplaceable loss to the City's history and culture.

Non-City-Owned Resources

In addition to the critical City assets discussed thus far, this assessment also considered the exposure of certain non-City asset types to give a more holistic view of climate change risks. Specifically, an exposure assessment of state highways and freeways as well as privately owned land was included to provide a more comprehensive view of how climate hazards may impact the City. Vulnerability scores were not calculated for these assets, as the City does not have full insight into the sensitivities and adaptive capacities of assets it does not manage.

State-Owned

Though state highways and freeways are not owned or managed by the City, these assets are part of the transportation infrastructure network within the City and were included in this vulnerability assessment to provide a more holistic view of the transportation network serving the City. Like bridges and major arterials (discussed under the Transportation and Storm Water Vulnerability Findings section above), these two asset types are broken down into roadway segments as defined in the City's asset management system.

The results of the exposure assessment for state highways and storm water are shown in Table 75. "N/A" indicates that the assets were not found to be exposed to the hazard. The City found that state highways face exposure to all hazards, and freeways face exposure to all hazards except coastal erosion.

Table 75. Exposure of State Highways and Freeways to Climate Change Hazards[52]

	SLR	Storm Surge with SLR	Coastal Erosion	Precipitation	Heat	Wildfire
State Highways	High	High	High	High	High	High
Freeways	High	High	N/A	High	High	High

State Highways and Freeways Exposure to Coastal Hazards

Sea Level Rise (SLR) Projections for San Diego
2030: 0.25 m
2050: 0.5 to 0.75 m
2100: 1.0 to 2.0 m

Coastal hazards include sea level rise, storm surge, and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide on average each day assuming each sea level rise scenario. Storm surge flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm assuming each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario.

Two percent of freeway assets may be exposed to sea level rise while nearly twenty percent of state highways may be exposed to sea level rise; however, there are significant local exposure concerns in some coastal neighborhoods (Figure 49).

A few more state highway and freeway critical assets face exposure to flooding with storm surge, but the proportion still stays below 5 percent, with a total of up to 103 state highway and freeway road segments exposed to a potential 2100 storm surge event (Figure 50). In a storm surge scenario, assets become exposed across a broader spectrum of sea level rise ranges. Neither state highways nor freeways are exposed to cliff erosion (Figure 51). As Figure 52 shows, four state highway segments may be exposed to beach erosion.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the coastal hazard scenarios.

[52] The exposure scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS and the best available spatial projections and localized modeling for the chosen climate hazard scenarios. The scores reported here do not reflect the exposure of specific, individual assets, but rather the highest asset type exposure.

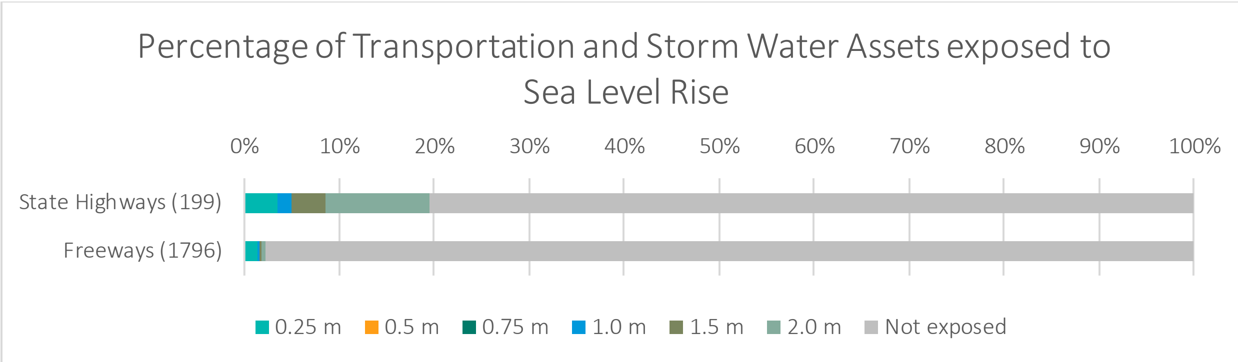

Figure 49. State highway and freeway critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

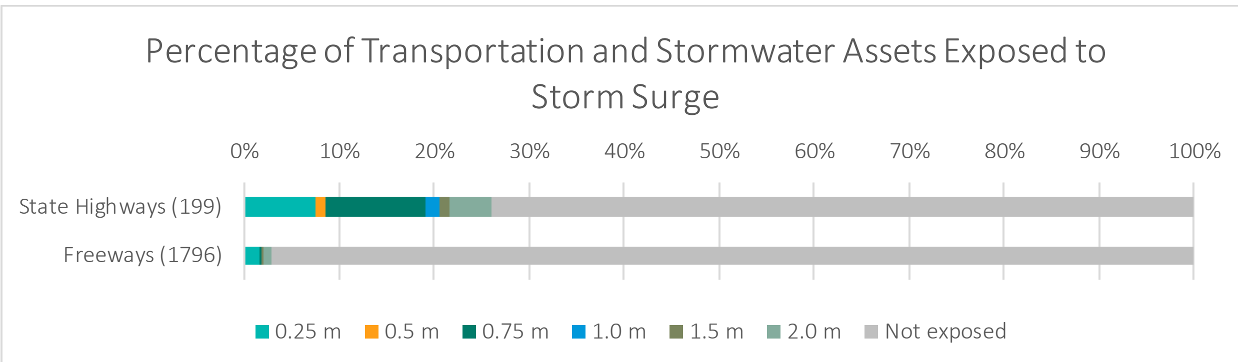

Figure 50. State highway and freeway critical assets exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets would be exposed to storm surge prior to being exposed to average daily flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.

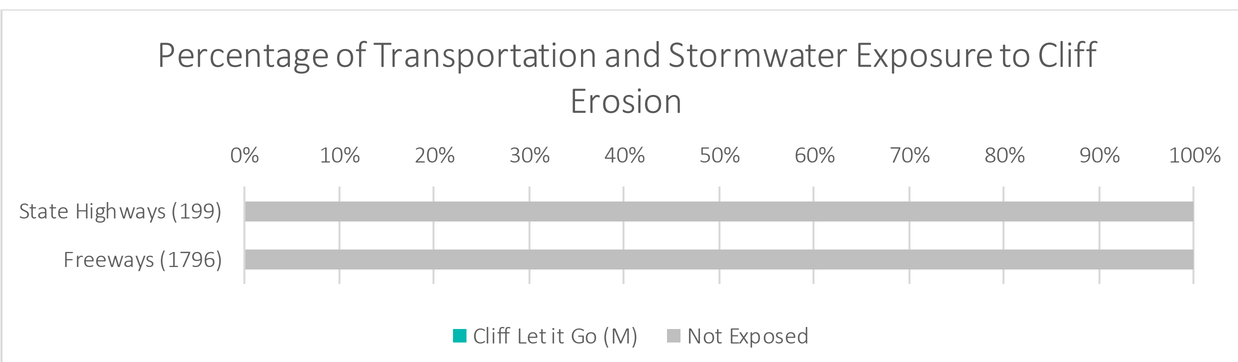

Figure 51. State highway and freeway critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

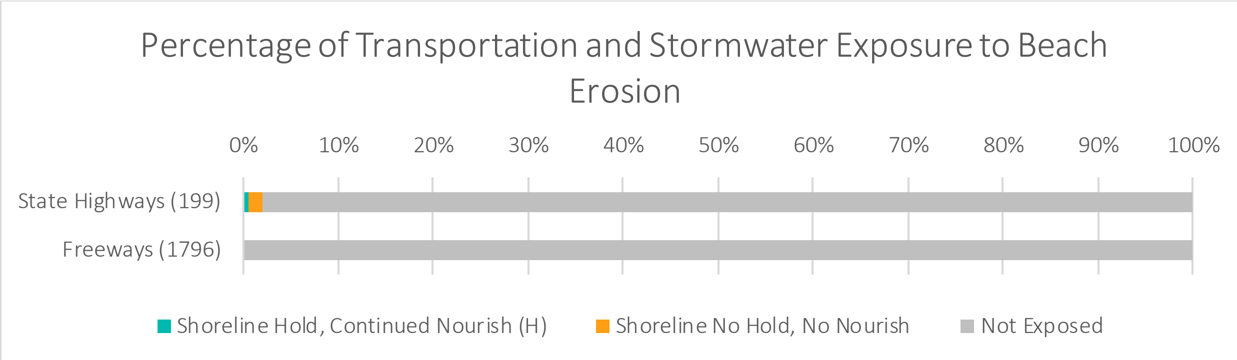

Figure 52. State highway and freeway critical assets exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline Hold, Continued Nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

State Highway and Freeway Exposure to Precipitation-driven Flooding

Both asset types have assets within the 100- and 500-year floodplains, though these exposed assets represent a relatively small proportion of all state highway and freeway assets (Figure 53). There are 360 freeway segments that lie in a floodplain, with about half of those lying in the 100-year floodplain. Like bridges, state highways may be less exposed to precipitation-driven flooding, but most of the assets that are exposed lie in the 100-year floodplain.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to precipitation-driven flooding.

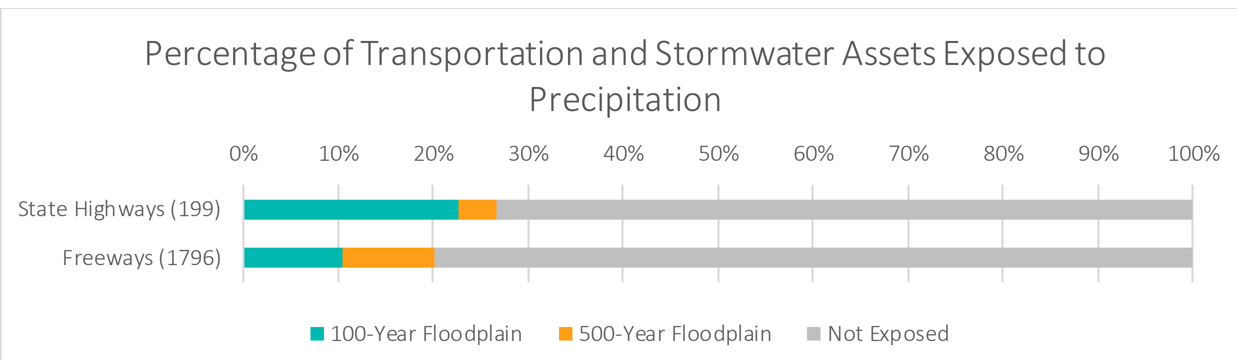

Figure 53. State highway and freeway critical assets exposed to precipitation. The value after each asset name indicates the asset count. All assets in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows assets that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

State Highways and Freeways Exposure to Heat

The City estimated that both state highway and freeway asset types face exposure to heat, as heat exposure is ubiquitous throughout the City. However, the City did not quantitatively analyze heat exposure for state highway and freeway assets, as segments of these road types crossed between heat island zones, which led to double-counting segments and therefore would have resulted in an inaccurate count.

State Highways and Freeways Exposure to Wildfires

> **Wildfire Hazard Zones for San Diego**
>
> High: Native vegetation and 100-foot setback zones

The City found that both state highway and freeway asset types are exposed to wildfires (Figure 54). Because these segments are long enough to overlap with multiple different fire hazard zones, only the percentage of state highway and freeway segments exposed to the highest level of exposure is shown.

See Appendix C: Exposure Data for more detailed information on the number of assets exposed to each of the fire hazard zones.

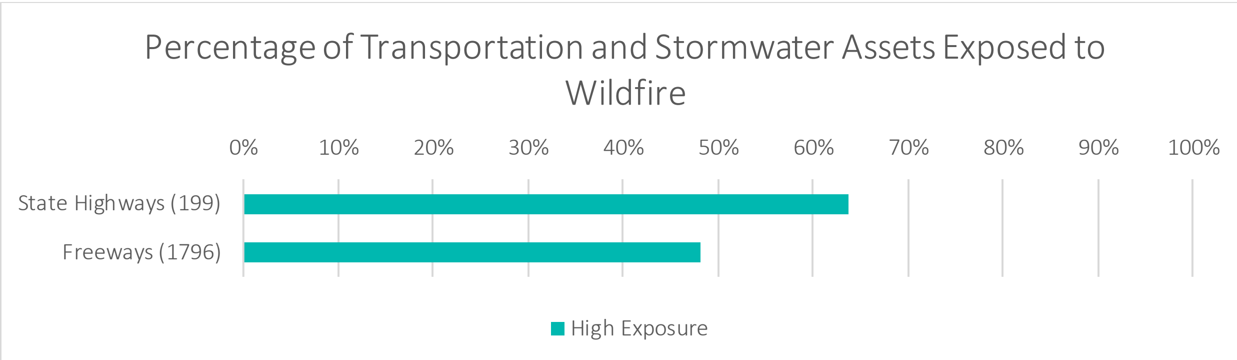

Figure 54. State highway and freeway assets exposed to wildfire. The value after each asset name indicates the asset count.

Non-City-Owned Assets

The City also reviewed the exposure of private land use types to gain a more comprehensive view of how climate change might impact various sectors in the City. Vulnerability scores were not calculated for these assets, as the City does not have full insight into the sensitivities and adaptive capacities of assets it does not manage.

Assets in the "non-city-owned assets" category would also face exposure to climate change hazards. The City identified seventy-two unique land use types and grouped them into seventeen categories: agricultural, commercial, community, cemetery, entertainment, health, hotel/motel, industrial, institutional, marina docks, office space, open space, residential, restaurant, rural, not defined, and vacant. For this exposure assessment, each parcel was assigned one or more land use types based on the tax assessors' land use code (Table 76).

Table 76. Private Land Use Types. Source: Tax Assessor's Database

Category	Land Use Types
Agricultural	1 to 10 acres non-irrigated; 41 to 160 acres non-irrigated; 161 to 360 acres non-irrigated; 361 acres and up non-irrigated; agricultural preserve (under contract); avocado; citrus; irrigated crops other vegetable, floral, feeding (hay or seed crops); livestock; misc. agricultural; trees misc. (other than citrus or avocado)
Commercial	Auto sales/service agency; automotive repair garages; car wash; community shopping center; garage parking lot/used car; generic commercial office retail 1-3 stories; generic radio station/bank/misc.; grocery/drug store large chain

	generic; neighborhood shopping center; regional shopping center; service station—generic
Community	Church; church rectory, parking and other church related use; co-op generic; meeting hall, gym—generic; public building (school, firehouse, library, etc.); theater—generic
Cemetery	Cemetery; mausoleum; mortuary
Entertainment	Bowling alley; golf course
Health	Generic—medical/dental office; hospital; rest home/convalescent hospital
Hotel/motel	Hotel/motel
Industrial	Factory/heavy manufacturing; factory/light manufacturing; industrial condos; misc. industrial/special land; natural resources—mining, extractive, processing cement/silica products, rock and gravel; storage bulk chemical/oil refinery; warehouse—processing/storage/distribution
Institutional	Institutional
Marina docks	Marina docks
Office space	Generic—four- and more story office building; office condominiums
Open space	Open space
Residential	Condominiums and other residential classifications; duplex—generic; manufactured home in park—not specified; single family residential—generic; time share generic; trailer park
Restaurant	Restaurant/night club/tavern
Rural	Rural land other
Not defined	Information parcel—generic; miscellaneous/special; multiple 2 to 4 units—generic; multiple 5 to 15 units—generic; multiple 16 to 60 units—generic; multiple 61 units and up—generic; non-taxable; special—sliver, small parcel
Vacant	Institutional—vacant; irrigated farm vacant water available; vacant industrial; vacant land commercial; vacant recreational; vacant residential—generic; vacant taxable govt. owned property

The City is unable to assess the sensitivity and adaptive capacity of non-City-owned assets to climate change hazards since the specifics of the building construction, maintenance, emergency plans, and other details are unknown. However, assessing exposure to climate change hazards provides insights into the potential scope of future concerns.

The City has assessed the exposure of private land to sea level rise, storm surge with sea level rise, coastal erosion, precipitation, and wildfire. Extreme heat exposure was not assessed in this study because the entire City faces increasing heat exposure over time. Temperatures would continue to be lowest along the coastline and increase farther inland; however, all buildings may need to consider more energy efficient air conditioning and passive cooling strategies (such as use of trees and vegetation) to adapt to rising temperatures. Land that is primarily open space (i.e., agricultural, golf courses, privately owned open space, and rural land) would benefit from further exploration of the impacts of heat on ecosystems present on the land. Similarly, because extreme heat can impact public health and social equity, it would be beneficial to assess community-level extreme heat impacts and social equity considerations.

For all exposure estimates, it is worth noting that the number of exposed parcels reflects whether any part of the parcel overlapped with a hazard. Exposure of a parcel of land does not necessarily mean that the buildings within the parcel would be exposed. For example, a parcel may extend to the coastline and therefore be exposed to sea level rise, but the buildings are all situated on the inland side of the parcel.

The land use category with the greatest exposure to sea level rise is marina docks: due to their location on the waterfront, ninety-one percent of these parcels are currently exposed (Figure 55). By definition, marina docks are at the waterfront and exposed to the sea. Four to six percent of entertainment, hotel and motel, and restaurant parcels may be exposed to sea level rise by 2030. The number of exposed parcels is not expected to increase significantly between 2030 and 2050.

Under the high emissions scenario, between five percent and sixty-two percent of hotel and motel parcels may be exposed to sea level rise in 2100. Up to eleven percent of entertainment and restaurant parcels may also be exposed to sea level rise in 2100. Other land use categories may not experience significant exposure between now and 2100 (about five percent or less of the remaining asset types may be exposed in 2100).

Up to 5,550 residential parcels may face exposure to sea level rise and almost 9,000 residential parcels may face exposure to storm surge with sea level rise in 2100. While this is a low percentage of the overall housing stock, it represents a significant vulnerability for those homeowners.

With storm surge considered in combination with sea level rise, the most notable difference in exposure is that a large number of hotel and motel parcels may be exposed much earlier: between five and fifty-eight percent of these parcels may face exposure by 2050 (compared with up to five percent by 2050 with sea level rise alone) (Figure 56). Almost ninety-five percent of marina dock parcels may be exposed to storm surge by 2030; most of these already face exposure.

Very few private parcels are exposed to cliff erosion (Figure 57). There are no cemetery, health, marina docks, office space, open space, or rural land parcels that face exposure, and a very small percentage (less than five percent) of other land use categories face exposure to cliff erosion. About 2,500 residential parcels face exposure to cliff erosion assuming 2.0 meters of sea level rise (which is the upper range for 2100).

Similarly, very few parcels are exposed to beach erosion, even if the City were to stop beach nourishment and seawall repair (Figure 58). Community, cemetery, health, industrial, marina dock, office space, open space, and rural land parcels face no exposure to beach erosion, and other land use categories face very small (less than 5 percent) exposure to beach erosion.

All land use categories face some level of exposure to precipitation-based flooding. The land use category facing the greatest proportional exposure is marina docks: about eighty-five percent of marina dock parcels lie in the FEMA 100-year floodplain, and almost ninety percent lie in the 500-year floodplain (Figure 59). The next-highest exposure is faced by entertainment parcels, of which more than thirty percent lie in the 100-year floodplain. Over ten percent of cemetery, industrial, and institutional parcels lie in the 100-year floodplain, and over ten percent of hotel and motel and restaurant parcels lie in the 500-year floodplain. Less than ten percent of the remaining land use categories lie in the 100-year or 500-year floodplain.

All land use categories except marina docks face some level of exposure to wildfire. Rural land faces the highest relative exposure to wildfire, with nearly ninety percent of parcels facing high exposure. Hotel/motel parcels face the lowest relative exposure to wildfire, with only four percent of parcels facing high exposure (Figure 60).

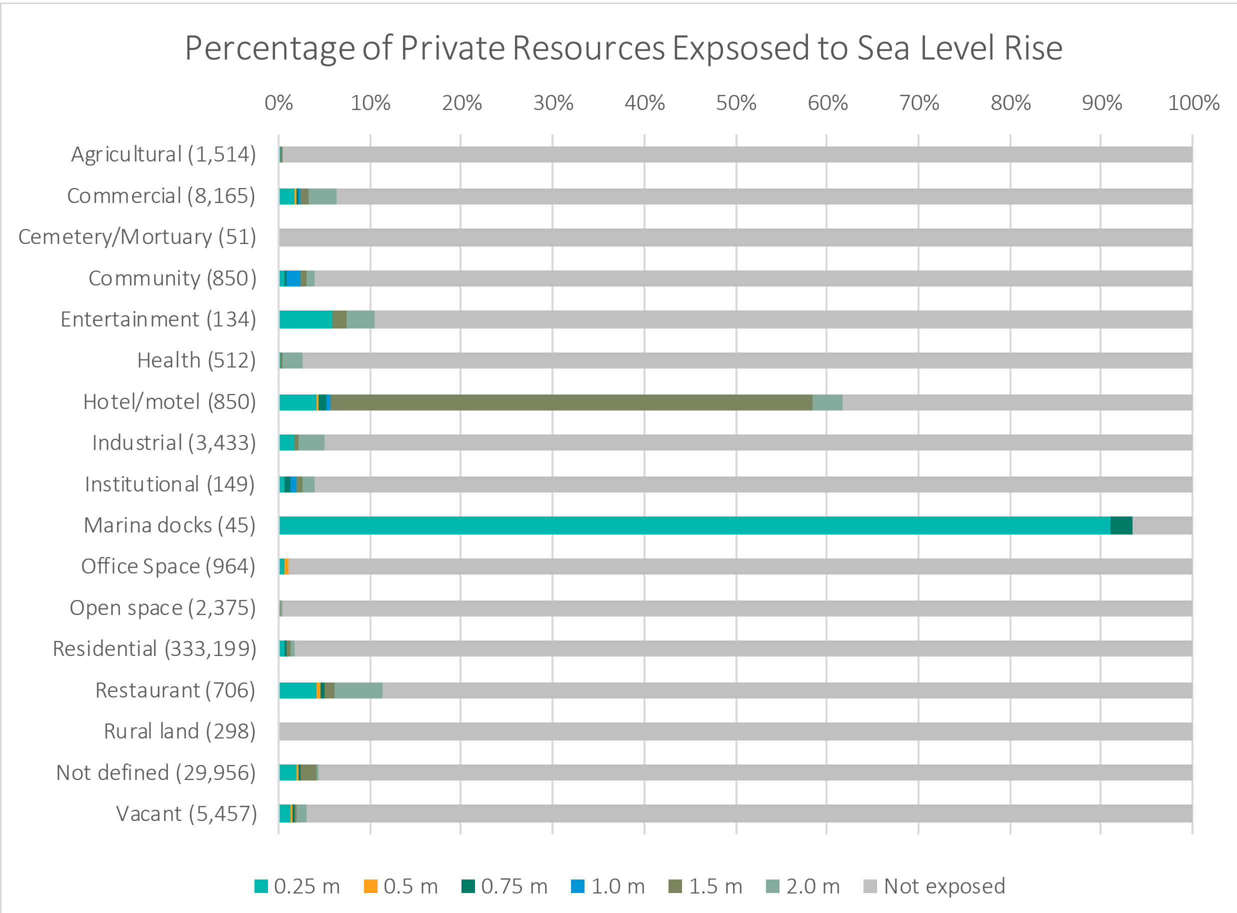

Figure 55. Private resources exposed to sea level rise. The value after each land use category indicates the total number of parcels of that land use category. The colored bars for each increment of sea level rise show how many additional parcels become inundated in each sea level rise scenario.

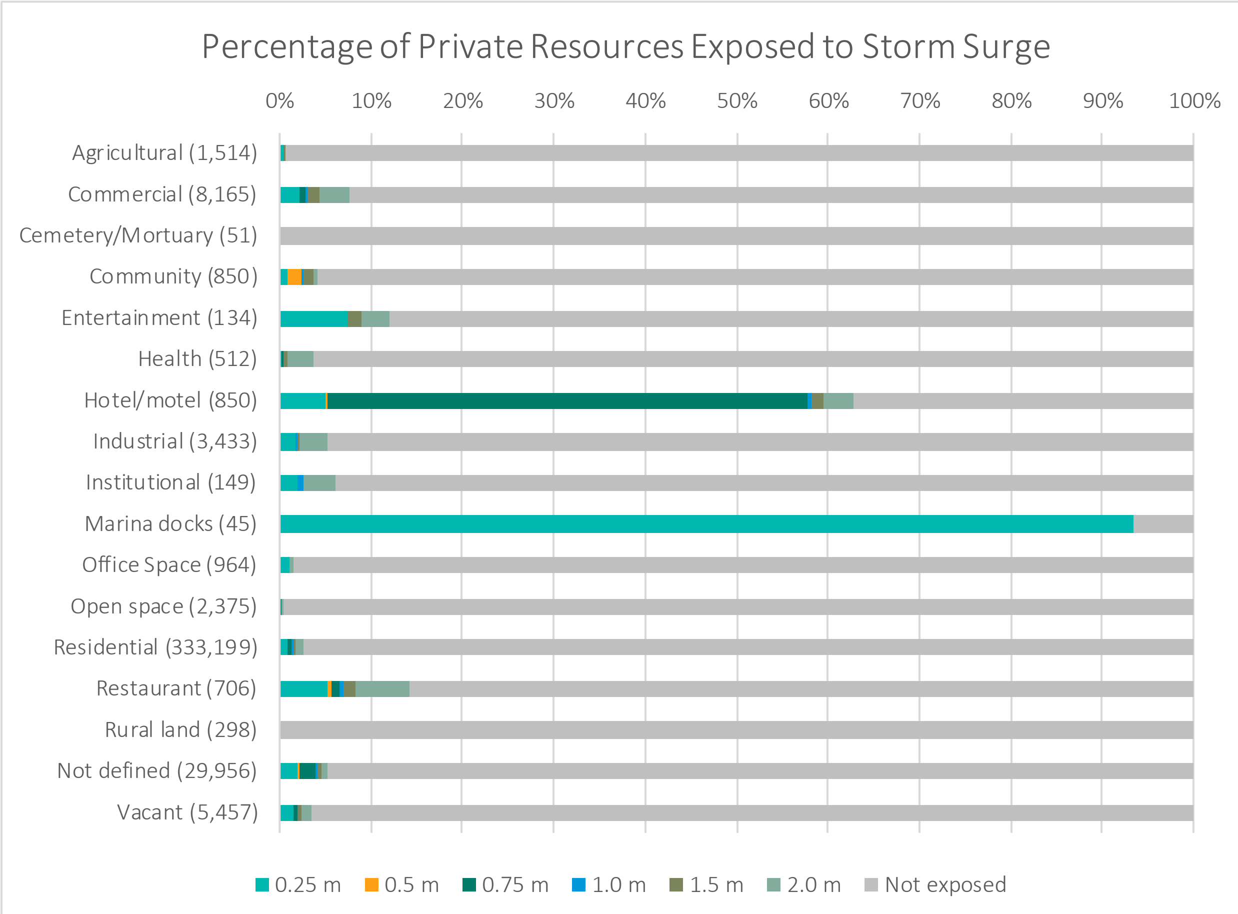

Figure 56. Private resources exposed to storm surge with sea level rise; this includes the 100-year storm on top of sea level rise. The value after each land use category indicates the total number of parcels of that land use category. The colored bars for each increment of sea level rise show how many additional parcels become inundated in each sea level rise scenario.

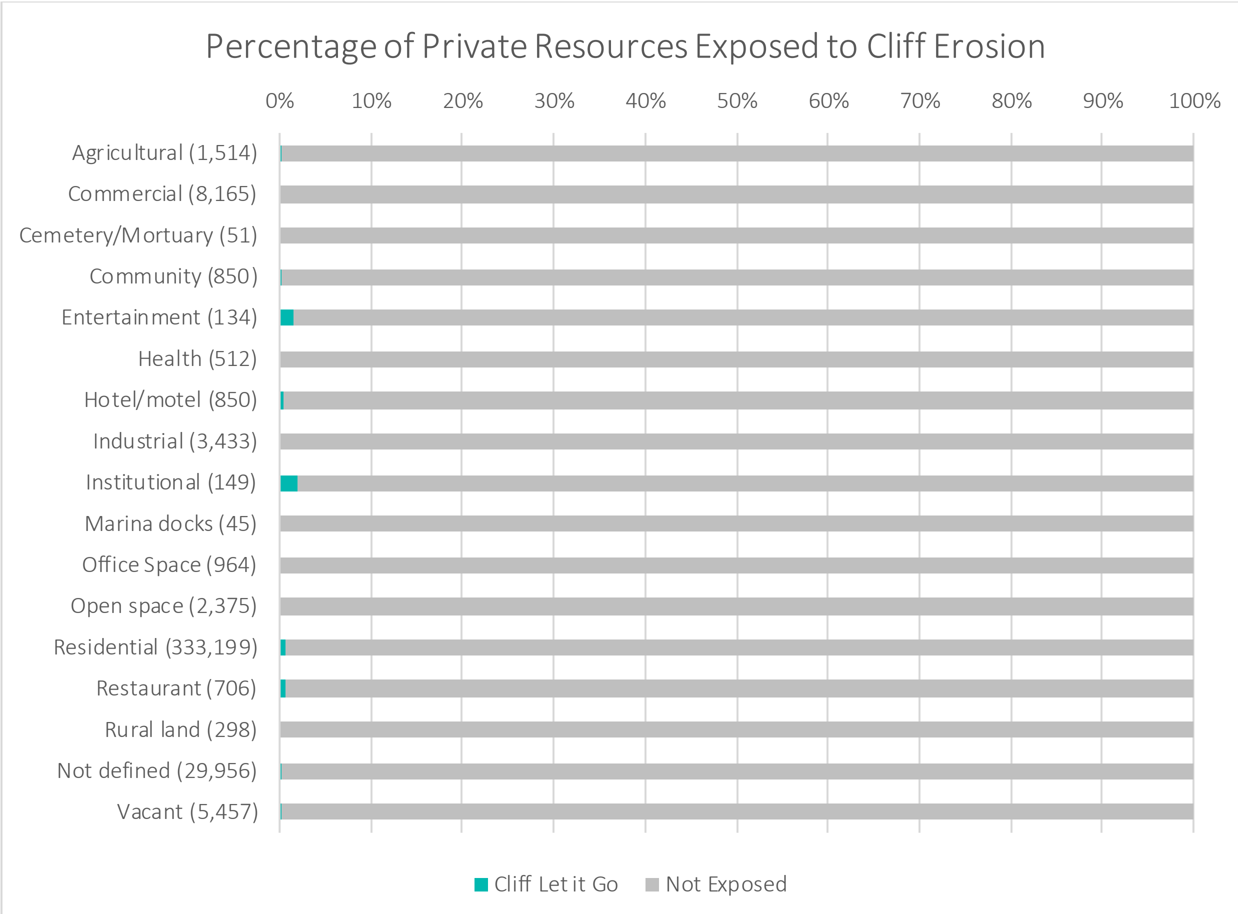

Figure 57. Private resources exposed to cliff erosion. The value after each land use category indicates the parcel count. "Cliff Let it Go" represents the percentage of parcels exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

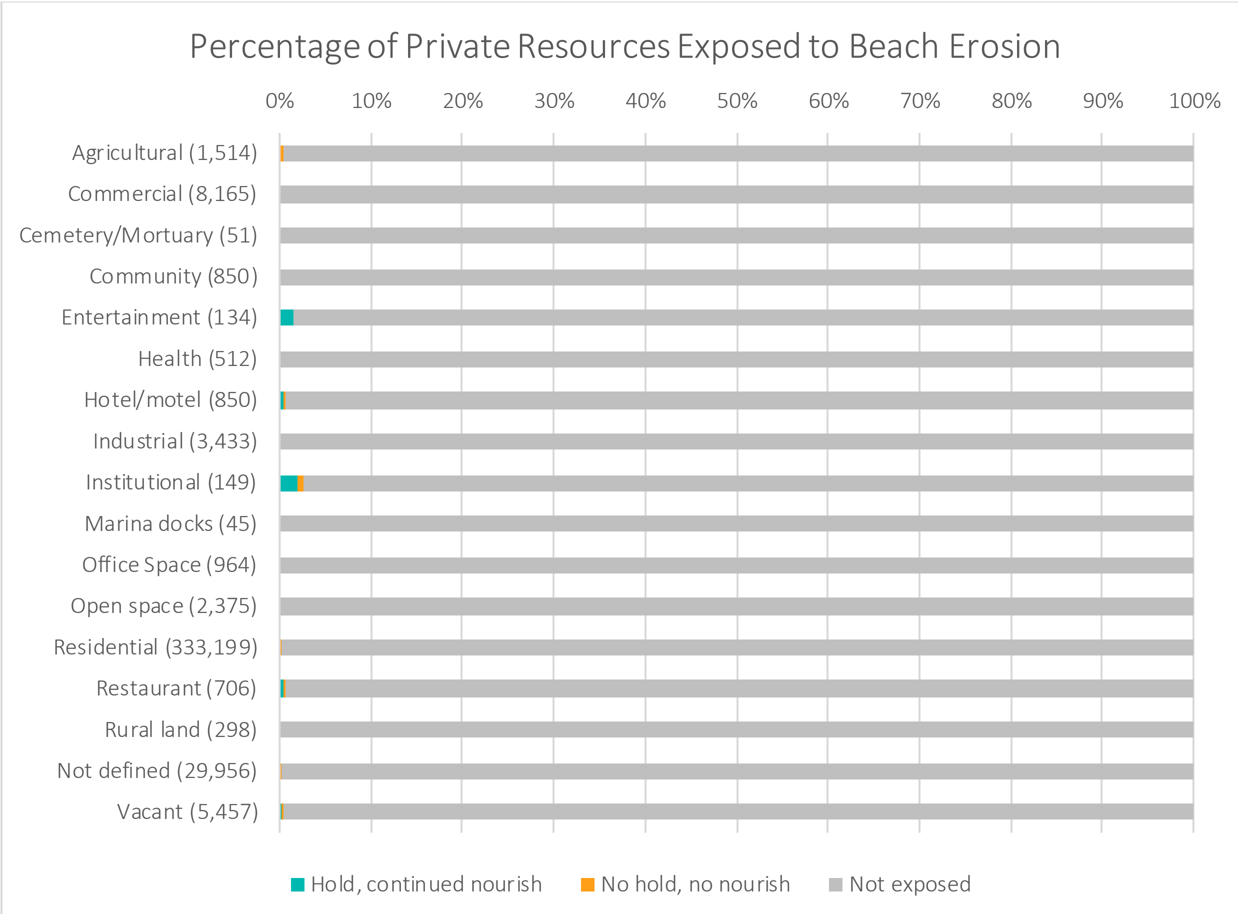

Figure 58. Private resources exposed to beach erosion. The value after each land use category indicates the parcel count. "Hold, continued nourish" represents the percentage of parcels exposed to flooding if the City continues beach nourishment and sea wall repair, while "No hold, no nourish" represents the percentage of parcels exposed if the City were to stop beach nourishment and seawall repair.

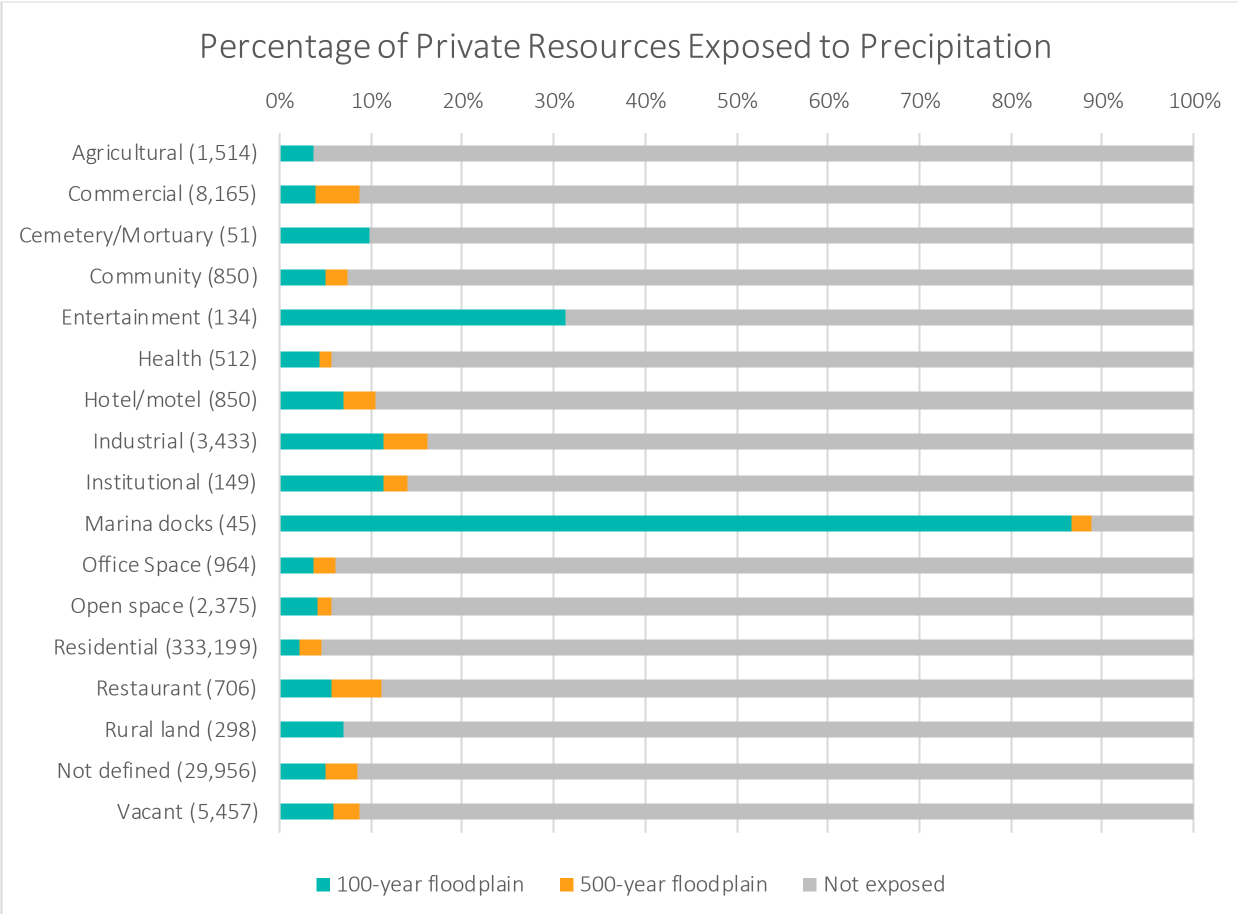

Figure 59. Private resources exposed to precipitation. The value after each land use category indicates the parcel count. All parcels in the 100-year floodplain also lie in the 500-year floodplain; the orange colored bar for the 500-year floodplain shows parcels that are outside the 100-year floodplain but experience flooding under more extreme precipitation events.

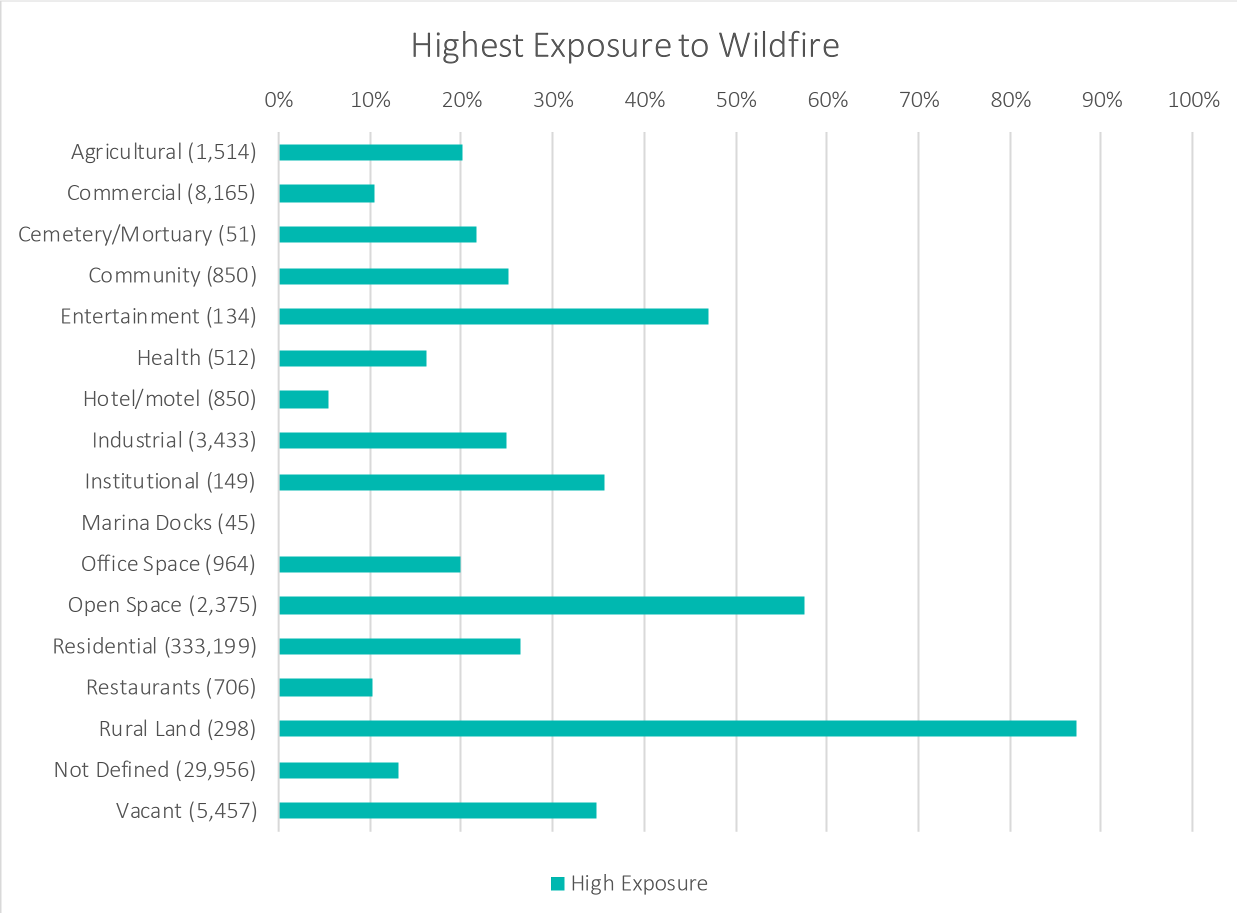

Figure 60. Private resources exposure to wildfire. The value after each land use category indicates the parcel count. Because parcels are large enough to overlap with multiple different fire hazard zones, only the percentage of parcels exposed to the highest level of exposure is shown.

Building Toward the *Climate Resilient SD Plan*

This vulnerability assessment is part of the City's overall effort to create a *Climate Resilient SD* Plan, whose goals include:

- Address climate equity by prioritizing and empowering our most vulnerable populations to climate change, with strong consideration of communities of concern;
- Raise awareness of projected/potential climate change impacts to the City;
- Gain a comprehensive understanding of the City's climate change vulnerabilities;
- Build City capacity for preventive and responsive action; and
- Identify potential climate adaptation and resilience strategies.

Based on the findings of this vulnerability assessment and consultations with stakeholders, the City identified key vulnerable asset types for inclusion in Phase 2, the detailed risk assessment. The detailed risk assessment investigated climate risk and impact consequences at the scale of individual selected assets, allowing the City to identify selected high-risk assets and develop targeted adaptation strategies. The next step in the process is for the City to develop a comprehensive *Climate Resilient SD* Plan, combining the findings of the vulnerability and risk assessment and identified adaptation strategies.

Glossary

100-year floodplain: Flood hazard areas identified by the Federal Emergency Management Agency (FEMA) that are defined as the area that will be inundated by the flood event having a one percent chance of being equaled or exceeded in any given year.

500-year floodplain: Flood hazard areas identified by FEMA that are defined as the area that will be inundated by the flood event having a 0.2-percent chance of being equaled or exceeded in any given year.

Adaptation: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities" (California Coastal Commission, 2018).

Adaptive Capacity: "The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences" (California Coastal Commission, 2018) citing (Willows, 2003).

Assets: "People, resources, ecosystems, infrastructure, and the services they provide. Assets are the tangible and intangible things people or communities value" (US Climate Resilience Toolkit, 2019).

CNG: Compressed natural gas, which is used as a fuel for specialty fleet vehicles.

Consequence: The effect of climate change exposure on community structures, functions, and populations and on the asset owner or service providers' ability to maintain a standard condition or level of service (sometimes referred to as impacts) (CEMA and CNRA, 2012).

Drain Pump Stations: Facilities including pumps and equipment for pumping fluids from one place to another, in particular for the City, these stations are for pumping storm water and wastewater to treatment plants and outfalls.

Exposure: "The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm" (Bedsworth, 2018) citing (IPCC, 2012).

Hazard: "An event or condition that may cause injury, illness, or death to people or damage to assets" (US Climate Resilience Toolkit, 2019).

Impact: "Effects on natural and human systems that result from hazards" (US Climate Resilience Toolkit, 2019).

Outfalls: Where storm water and wastewater are discharged into bodies of water.

Sensitivity: "The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (*e.g.*, a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (*e.g.*, climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors)" (California Coastal Commission, 2018).

Resilience: "The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption" (US Climate Resilience Toolkit, 2019).

Risk: The potential consequences if something is damaged or lost, considered together with the likelihood of that loss occurring.

Urban Heat Island (UHI): Large urban areas, especially those inland from the coast, often experience higher temperatures during hot summer months when compared to more rural communities, which is known as the urban heat island effect. This phenomenon is due to the absorption and retention of heat by pavement and buildings, in addition to a lack of coastal breezes.

Vulnerability: "The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, include.ng its sensitivity, and its coping and adaptive capacity" (California Coastal Commission, 2018).

Wave runup: The height above stillwater elevation reached by a wave along a beach or structure (FEMA, 2005).

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Department Consultations

The Planning Department consulted with staff members across various City departments to better understand critical asset consequences and vulnerability. The findings associated with these citations represent the judgments based on the best information available to these individuals, who were consulted between January 2019 and February 2020, and do not reflect official departmental policies.

- City of San Diego Office of the Mayor, 2019
- City of San Diego Environmental Services Department (ESD), 2019
- City of San Diego Facilities Department, 2019
- City of San Diego Fire-Rescue Department, 2019
- City of San Diego Fleet Operations, 2019
- City of San Diego Historic Preservation Planning, 2019 and 2020

- City of San Diego Multi-species Conservation Plan (MSCP) team, 2019
- City of San Diego Parks and Recreation Department, 2019 and 2020
- City of San Diego Planning Department, 2019 and 2020
- City of San Diego Police Department, 2019
- City of San Diego Public Utilities Department (PUD), 2019 and 2020
- City of San Diego Real Estate Assets Department (READ), 2019
- City of San Diego Sustainability Department, 2019
- City of San Diego Transportation and Storm Water Department (TSWD), 2019

Acknowledgments

The City of San Diego thanks the organizations and individual members of the Climate Resilient San Diego SAG for participating in meetings that led to the development of this report. The participating organizations include:

- CalOES
- Department of Defense
- FEMA, Region IX
- Caltrans Headquarters
- Caltrans District 11
- Port of San Diego
- San Diego MTS
- Scripps Institute of Oceanography
- Health and Human Services Agency
- Community Action Partnership
- County of San Diego
- U.S. Fish and Wildlife Service
- CDFW
- Coastal Conservancy
- Circulate San Diego
- Clean Tech San Diego
- San Diego Bike Coalition
- Environmental Health Coalition
- SANDAG
- UC San Diego
- San Diego Chamber of Commerce
- San Diego Gas & Electric
- San Diego Audubon
- El Dorado Properties
- San Diego Regional Airport Authority

Appendix A: Climate Data and Projections

The City of San Diego worked with ICF, a consulting firm, to conduct this vulnerability assessment. This appendix was originally a memorandum prepared by ICF to provide background information on and justification for the selected climate change scenarios used to estimate projected climate change exposure in this assessment.

Coastal Hazards

The primary threats assessed under the umbrella of coastal hazards include sea level rise, coastal flooding, and coastal erosion.

Sea Level Rise and Coastal Flooding

Sea levels rose 0.71 feet in San Diego during the 20th century (NOAA, 2018). By the end of the 21st century, San Diego could experience another 3.6 to 10.2 feet of sea level rise.

Coastal storms are projected to occur more frequently in the future, which will further exacerbate flooding along the coast.

Past and Present Conditions: Over the past century, mean global sea level has risen approximately 1.7 mm per year (about 0.07 inches per year) accelerating to a rate of 3.2 mm per year since 1993 (IPCC, 2013). From 1906 to 2017, the tide gauge at San Diego suggests a rise of approximately 2.17 mm per year (about 0.09 inches per year), approximately thirty-two percent higher than the global rate (see Figure 61) (NOAA, 2018).

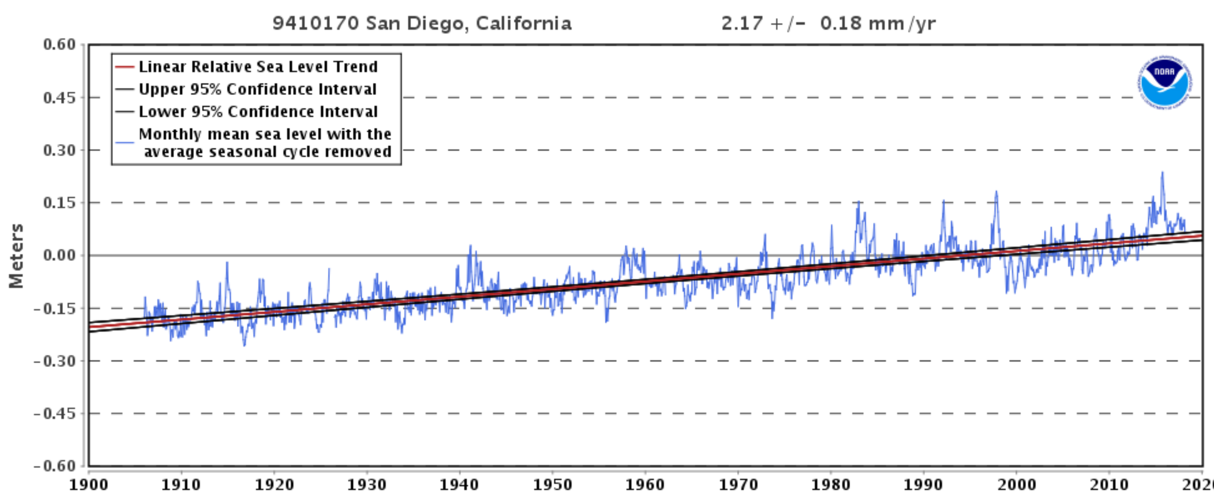

Figure 61. The relative sea level trend is 2.17 millimeters/year with a ninety-five percent confidence interval of +/- 0.18 mm/yr. based on monthly mean sea level data from 1906 to 2017, which is equivalent to a change of 0.71 feet in 100 years (tide gauge 9410170 San Diego, CA). Source: NOAA 2018.

Future Conditions: According to the recent California Coastal Commission Sea Level Rise Policy Guidance November 2018 update, sea levels in San Diego may rise by 0.6 to 1.1 feet by 2030, 1.2 to 2.8 feet by 2050, and 3.6 to 10.2 feet by 2100 (California Coastal Commission, 2018). Similarly, Kalansky et al. (2018) found that in San Diego County, sea level is projected to rise by approximately one foot by mid-century, and three feet or more by end-of-century. This range demonstrates the increasing uncertainty associated with estimating sea level rise in the long term, particularly in the latter half of the 21st century. The contribution of thermal expansion (i.e., ocean water volume expanding as ocean water warms), and small glaciers to sea level rise is relatively well-researched, while the impacts of climate change on large ice sheets are less understood. In general, the rise is projected to accelerate toward the second half of the century.

A variety of factors impact local relative sea level rise (i.e., the sea level rise projections for a specific location rather than the global average sea level rise projections), including vertical land movement, ocean dynamics, and changes in the Earth's gravitational and rotational fields (NRC, 2012). Through 2100, San Diego is projected to subside at a rate of 1.4 mm/year, and the glacial geostatic adjustment[53] is projected to cause local relative sea level to increase by 0.4 mm/year (NRC, 2012). These values are factored into San Diego region sea level rise projections.

ICF has integrated the sea level rise and storm surge scenarios from the CoSMoS sea level rise and storm surge modeling into an interactive online map that can be used to explore current and future flood risks. The primary CoSMoS layers included in the tool are provided in Table 77. The 1.5-meter CoSMoS scenario has been added to provide additional insight on the timing and phasing of future flooding. The mapping tool includes daily inundation, annual storm, and 100-year storm events for each of the sea level rise increments.

Table 77. Sea Level Rise Scenarios following California Coastal Commission Sea Level Rise Policy Guidance and Projections

Year	Low Risk Aversion Scenario 17% probability SLR meets or exceeds		Medium-High Risk Aversion 0.5% probability SLR meets or exceeds		Extreme Risk Aversion Scenario H++ scenario, no assigned probability	
	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment
2030	0.6 ft.	0.25 m (0.8 ft.)	0.9	0.25 m (0.8 ft.)	1.1 ft.	0.25 m (0.8 ft.)
2050	1.2 ft.	0.25 m (0.8 ft.)	2.0 ft.	0.5 m (1.6 ft.)	2.8 ft.	0.75 m (2.5 ft.)
2100	3.6 ft.	1 m (3.3 ft.)	7.0 ft.	2 m (6.6 ft.)	10.2 ft.	2 m (6.6 ft.)

Extreme flood frequency is expected to increase under all projections of sea level rise. In addition, rising seas boost the occurrence of severe floods (such as the 500-year flood) more than moderate floods (such

[53] The Earth's crust is still reaching a state of equilibrium after the melting of the glaciers at the end of the last ice age. This process is called glacial geostatic adjustment. Some locations that were compressed due to the huge weight of the ice are still rebounding, while areas that were near, but not covered with glaciers were pushed up during the ice age and are still subsiding.

as the 10-year flood) along the Pacific coast of the United States (Buchanan, 2017). By elevating storm tide, sea level rise makes it easier for waves to surpass natural barriers, increasing the relative frequency of flooding along the Pacific coast.

Coastal Erosion

Coastal erosion has long been an issue along Sunset Cliffs, La Jolla Cove, and Torrey Pines. In addition, the City regularly places new sand on beaches to maintain their width. With sea level rise and changes in storms, coastal erosion is expected to increase, though there is considerable uncertainty regarding where and when that may occur.

Past and Present Conditions: The relatively soft sandstone bluffs that are common along the San Diego coast are prone to erosion from waves and from storm water runoff. The last City-wide coastal erosion assessment, consisting of geotechnical reports, site visits, and photographic documentation of erosion, was completed in 2003 (City of San Diego, 2003). That study identified eleven high-priority sites with conditions that "present potential public hazards." These sites include:

1. Osprey Street to Adair Street (Spalding Park)
2. Hill Street to Guizot Street
3. Guizot Street to Froude Street
4. Froude Street to Osprey Street
5. Nautilus Street to Westbourne Street (Stairwell)
6. Diamond Street to Missouri Street
7. Coast Boulevard – split to Children's Beach (bluff top and sidewalk)
8. La Jolla Cove (North of 1325 Coast Blvd)
9. Mission Beach Park
10. Sun Gold Point to Cortez Place
11. Pt. Loma Ave to Bermuda Ave (Pt. Loma Ave street-end and storm drain)

Figure 62. Erosion assessment images for Hill Street to Guizot Street from 1993, 2003, and 2018. Source: ICF 2018.

In 2018, ICF delivered a high-level update the 2003 assessment (ICF, 2018). This update included re-visiting the sites from the 2003 assessment to take new photographs and documents visual changes in the level of erosion. The update indicates that while the City has made improvements to pedestrian access and safety along the erosion sites, more sites pose threats to pedestrians relative to 2003. For instance, currently, twenty-seven percent of the seventy-one sites identified pose pedestrian hazards, have limited pedestrian access because of erosion, and/or have signs of imminent bluff collapse, while just sixteen percent of sites showed these signs in 2003.

Future Conditions: Cliff erosion is likely to increase with sea level rise and heavier rainfall events, but modeling when and where can be difficult. New research by Scripps indicates that cliffs cycle through periods of erosion and stability, meaning that historical erosion rates are not always an accurate predictor of future erosion (Young, 2018). Areas that have been stable for some time may start eroding while areas that have been actively eroding may stabilize. Unfortunately, research has not yet determined how to predict in detail when cliff erosion may slow or accelerate.

Beach erosion is also likely to accelerate with sea level rise. While the City currently nourishes the beaches, it is likely that historical rates of nourishment would be insufficient to halt future beach erosion. A recent study (Vitousek, 2017) found that, although subject to considerable uncertainty, significant impacts to the shoreline would occur due to accelerated sea level rise, with 31 percent of beaches in Southern California lost by 2100 under the 0.93 meter (3 feet) sea level rise projections.

ICF integrated coastal erosion into the interactive online map tool. The layers include CoSMoS cliff erosion and shoreline change. Given the complexity and uncertainty of modeling coastal erosion, ICF plans to supplement the CoSMoS erosion modeling with the institutional knowledge of City departments through discussions on coastal erosion vulnerabilities.

Salt Water Intrusion

As groundwater resources are affected by changes in precipitation, drought events, and withdrawal rates, and as sea levels rise, salt water can seep into underground aquifers; however, determining when and where this may occur is still being researched by the scientific community.

Past and Present Conditions: A supplemental consideration for coastal hazards is the threat posed by salt water intrusion. In San Diego County, groundwater levels have declined, leading to salt water intrusion over time (Wen, 2014).

Future Conditions: Research indicates that further salt water intrusion could occur with rising sea levels (San Diego Foundation, 2012). In particular, the San Diego Formation aquifer may experience salt water intrusion from San Diego Bay depending on the extent of future groundwater pumping, precipitation, presence of channels, storm events, and sea level rise. The amount of future salt water intrusion and the exact areas cannot be determined at this time.

Precipitation

The primary concerns for precipitation-driven hazards are historical flood areas and changes in annual and extreme precipitation. Supplemental considerations include changes in drought and landslides.

Annual Average Precipitation and Extreme Precipitation

Precipitation is one of the more difficult variables for climate change models to project. For the San Diego region, the models only show a slight change in average annual rainfall, but overall there is expected to be more variability in rainfall from year to year and more intense transitions between droughts and deluges.

Past and Present Conditions: California can experience wide swings in precipitation from drought years to El Niño years. From 1939 to 2016, the average annual rainfall at San Diego Airport was 10.13 inches (Western Regional Climate Center, 2018).

Future Conditions: Annual average precipitation values from Cal-Adapt and other sources project only modest changes (Seager, 2015). While historical annual average precipitation was ten inches, approximately nine to ten inches are expected by mid- and late century, under both low and high emissions scenarios. These projections are based on the ensemble average of four recommended climate models for the area (MIROC5, HadGEM2-ES, CNRM-CM5, CanESM2).

Projections for total annual precipitation in the State of California have not reached a firm consensus; some simulations indicate that the region would become drier while others indicate that it would become wetter (Messner, 2009). For example, a study accounting for possible warm wet winters associated with El Niño conditions, projects a twelve percent increase in precipitation in California from 2020 to 2100, compared with 2000 to 2017 (Allen, 2017). Another recent study projects that there would be both more extreme wet years *and* more extreme dry years, as shown in the top and middle graphs of Figure 63 (Swain, 2018). Specifically, 1-in-25 year wet extremes (similar to the 2016 to 2017 wet season) and 1-in-100 year dry extremes (slightly drier than 2013 to 2014) are expected to become 2.5 times more frequent by the end of the century, relative to 1985 to 2017 (Swain, 2018). Overall there is expected to be more variability in precipitation and more intense transitions between the two, as occurred in 2015 to 2016 and 2016 to 2017 when an extremely dry year was followed by an extremely wet year, as shown in the bottom graph of Figure 63 (Swain, 2018).

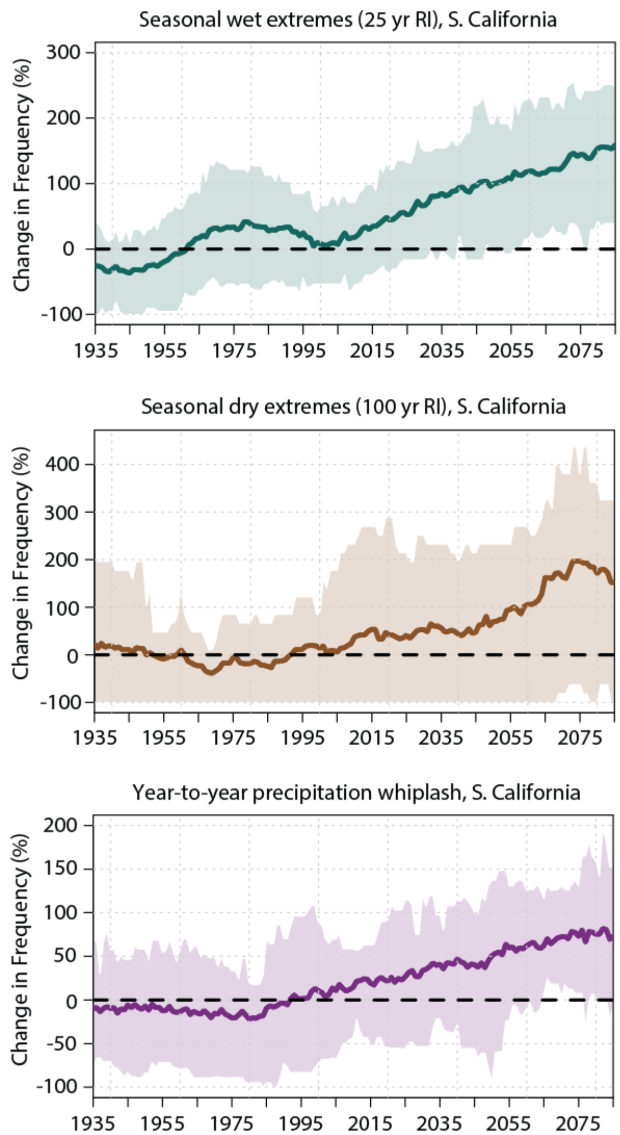

Figure 63. Relative change [percent] in extremely wet seasons (top), extremely dry seasons (middle), and year-to-year whiplash (bottom) by end of century in Southern California. Source: Swain et al. 2018.

The City of San Diego will likely continue to be vulnerable to extreme precipitation events and drought. One study estimated that while San Diego would see fewer rainy days by 2050, the biggest rainstorms would be bigger than they are now in terms of rainfall (Higbee, 2014). Extreme precipitation events (that historically occurred every twenty-five years, on average) are expected to become 2.5 times more frequent in Southern California (Swain, 2018). That implies that what would be considered extreme in the future will be even stronger than what we experience as extreme now.

Precipitation-Driven Flood Areas

Areas of San Diego (e.g., Mission Valley) already flood when there are heavy rainfall events. As rainfall events get stronger in the future, the area affected by inland flooding would increase.

Past and Present Conditions: Historically, FEMA has prepared 100-year and 500-year flood channel maps to indicate potential areas of inland flooding during heavy rainfall events, based on past conditions. These FEMA maps have been incorporated into the online mapping tool that ICF is creating for the City of San Diego. Although there are some known shortcomings to these maps—primarily that they are based solely on historical climate and do not yet incorporate projected changes in climate—they are the best information that is comprehensively available for the City.

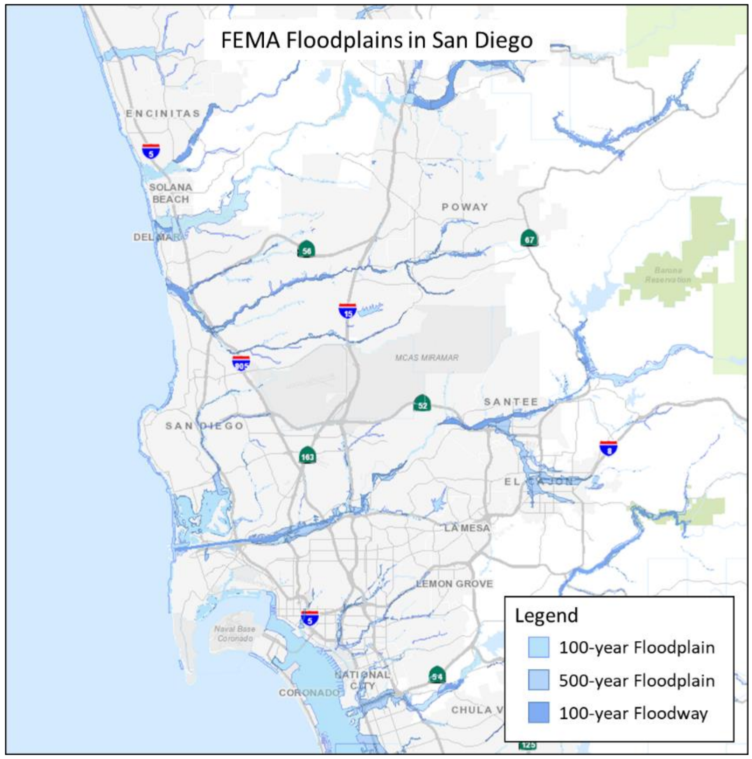

Figure 64. FEMA floodplains in San Diego. Source: SANDAG SanGIS.

Inland flooding is also impacted by the ability of storm water to drain. Increases in sea level rise may inhibit gravity-fed drainage systems if the water cannot escape through the outfalls.

Future Conditions: With heavier rainfall events would come expanded and new areas of inland flooding. Mapping of potential changes in the frequency and extent of inland flooding events in the region is not available currently.

Droughts

Drought has ravaged California in recent years and the future doesn't look much better. While droughts will always be cyclical, droughts are projected to become more frequent and drier.

Past and Present Conditions: California has recently emerged from one of the worst droughts in its history. It is thought that climate change has already begun to increase the occurrence of warm-dry conditions that result in drought (Diffenbaugh, 2015).

Future Conditions: While projections of precipitation indicate high inter-annual variability, droughts themselves are projected to be drier (by twenty percent) and occur more frequently in San Diego by the early twenty-first century (Messner, 2009). Swain et al. (2018) expect that extremely dry years (that historically occurred once every

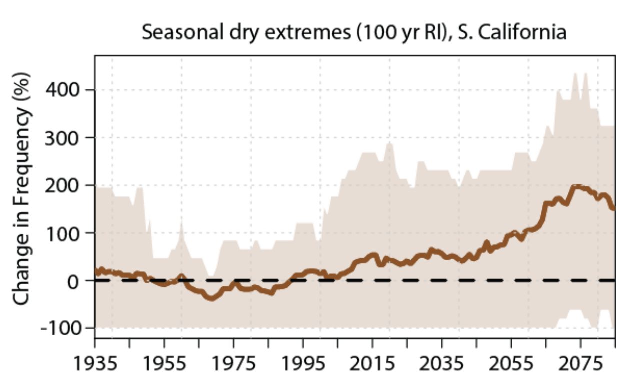

Figure 65. Relative change [percent] in extremely dry seasons. Source: Swain et al. 2018.

100 years, on average) would become 2.4 times as frequent in Southern California after 2050, relative to the pre-industrial era, as shown in Figure 65. Extended droughts, or "mega-droughts" are also projected to become more pervasive in the future. Figure 66, below, shows projections for maximum temperature and average annual rainfall under a twenty-year mega-drought drought scenario.

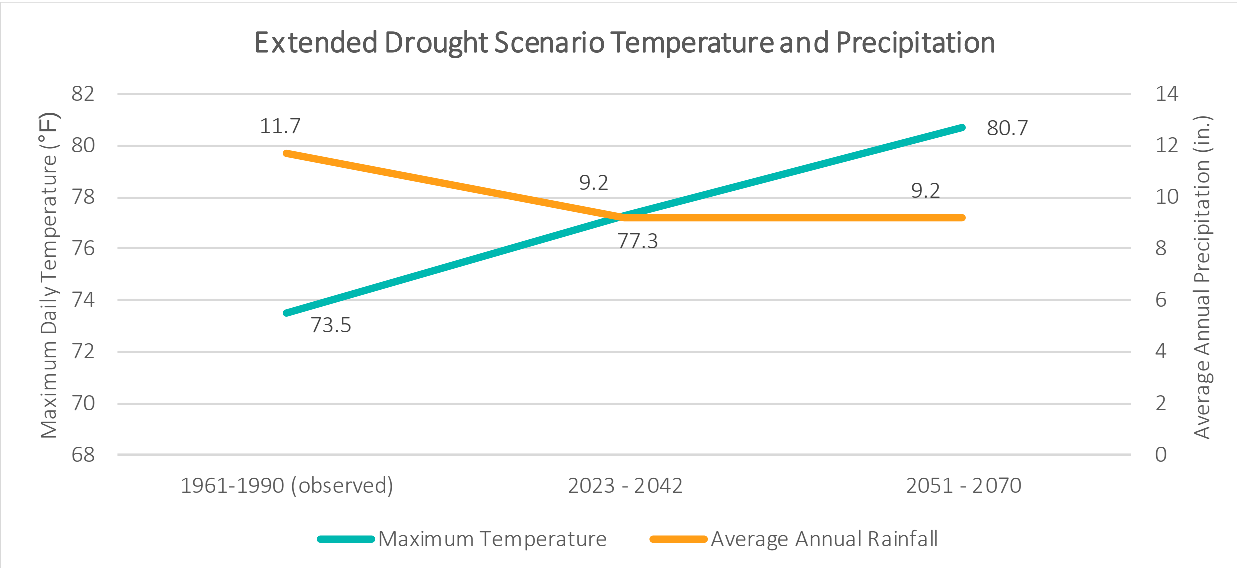

Figure 66. Extended drought scenario simulation of maximum daily temperatures and average annual precipitation, from the HadGEM2-ES climate model, emissions scenario RCP 8.5. Time periods are based on twenty-year water year (i.e., Oct to Sep) averages. Source: Cal-Adapt 2018.

Landslides

With changing wildfire and precipitation patterns, the risk of mudslides and landslides may be increasing in San Diego.

Past and Present Conditions: The County of San Diego analyzed landslide risks in the 2010 Multi-Jurisdictional Hazard Mitigation Plan (San Diego County, 2010). The map of high-risk areas can be viewed here.

Future Conditions: The threat of landslides, including mudslides, is also projected to change under climate change. Extreme precipitation is one of the main causes of slope instabilities. As such, climate change-induced increases in extreme precipitation events have the potential to decrease slope stability and increase the frequency of landslides (Robinson, 2016). Additionally, the risk of rain-induced landslides is significantly higher following a wildfire. The section below discusses wildfire risks. Mapping of potential changes in the frequency and extent of landslide and mudslide events is not available currently.

Temperature

To evaluate the threat of temperature changes, ICF assessed projections for extreme temperature and expanding summer season, cooling and heating degree days, heat waves, and urban heat island.

Daily Temperatures

Extreme Heat Days

San Diego is known for its pleasant temperatures—in the past, extreme highs (93 degrees Fahrenheit) have only occurred about four days a year. However, those pleasant temperatures are projected to change. By the 2080's, each year could include up to a month with daily highs over 93 degrees Fahrenheit.

Past and Present Conditions: San Diego routinely experiences hot summer days. "Extreme heat" for the City of San Diego is defined as a day with a maximum temperature exceeding 93.1 degrees Fahrenheit.[54] Historically (1960 to 1990), there have been four extreme heat days per year in the City of San Diego.

Future Conditions: Climate projections indicate that San Diego will experience more frequent extreme heat days. ICF used Cal-Adapt to investigate the average annual extreme heat days for mid-century and end-of-century time periods under both low and high emissions scenarios (Figure 67).[55] By mid-century (2035 to 2064), extreme heat days could increase to eleven days under a low emissions scenario and fifteen days under a high emissions scenario. By the late century (2070 to 2099), this could further increase to sixteen days under the low emission scenario and thirty-two days under the high emission scenario.

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[54] More specifically, an extreme heat day is defined as a day in April through October when the maximum temperature exceeds the City of San Diego's ninety-eighth percentile of historical maximum temperatures between April 1 and October 31 based on observed daily temperature data from 1961 to 1990. This threshold for extreme heat days is calculated to be 93.1 degrees Fahrenheit. In other words, historically, this temperature was only exceeded in the City of San Diego two percent of all days.

[55] Four climate models were used for this analysis (HadGEM2-ES, CNRM-CM5, CanESM2, and MIROC5), all of which have been selected by California state agencies as priority models for research contributing to California's Fourth Climate Change Assessment.

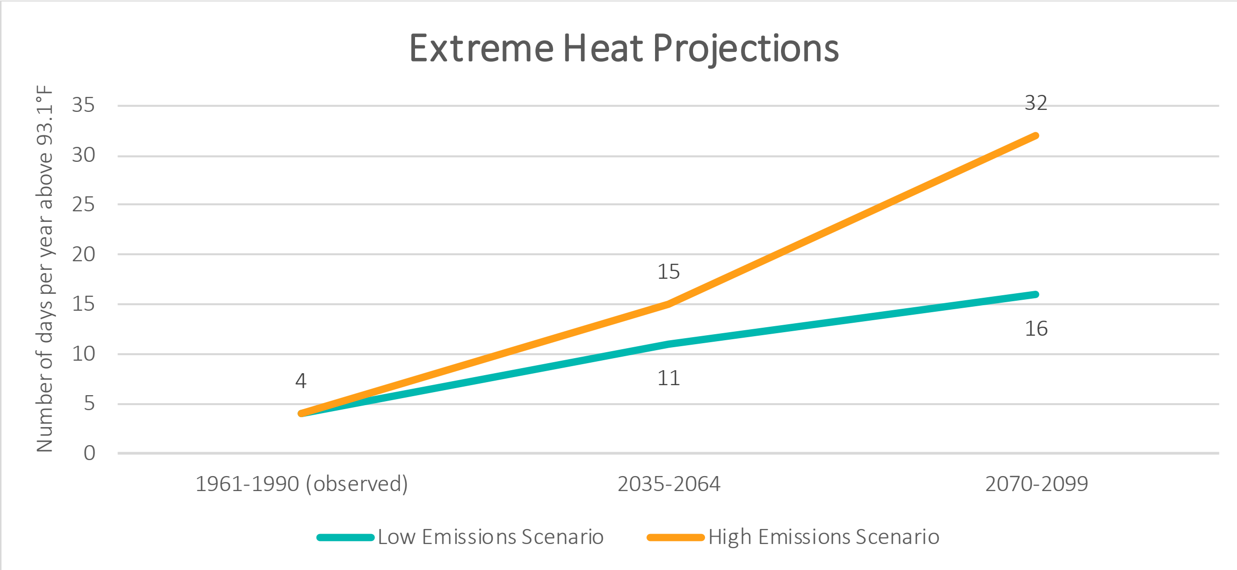

Figure 67. Extreme heat projections for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Average Daily Maximum Temperatures

It's not only the hottest days that are going to get hotter— average winter, spring, summer, and fall temperatures will be hotter than they used to be. In the 2040s, the daily high could be 5 degrees Fahrenheit higher throughout the year, and in the 2080s it could be up to 8 degrees Fahrenheit higher.

Past and Present Conditions: Another way of considering increasing extreme temperatures is the gradual increase in the annual average maximum temperature. Historically (1961 to 1990), the annual average daily maximum temperature for San Diego was 73.6 degrees Fahrenheit.

Future Conditions: Using Cal-Adapt and the same climate models and timeframes as for extreme heat days, ICF concluded that by the end of the century, under a high emissions scenario, daily maximum temperatures could be almost 8 degrees Fahrenheit warmer than they are today (Figure 68). By mid-century (2035 to 2064), daily maximum temperatures are projected to increase to 77.2 degrees Fahrenheit under a low emissions scenario and to 78.1 degrees Fahrenheit under a high emissions scenario. By the late century (2070 to 2099), these temperatures are projected to reach 78.5 degrees Fahrenheit under the low emission scenario and 81.3 degrees Fahrenheit under the high emission scenario.

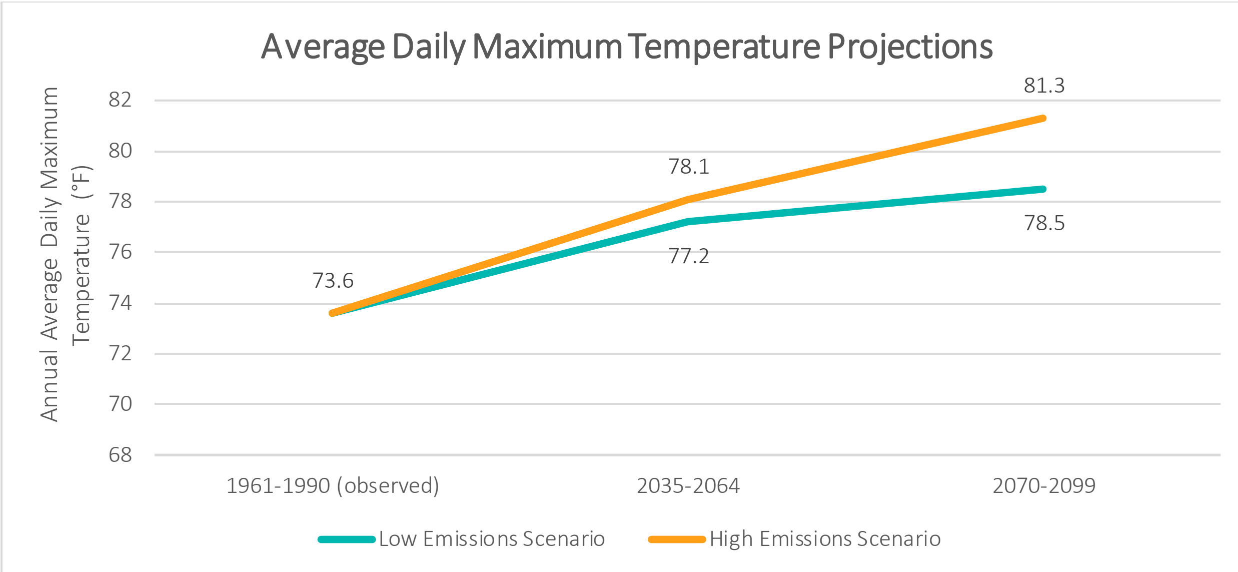

Figure 68. Average daily maximum temperature projections for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Expanding Summer Season

June gloom may become a thing of the past as hot summer days shift from starting in August to kicking off the summer season as early as June.

Past and Present Conditions: Historically, San Diego's summer season has started later than other parts of the United States. Most extreme heat days occurred in August to October (Cal-Adapt, 2018).

Future Conditions: According to climate change projections, in addition to more hot days, those days are expected to occur over a wider range of months, effectively lengthening the summer season. Figure demonstrates that in the future, extreme heat days may be experienced much more often as early as June. The blue boxes in Figure show that increase: extreme heat days in the 1960s and 1970s were concentrated in September and October, while extreme heat days from the 2070s onward occur frequently from June through October.

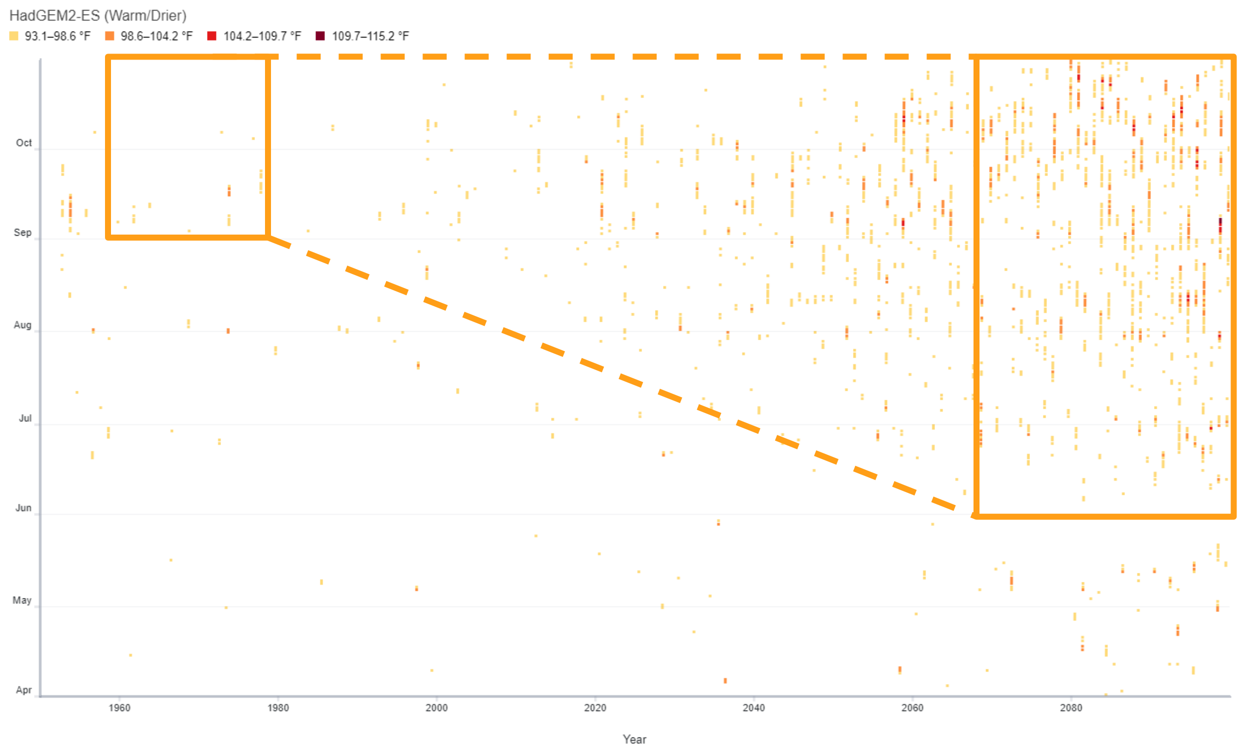

Figure 69. Timing of Extreme Heat Days (RCP 8.5, HadGEM2-ES model). Source: Cal-Adapt 2018.

Cooling Degree Days and Heating Degree Days

Even today, more and more residents and businesses are installing air conditioners. By the end of the century, demand for air conditioning could double or triple over historical levels. On the other hand, demand for winter heating could become almost non-existent by the end of the century.

Past and Present Conditions: Cooling degree days and heating degree days are used by utilities and other planning entities as an indicator of forecasted demand for energy to run air conditioning and heaters. For the purposes of analysis, Cal-Adapt uses the following approach to calculate cooling degree days:

> "A Cooling Degree Day (CDD) is defined as the number of degrees by which a daily average temperature exceeds a reference temperature. The reference temperature is typically 65 degrees Fahrenheit, although different utilities and planning entities sometimes use different reference temperatures. The reference temperature loosely represents an average daily temperature below which space cooling (e.g., air conditioning) is not needed. The average temperature is represented by the average of the maximum and minimum daily temperature."

For example, a day with an average temperature (i.e., not the maximum temperature, but the average throughout the day) of 72 degrees Fahrenheit would be counted as 72°F–65°F = 7 CDDs.

CDDs serve as a proxy for energy demand, since the reference temperature represents the temperature at which space cooling, such as air conditioning, is turned off. When average temperatures climb above this reference temperature, space cooling is turned on, and is used more frequently and intensely as the temperature gets hotter. Historically, there are roughly 1,000 CDDs in a year for San Diego.

Heating degree days are calculated in the same fashion but using a different reference temperature and summing days with an average temperature that falls below the threshold temperature. Historically, there are roughly 1,300 heating degree days in a year.

Future Conditions: Figure shows that the energy demand for cooling could double or triple current levels by the end of the century under low and high emission scenarios, respectively.

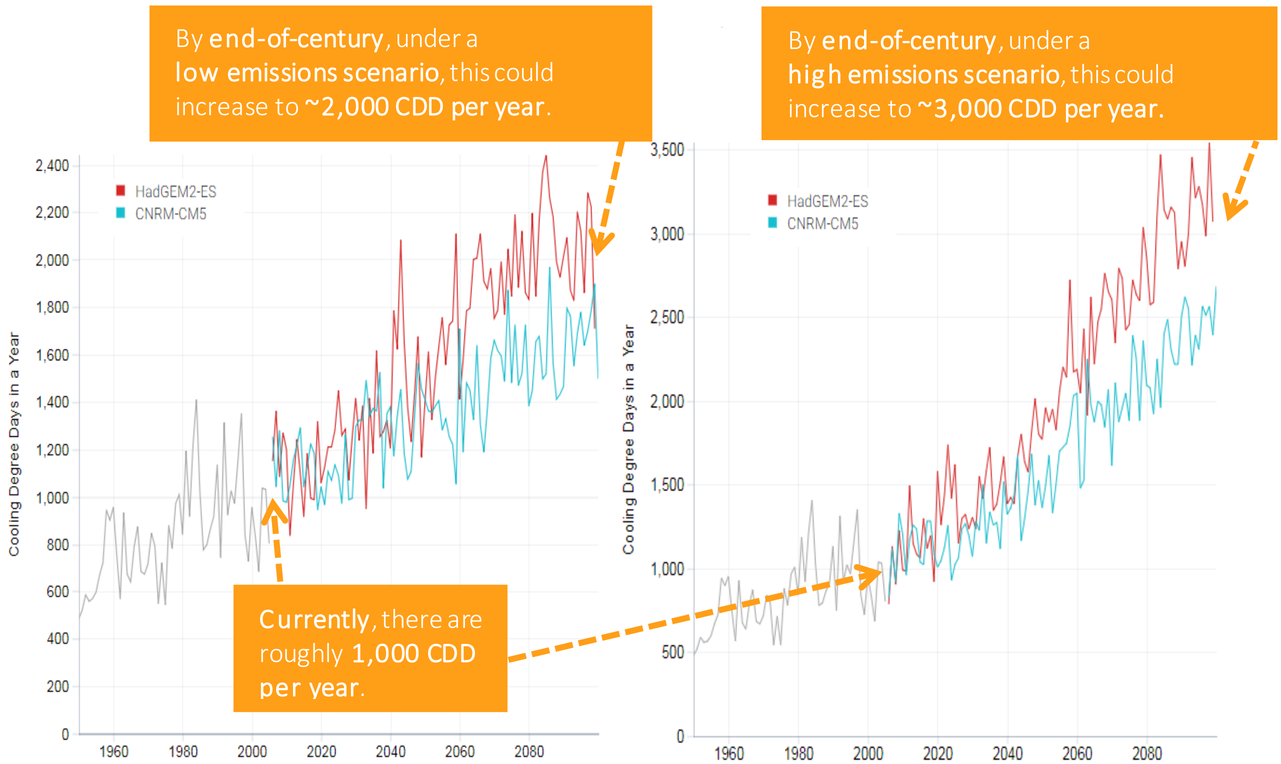

Figure 70. Left: Historical and projected Cooling Degree Days (CDD) under RCP4.5 and two climate models. Right: Historical and projected CDD under RCP 8.5 and two climate models. Source: Cal-Adapt 2018.

While CDDs are projected to increase, heating degree days are projected to decrease over time as the winters become warmer, thus decreasing the need for heating (see Figure 71) (Cal-Adapt, 2018). Historically, there are roughly 1,300 heating degree days per year. By the end of the century, San Diego could be experiencing as few as 500 to 100 heating degree days per year (under a low emission and high emission scenario, respectively). This means there will be less need for heating during colder months.

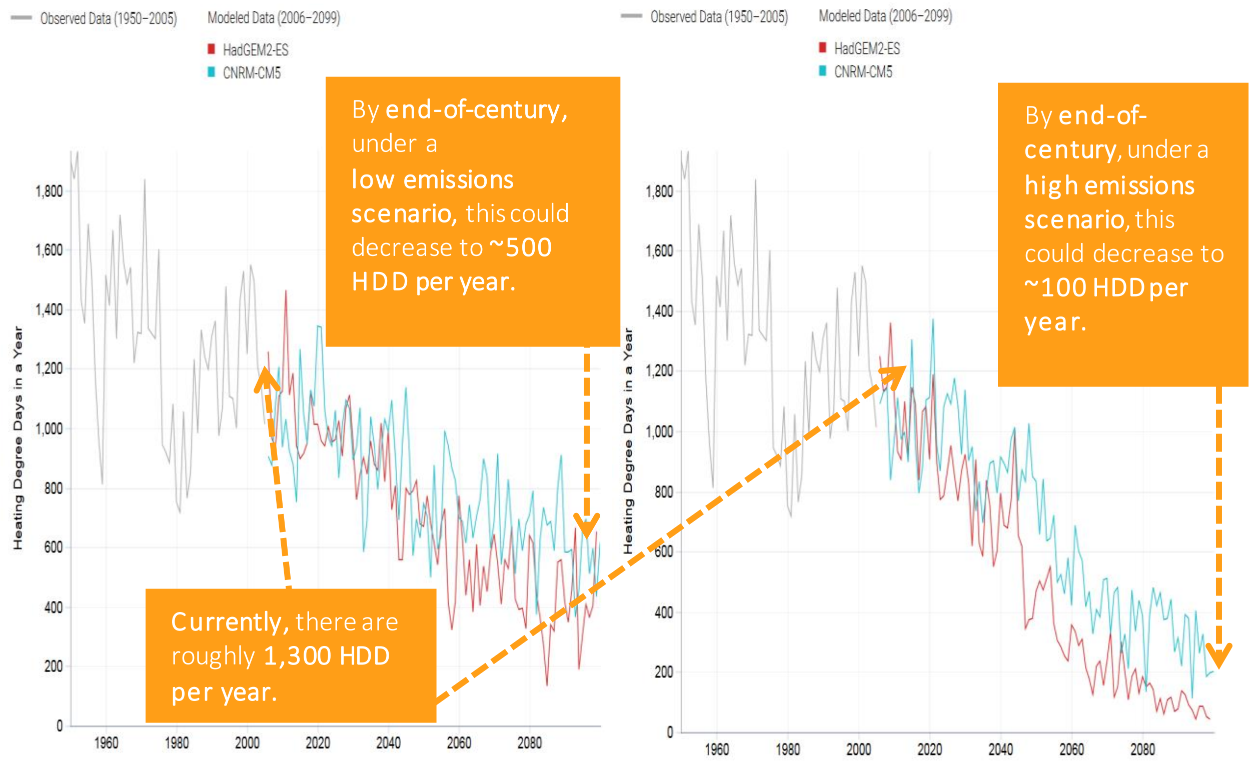

Figure 71. Left: Historical and projected Heating Degree Days (HDD) under RCP 4.5 and two climate models. Right: Historical and projected HDD under RCP 8.5 and two climate models. Source: Cal-Adapt, 2018.

Heat Waves

Everyone knows that heat waves aren't nearly as fun as riding the surf. By mid-century, heat waves could be occurring three to five times more frequently than historically and each heat wave could drag out for over twice as many days.

Past and Present Conditions: San Diego has not been prone to heat waves in the past. Historically (1960 to 1990), there has been one four-day heat wave[56] approximately every other year, and an average maximum of 2.5 consecutive extreme heat days per year in the City of San Diego.

Future Conditions: ICF surveyed recent literature and found that similar to extreme heat, heat waves are projected to increase in frequency, magnitude, and duration (Messner, 2009). Recently released California Fourth Climate Assessment data also show that heat wave frequency is projected to increase (Kalansky, Cayan, Barba, Brouwer, & Boudreau, 2018). San Diego is projected to experience 0.6 to 1.4 more four-day heat waves per year by mid-century, and 1.2 to 4.2 more heat waves per year by late

[56] Heat waves are defined as 4-day events where daily maximum temperatures exceed 93.1 degrees Fahrenheit.

century, as shown in Figure 72, below. These frequencies are averages over thirty years, which explains why they are not whole numbers.

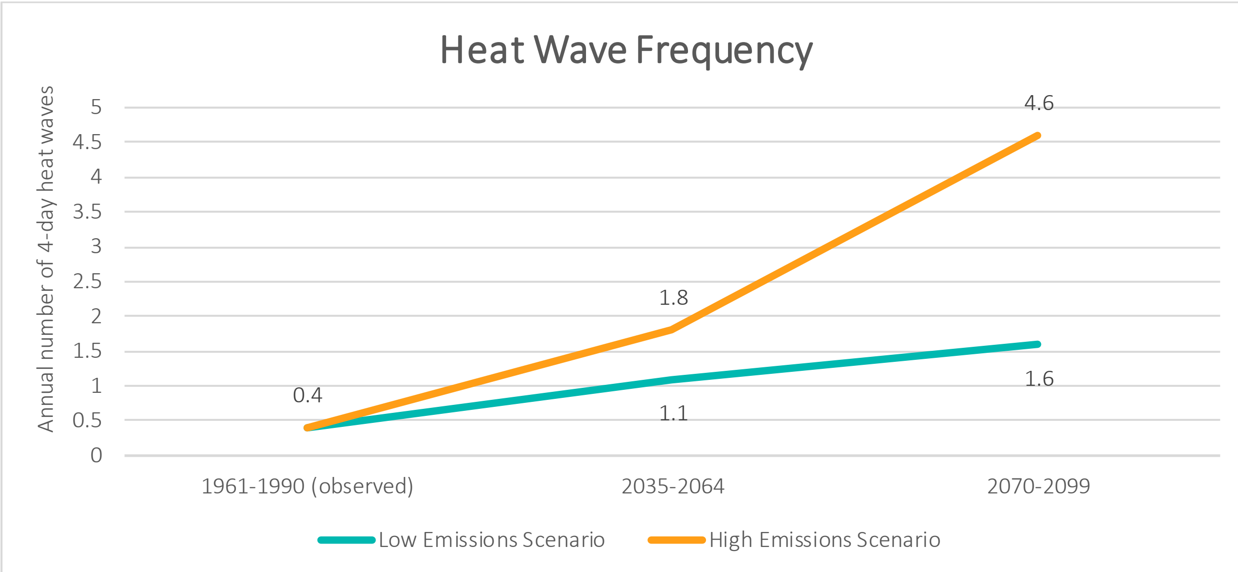

Figure 72. Four-day heat wave frequency projections for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Similarly, the longest stretch of consecutive extreme heat days is projected to increase, as shown below in Figure 73. By mid-century, the longest stretch of consecutive extreme heat days is projected to last nearly five days under a low emissions scenario, and nearly six days under a high emissions scenario. By late century, this period is projected to span over five days under a low emissions scenario, and over a week under a high emissions scenario.

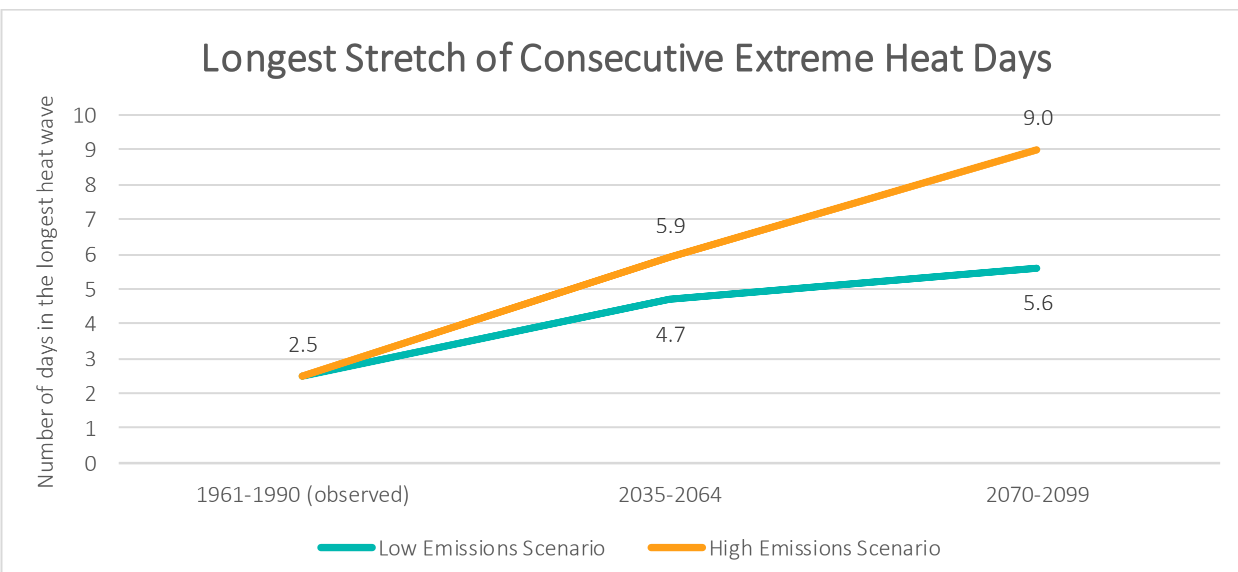

Figure 73. Projections for longest stretch of consecutive extreme heat days for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Minimum Temperatures and Warm Nights

Warm Nights

Warm nights pose a health risk as they limit nighttime cooling and physiological recovery during heat waves and prolong the period over which heat-driven negative health outcomes can take place (Steinberg, 2018)**. The frequency and duration of warm nights is projected to increase substantially by mid- and late century within San Diego.**

Past and Present Conditions: Daily minimum temperatures, which generally represent the nighttime low temperature, are important for allowing people and infrastructure to cool off before the start of another day. Historically (1961 to 1990), the annual average daily minimum temperature for San Diego was 52.9 degrees Fahrenheit.

By definition, warm nights in San Diego occur when the daily minimum temperature exceeds the minimum temperature heat threshold of 67.9 degrees Fahrenheit.[57] Historically (1960 to 1990), there have been four warm nights per year in the City of San Diego, which have generally been concentrated in August and September.

Future Conditions: While the daily maximum temperatures are projected to increase, so are the daily minimum temperatures, resulting in warmer nights (see Figure 74). Using Cal-Adapt and the same climate models and timeframes as for extreme heat days and average daily maximum temperatures, ICF concluded that by the end of the century, under a high emission scenario, daily minimum temperatures could be 8 degrees Fahrenheit warmer than they are today.

[57] 67.9 degrees Fahrenheit is the ninety-eighth percentile historical minimum temperature threshold.

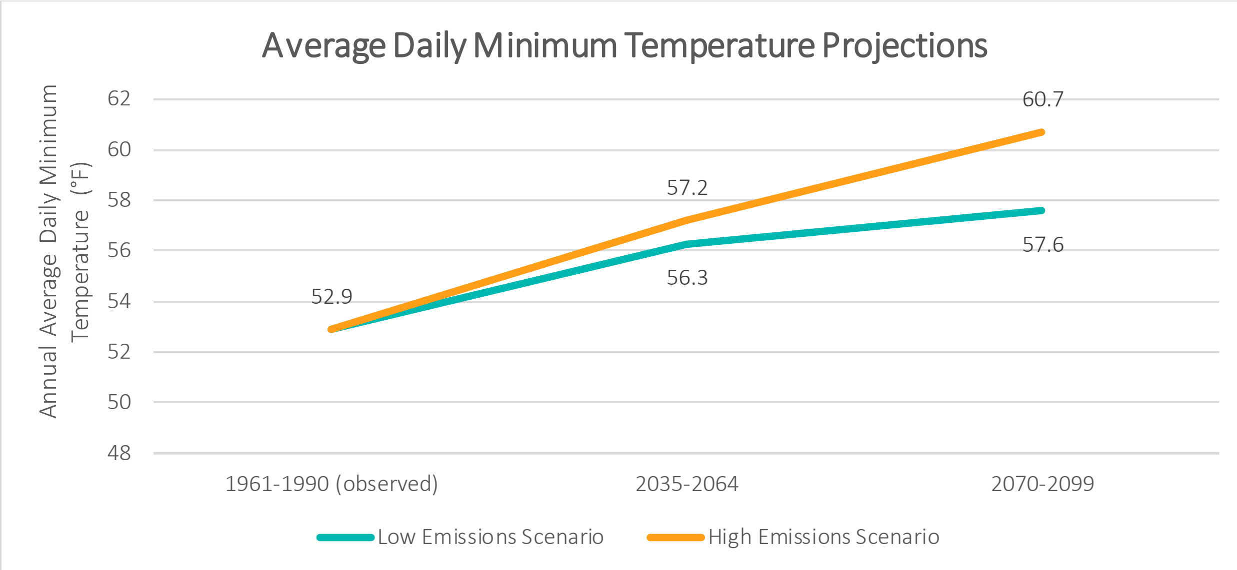

Figure 74. Average daily maximum temperature projections for San Diego throughout this century under low and high emissions scenarios. Source: Cal-Adapt 2018.

The annual number of warm nights is projected to increase substantially throughout the century, as shown in Figure 75, below. By mid-century, San Diego is projected to experience between three weeks and slightly over one month of warm nights per year. By late century, the City is projected to experience between a month and over three and a half months of warm nights per year.

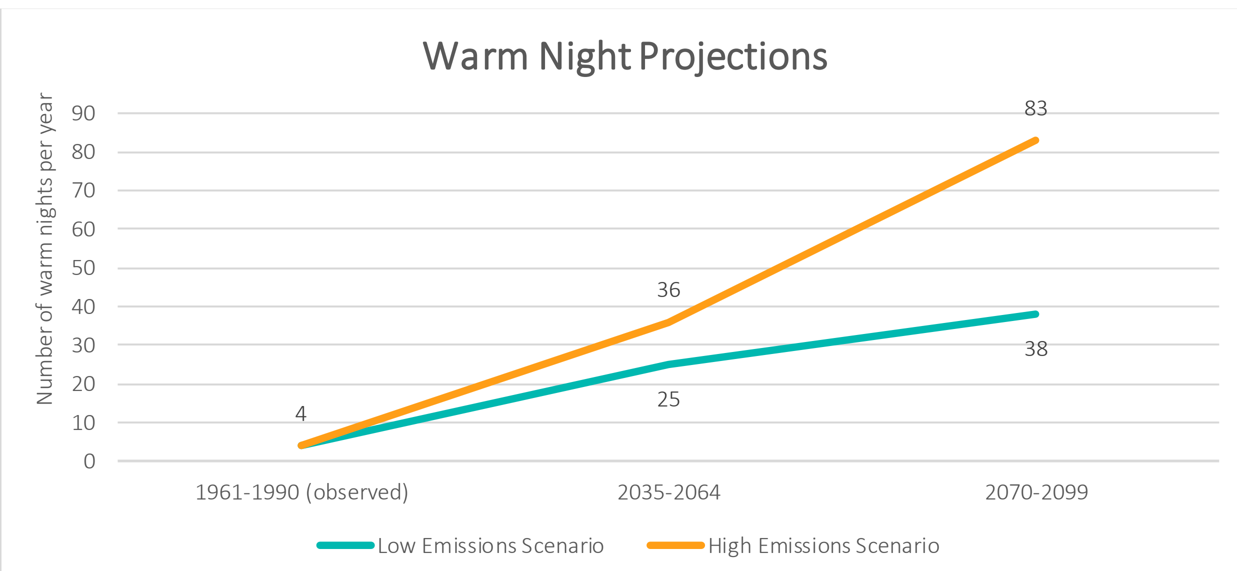

Figure 75. Projections for annual number of warm nights for San Diego throughout this century under low and high emissions scenarios. Source: Cal-Adapt 2018.

Warm nights are also expected to occur over a wider range of months, lengthening the season of warm nights. The blue boxes in Figure 76 show that lengthening: extreme heat days in the 1960s and 1970s are concentrated in August and September, while extreme heat days from the 2070s onward occur frequently from June through October.

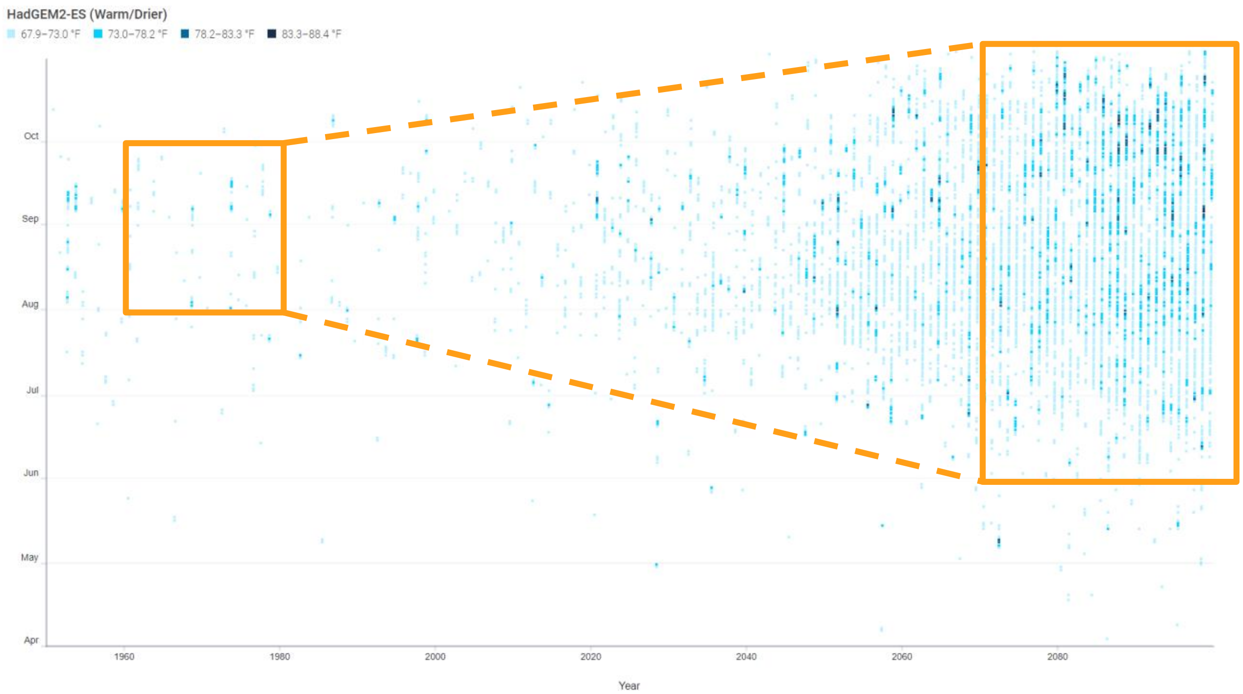

Figure 76. Timing of warm nights (RCP 8.5, HadGEM2-ES model). Source: Cal-Adapt 2018.

Night Heat Wave

Consecutive hot days and warm nights pose even greater human health risks. San Diego could be moving from very infrequent nighttime heat waves (about every other year) to up to six per year by mid-century, with the longest night heat wave extending stretching to almost two weeks.

Past and Present Conditions: On average, the City has experienced about one nighttime heat wave[58] every other year. The longest stretch of consecutive warm nights has historically lasted an average of 2.3 days.

Future Conditions: Nighttime heat waves are also projected to occur more frequently. San Diego is projected to experience three to five more nighttime heat waves per year by mid-century, and five to sixteen more nighttime heat waves per year by late century, as shown in Figure 77, below.

[58] Heat waves are defined as four-day events where daily minimum temperatures exceed 67.9 degrees Fahrenheit.

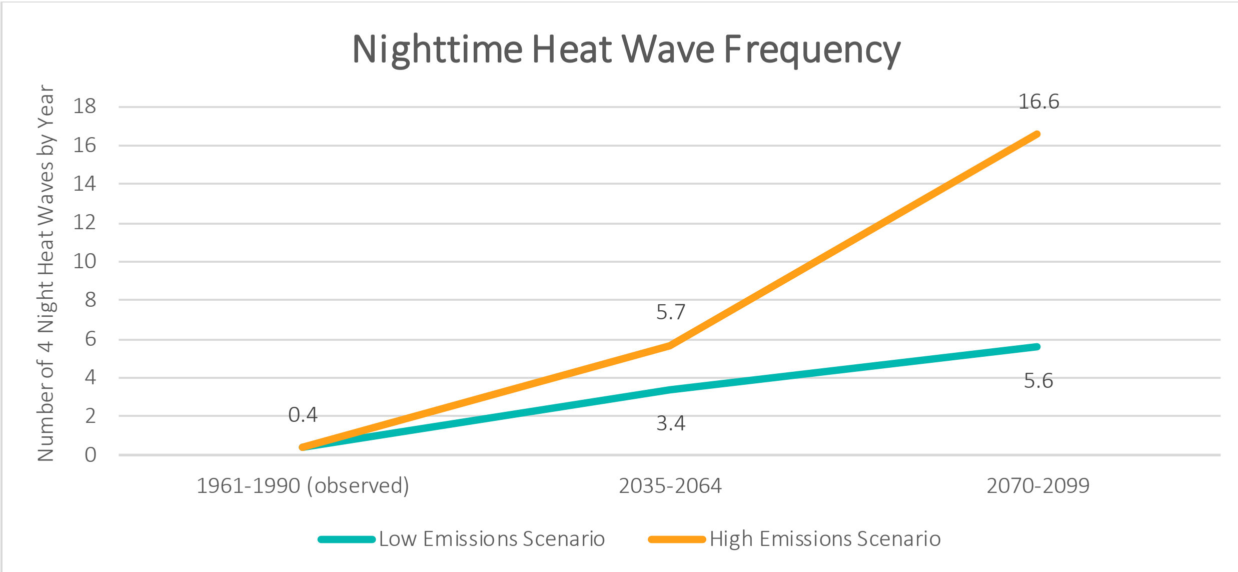

Figure 77. Nighttime heat wave frequency projections for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Similarly, the longest stretch of consecutive warm nights is projected to increase, as shown in Figure 78, below. By mid-century, the longest stretch of consecutive warm nights is projected to span over a week under a low emissions scenario, and nearly two weeks under a high emissions scenario. By late century, this period is projected to last for a week and a half under a low emissions scenario, and five and a half weeks under a high emissions scenario.

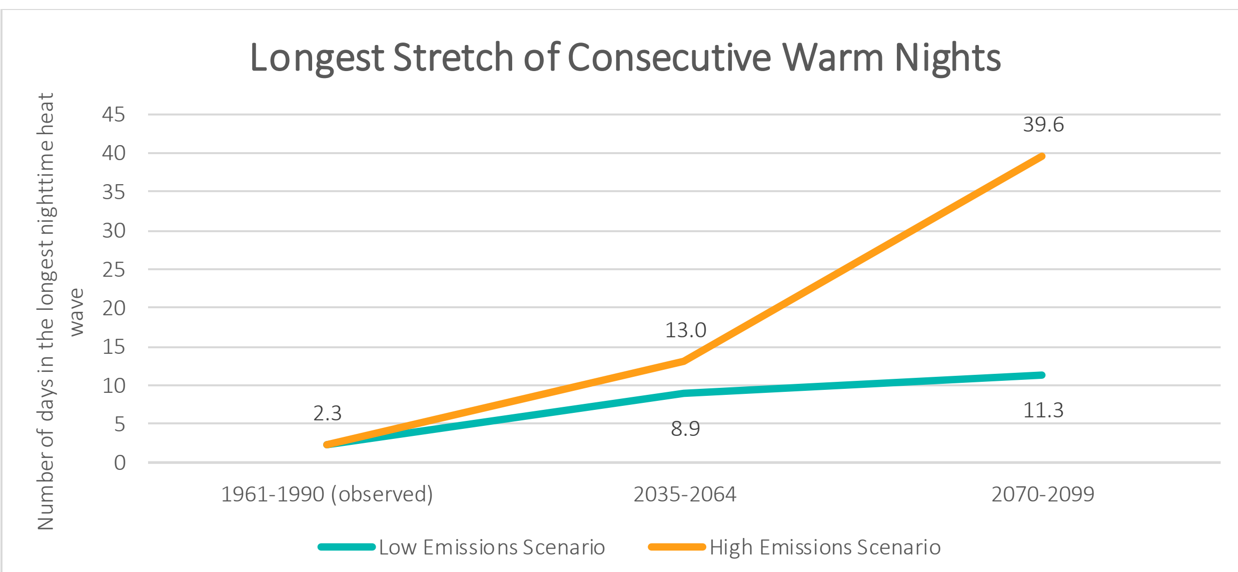

Figure 78. Projections for longest stretch of consecutive warm nights for San Diego throughout this century under low and high emission scenarios. Source: Cal-Adapt 2018.

Urban Heat Island

In San Diego, temperature gradients across the City are more dependent on the natural form of the City (i.e., cool coastal breezes lower the temperature close to the coast while inland temperatures remain hot) than on the built environment. While portions of downtown may be hotter because of the pavement and buildings than they would otherwise be, the natural landscape helps to keep them reasonably cool.

Past and Present Conditions: The built environment can influence temperatures on a micro scale. Dense urban environments with limited tree coverage and significant levels of pavement can increase temperatures above those experienced in more rural and natural areas, while coastal areas can benefit from ocean breezes to counteract these impacts. CalEPA has created an urban heat island map for San Diego. The urban heat islands are color coded according to their intensity, with green representing the smallest effect and red to white representing the greatest intensity. This information has been integrated into the online hazard map that ICF is developing.

This map generally shows what one would expect: it is hotter inland and cooler close to the coast. Unfortunately, it's difficult to determine from this map if the built form of San Diego is altering the temperature pattern in portions of the City. A recent study did find that urbanization in the Los Angeles and San Diego metropolitan areas has led to higher urban daytime air temperatures (Vahmani, 2016).

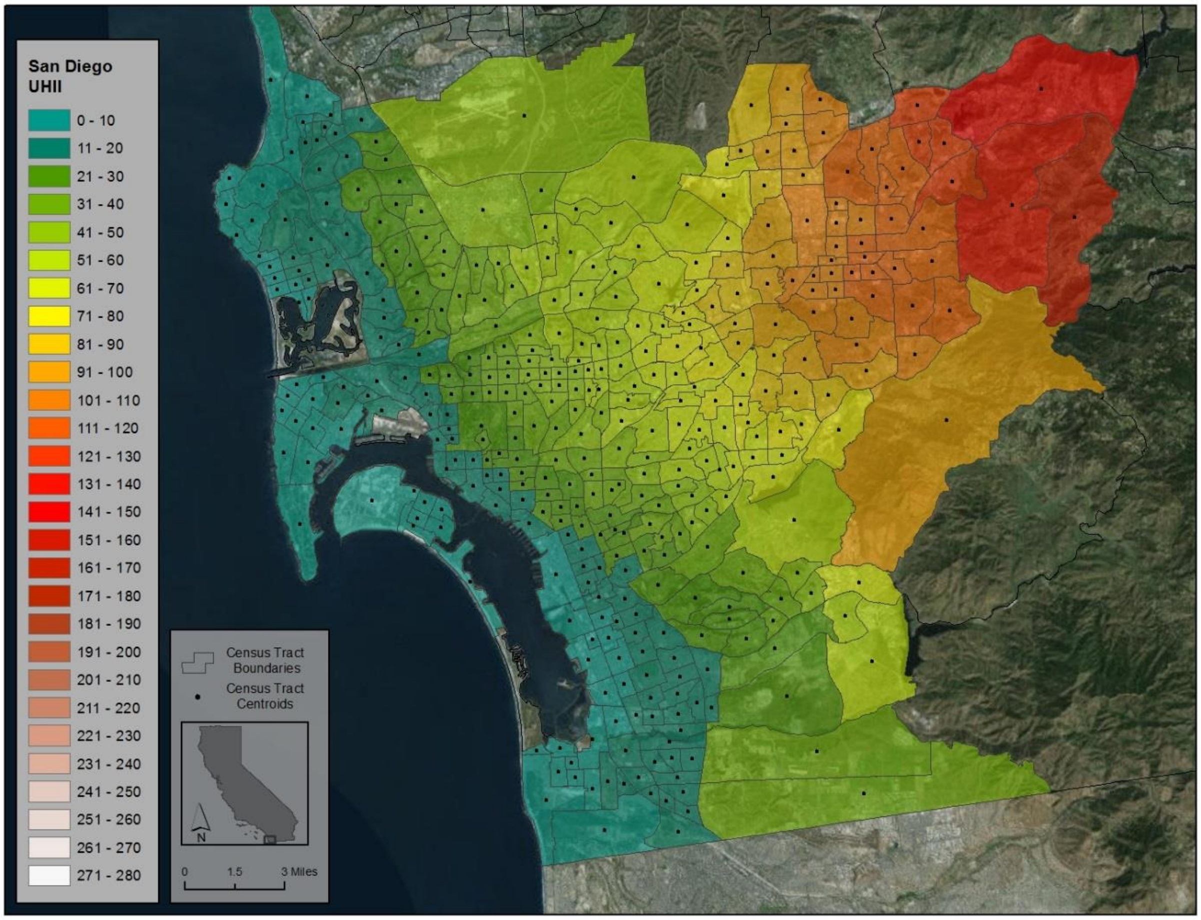

Figure 79. CalEPA Urban Heat Island Map. Source: CalEPA 2015.

Future Conditions: Future projections of urban heat island effects are difficult to produce since it is unclear how the built form will change over time. The City of San Diego vulnerability analysis will rely on the current understanding of urban heat island effects throughout the City.

Wildfires

Climate change will likely increase all the key drivers of wildfires – high temperatures, dry conditions, and flammable vegetation. While there is uncertainty in wildfire modeling, San Diego should anticipate wildfire risk to be of equal or greater severity than in recent decades.

Past and Present Conditions: Wildfires are driven by high ambient and extreme temperature, dry conditions, and the availability of fuel (e.g., vegetation). Historically, wildfires have been found to be larger and more severe in areas with intensive drought stress (Crockett and Westerling 2018). These wildfires were also followed by more tree mortality, increasing exposure to future wildfire.

Future Conditions: Climate change is projected to increase the drivers of wildfires and lead to an increase in fire risk (Yoon, 2015). The southwestern United States, including California, is expected to experience increased drought under climate change (Prein, 2016). Tree die-off in California has reached historic highs in recent years due to pine beetles, heat, and drought, which are expected to increase under climate change, providing more fuel for fires (US Forest Service, 2016). Increases in drivers of wildfires under climate change mean that wildfires would occur more frequently (Westerling, 2006) during a longer wildfire season (Chmura, 2011) and burn longer and more intensely (Westerling, 2006; Liu, 2010). In the San Diego region, wildfire risk is projected to increase, as is the risk of large catastrophic wildfires that arise from the Santa Ana winds (Kalansky, Cayan, Barba, Brouwer, & Boudreau, 2018). However, changes in wildfire risks within the City limits are less certain due to uncertainties around urban development and resulting fuel characteristics.

To assess the potential change in the occurrence of wildfire, the study team drew upon information supporting the Fourth California Climate Change Assessment. This includes a statistical model based on historical data of temperature, precipitation, vegetation, population density, fire occurrences, as well as downscaled projections of future temperature and precipitation by the mid- and late century. The ensemble average of four recommended climate models for the area (MIROC5, HadGEM2-ES, CNRM-CM5, CanESM2) were employed. Historically, an average of 657 hectares of land was burned annually across the City of San Diego. According to Cal-Adapt, an average of 311 to 319 hectares are expected to be burned annually by mid-century, under both the low and high greenhouse gas emission scenarios and a central population growth scenario. Under the same scenarios, an average of 291 to 301 hectares are expected to be burned annually by late century. These Cal-Adapt findings run counter to other studies which indicate an increase in wildfire hazard in future decades. This discrepancy may be due to the Cal-Adapt modeling approach, which assumes that an increase in urban infill reduces vegetation cover, reducing fire fuel availability. As a result, Cal-Adapt suggests a reduction in wildfire areas burned in urbanized areas of San Diego but suggests an increase in the less urbanized areas. Due to the uncertainty in the Cal-Adapt wildfire projections, and uncertainty surrounding changes in wildfire drivers such as fuel availability, fuel moisture, and the Santa Ana winds, it would be prudent for the City of San Diego to plan for a wildfire risk of equal or greater severity than that of recent decades.

Wildfires followed by heavy precipitation events could result in severe flooding and mudslides or landslides, such as those experienced in Southern California during the winter of 2017/18 (Bai, 2018).

Biodiversity

San Diego is proud to be a biodiversity hotspot, with hundreds of plant and animal species calling this area their home. However, climate change may shift habitat ranges around due to the climate factors discussed above. Some species will be able to keep up; others will not.

Past and Present Conditions: San Diego County is the most biodiverse county in North America and is part of the larger global biodiversity hotspot known as the California Floristic (San Diego State University Foundation, 2005; California Academy of Sciences, 2005). San Diego County harbors a great number of plant and animal species, many of which are endemic — meaning they are native to the area and not found anywhere else in the world. However, habitat destruction, pollution, and other factors are putting pressure on these important plants and animals. Approximately 200 of San Diego's species are threatened or endangered (The Nature Conservancy, n.d.)

Future Conditions: Changes in coastal hazards, temperature, precipitation, and wildfires are all climate stressors that may impact the San Diego region. A secondary impact of climate change resulting from these and other stressors may include changes in biodiversity, which is an important concern to the City.

All species have ideal ranges for climate conditions and thresholds beyond which their health and survival are impacted. These parameters determine which environments species can inhabit. As climate change shifts the expectations for what local areas may experience in terms of temperature, precipitation, and other climate factors, species may find that their current locations are no longer suitable habitats. In addition, sea level rise and wildfires could markedly change landscapes, destroying existing habitats and creating new ones.

Like humans, other species have several options when it comes to dealing with these changes. Species could migrate, following the changes in environment and climate conditions to stay within habitable zones (Groffman, 2014). For example, in California, fifteen percent of plant species are shifting their habitat ranges to higher elevations. This ability to migrate is more pronounced in non-native species than in native and endemic species, which may disrupt current ecosystem functioning and threaten biodiversity (Hewitt, 2016). However, such shifts are not feasible for many species that are slow-moving or that do not have anywhere to move to (Jennings M. K., 2018). For instance, cold-water-dependent aquatic species, like the southern steelhead and California newt, may already be at the limit of their habitat ranges within the San Diego rivers and creeks (Jennings M. K., 2018).

Species could also adapt and adjust to climate change. For example, many migratory birds in California have started nesting earlier in the spring and migrating later in the fall due to shifts in temperature over the past century (Margolis, 2017; Harvey, 2017)

Species may also experience climate-induced pressures in other ways, such as a mismatch in timing between animals' activities and the availability their food sources, or if species interactions and interdependencies are disrupted by varying responses between the species to climate change (Groffman, 2014).

Not all species would be able to move or adapt, and climate change would bring a number of direct and indirect pressures to ecosystems. Already, climate change is pushing species onto threatened, endangered, and extinct species lists, and the risk of species extinction is projected to increase under climate change (Groffman, 2014). The San Diego region is projected to become less biodiverse in the coming century.

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Appendix B: Hazard Maps

Coastal Flooding

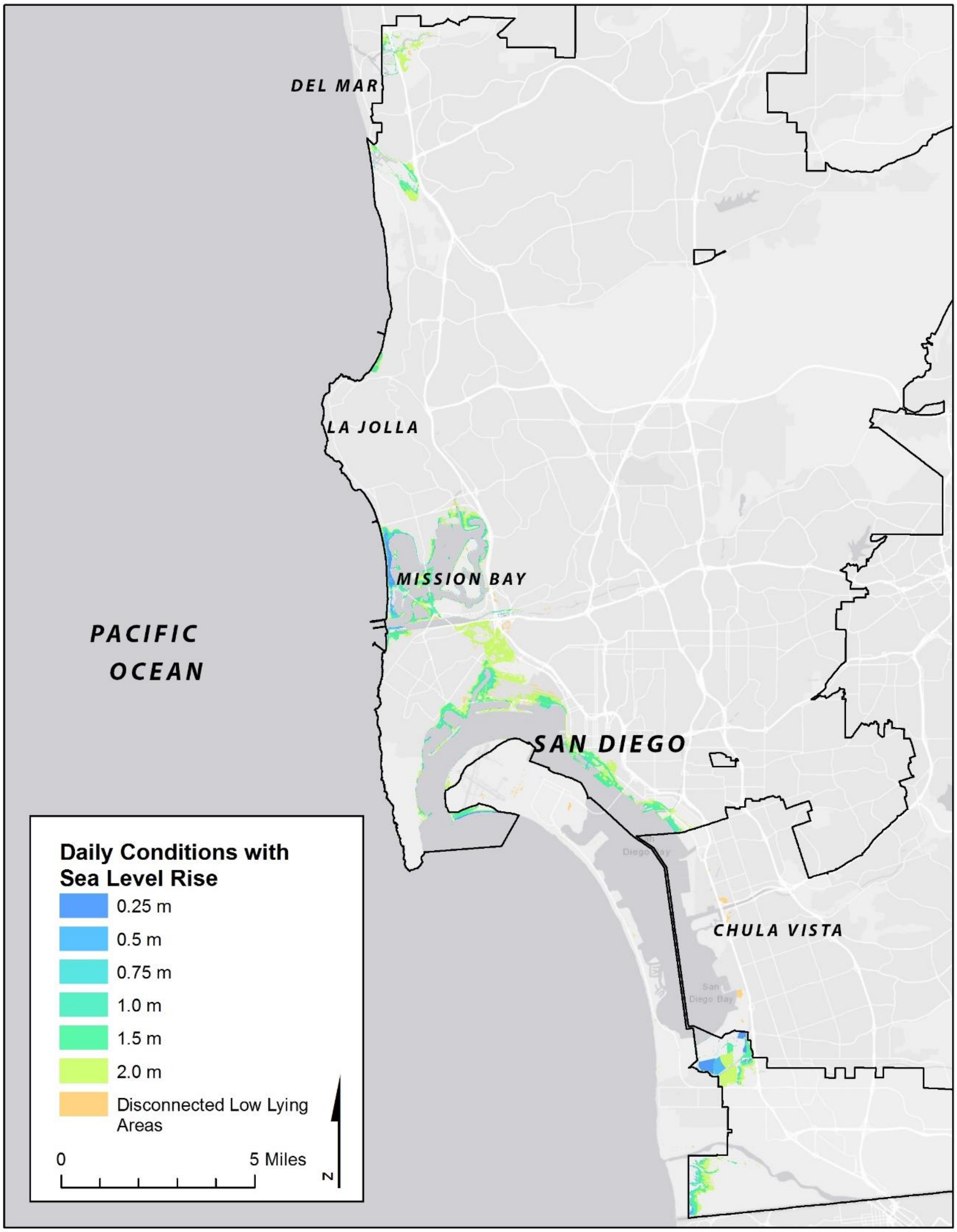

Figure 80. City-wide exposure to average daily flooding at various levels of sea level rise. Flooding data obtained from USGS. Map created: 2019.

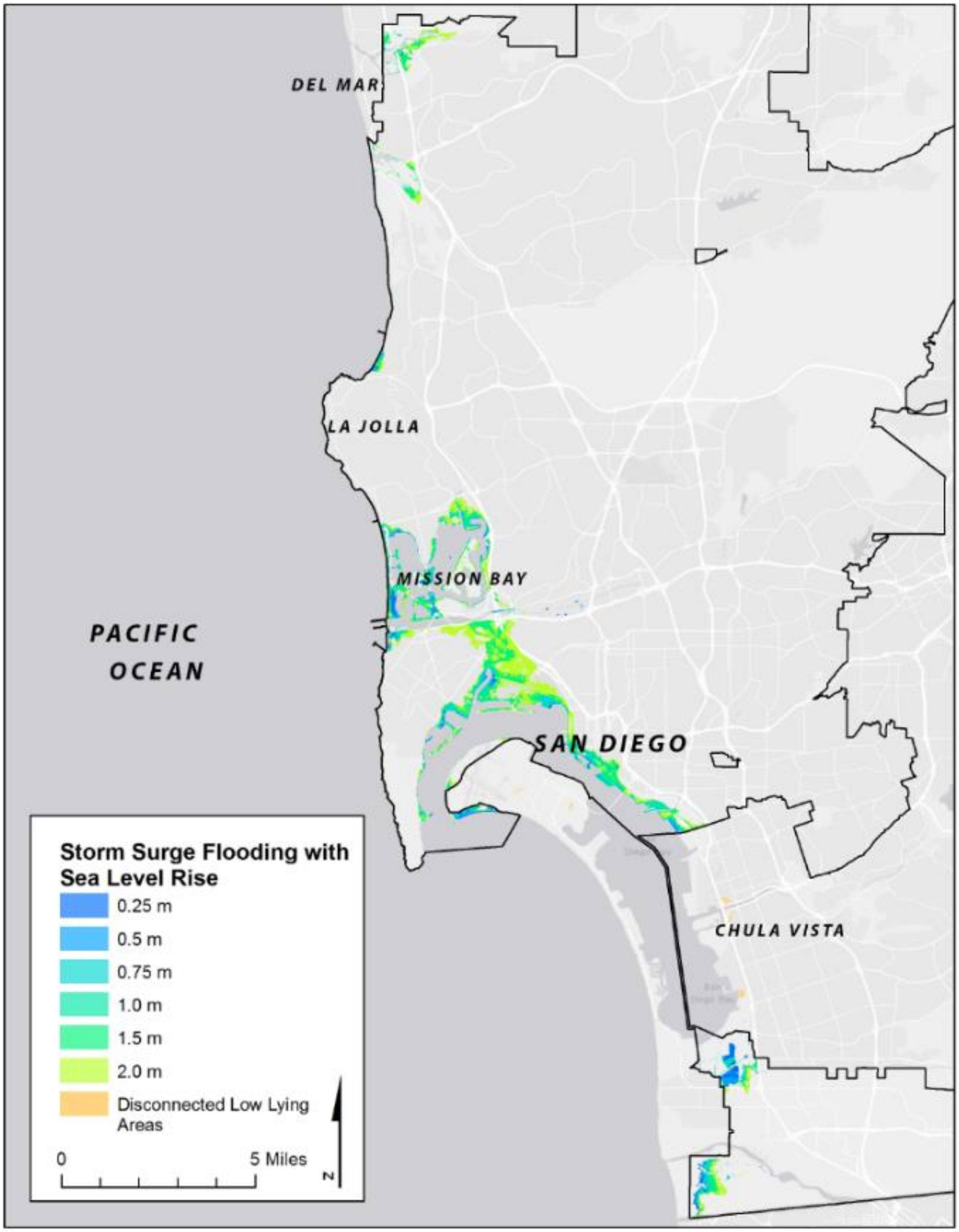

Figure 81. City-wide exposure to storm surge flooding at various levels of sea level rise. Flooding data obtained from USGS. Map created: 2019.

Coastal Erosion

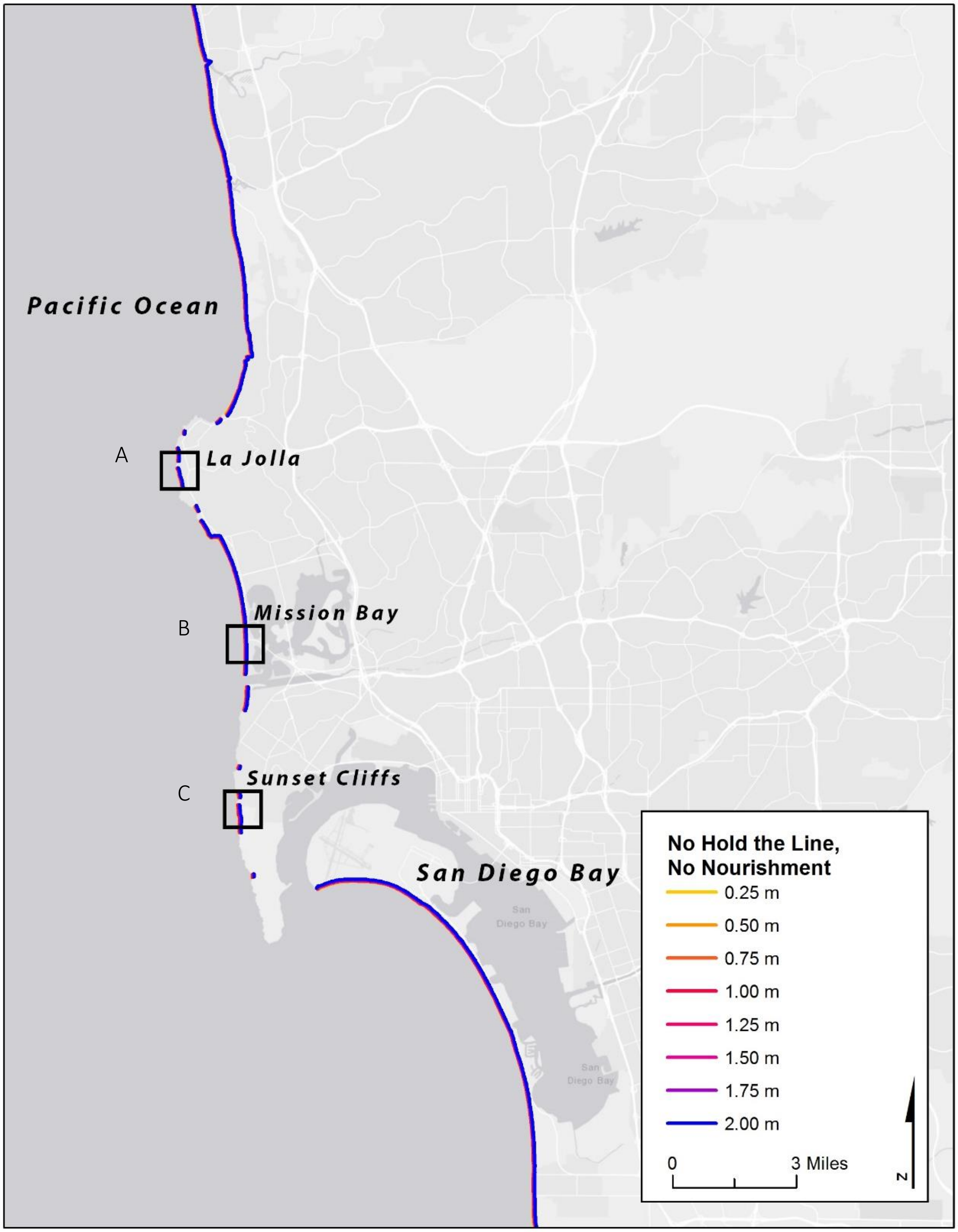

Figure 82. Beach erosion in the City of San Diego. Erosion data obtained from USGS. Map created: 2019.

The various levels of exposure to beach erosion are relatively similar and are difficult to distinguish at this City-wide scale. Three maps at a more detailed extent have been created for La Jolla, Mission Bay, and Sunset Cliffs (as shown by boxes in Figure 82.). In these maps, “No Hold the Line” and “No Nourishment” assumes that current coastal armoring will not be maintained, and the shoreline is allowed to retreat unimpeded and with no increases in sediment. These maps are presented below.

Figure 83. Scenarios of beach erosion given no protection at various levels of sea level rise at La Jolla. Erosion data obtained from USGS. Map created: 2019.

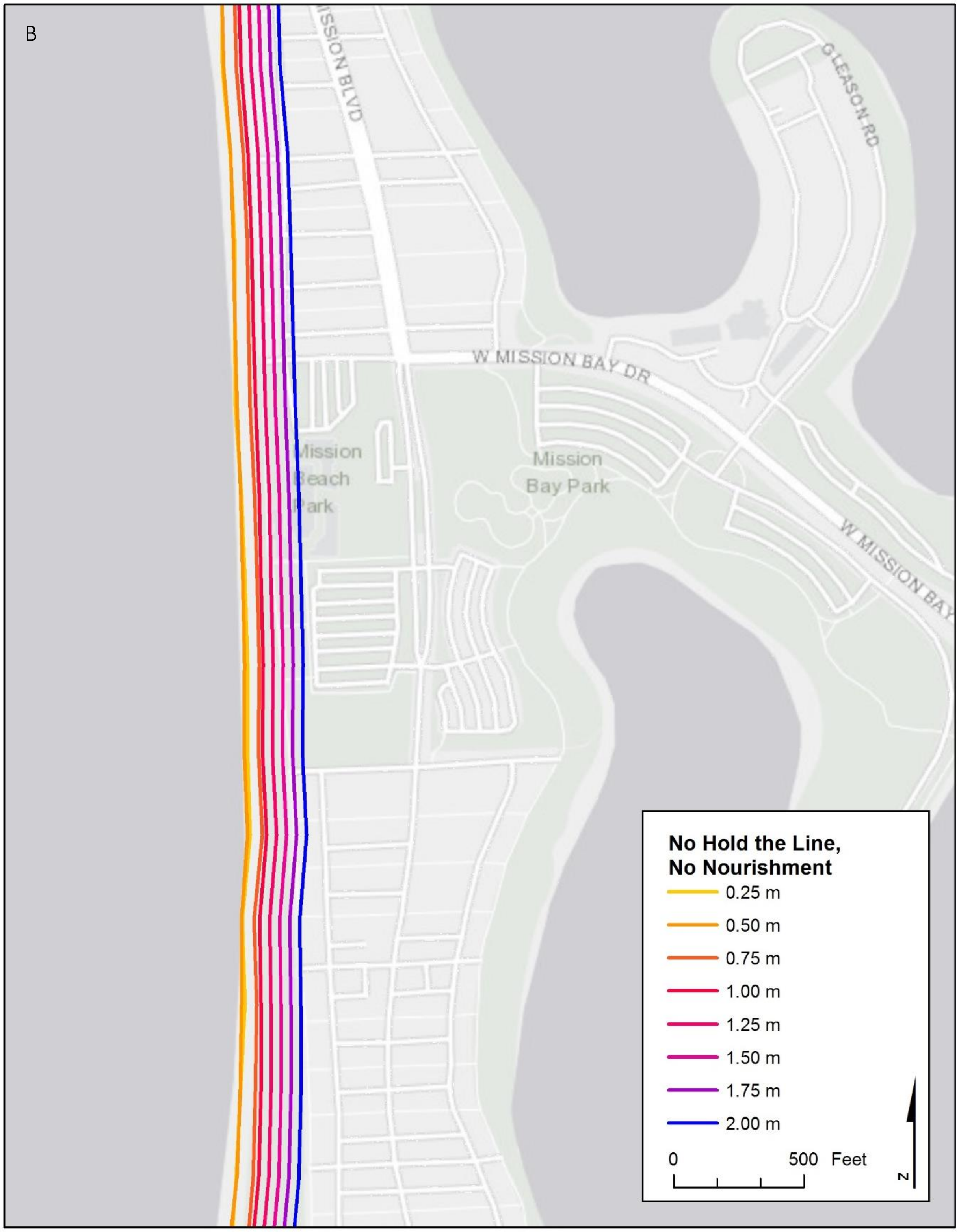

Figure 84. Scenarios of beach erosion given no protection at various levels of sea level rise at Mission Bay. Erosion data obtained from USGS. Map created: 2019.

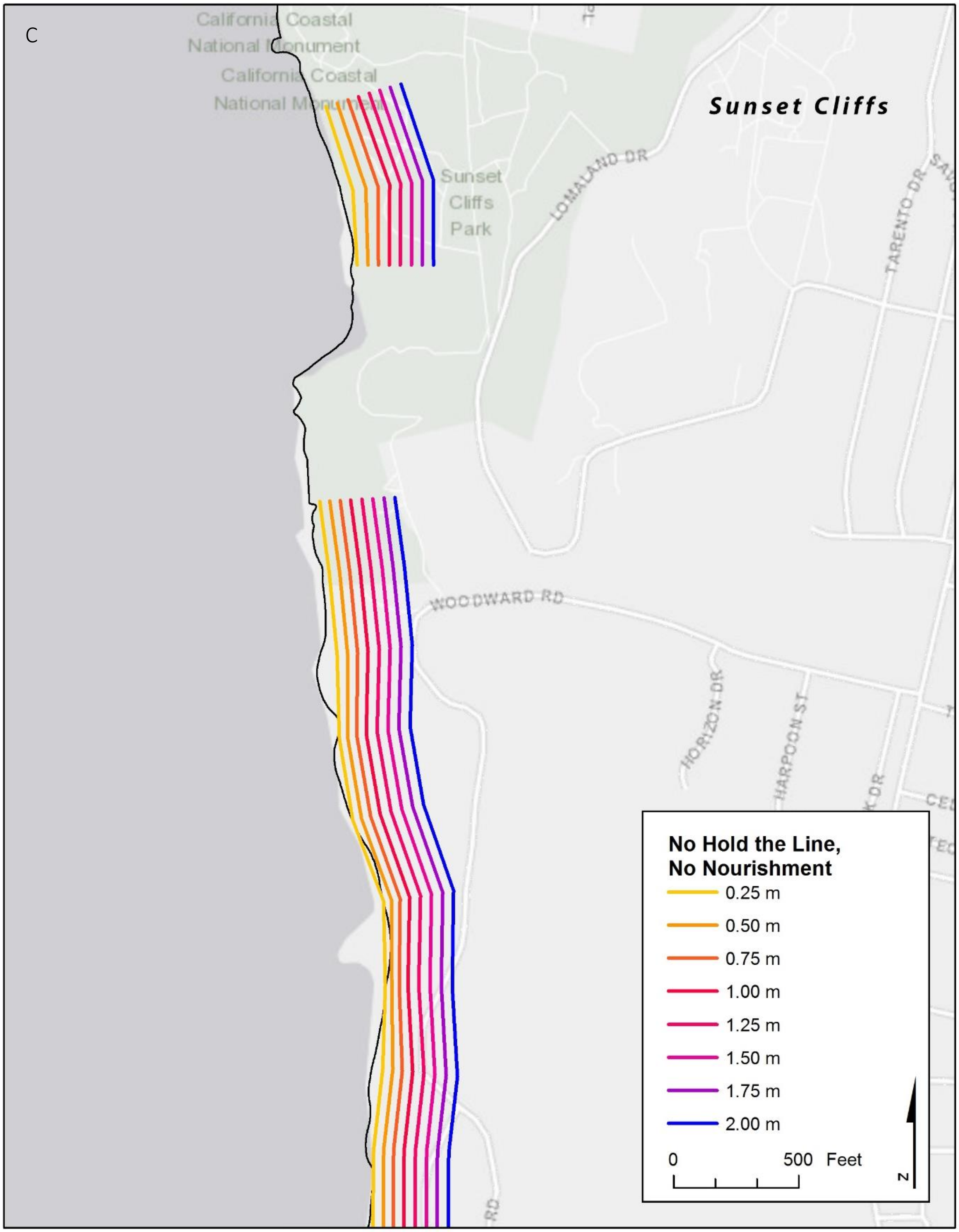

Figure 85. Scenarios of beach erosion given no protection at various levels of sea level rise at Sunset Cliffs. Erosion data obtained from USGS. Map created: 2019.

Precipitation

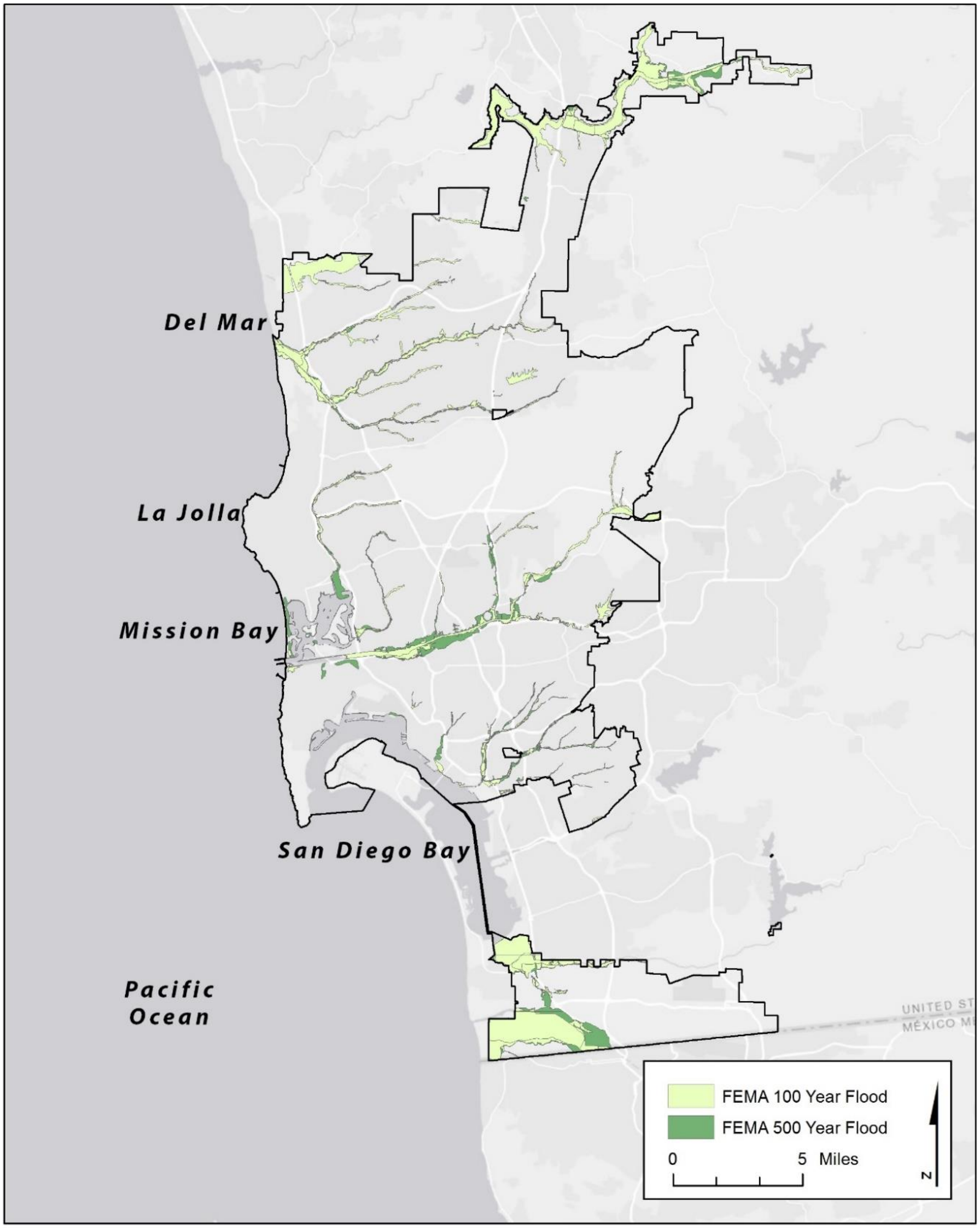

Figure 86. Precipitation exposure to the 100-year and 500-year floods in the City of San Diego. Floodplain data obtained from FEMA. These reflect 2012 FIRMs for all of the City except South Bay, for which the FIRM was last updated in 2016. Map created: 2019.

Wildfire

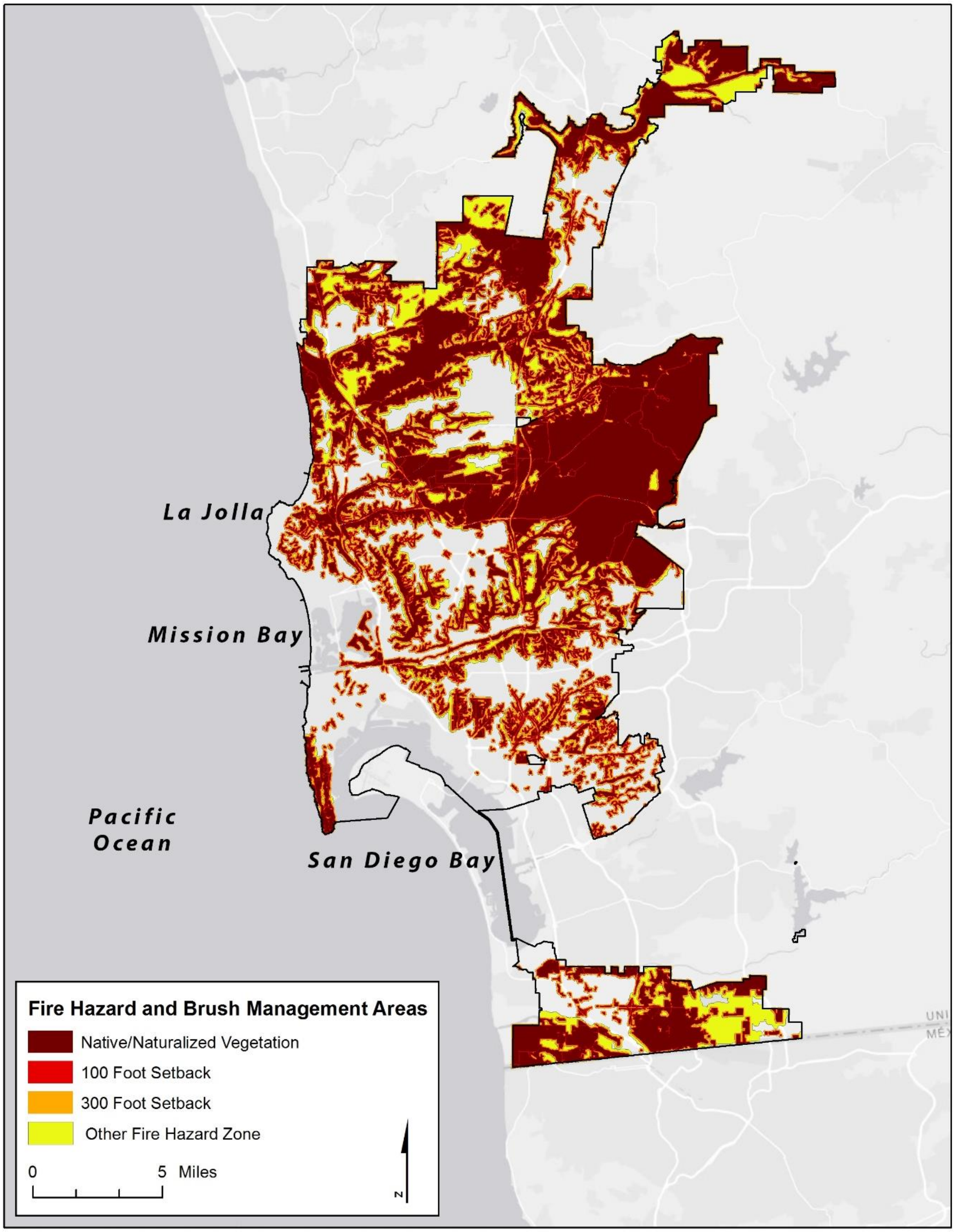

Figure 87. Extent of the wildfire hazard zones in the City of San Diego. Fire hazard zone data obtained from the City of San Diego. Map created: 2019.

Temperature

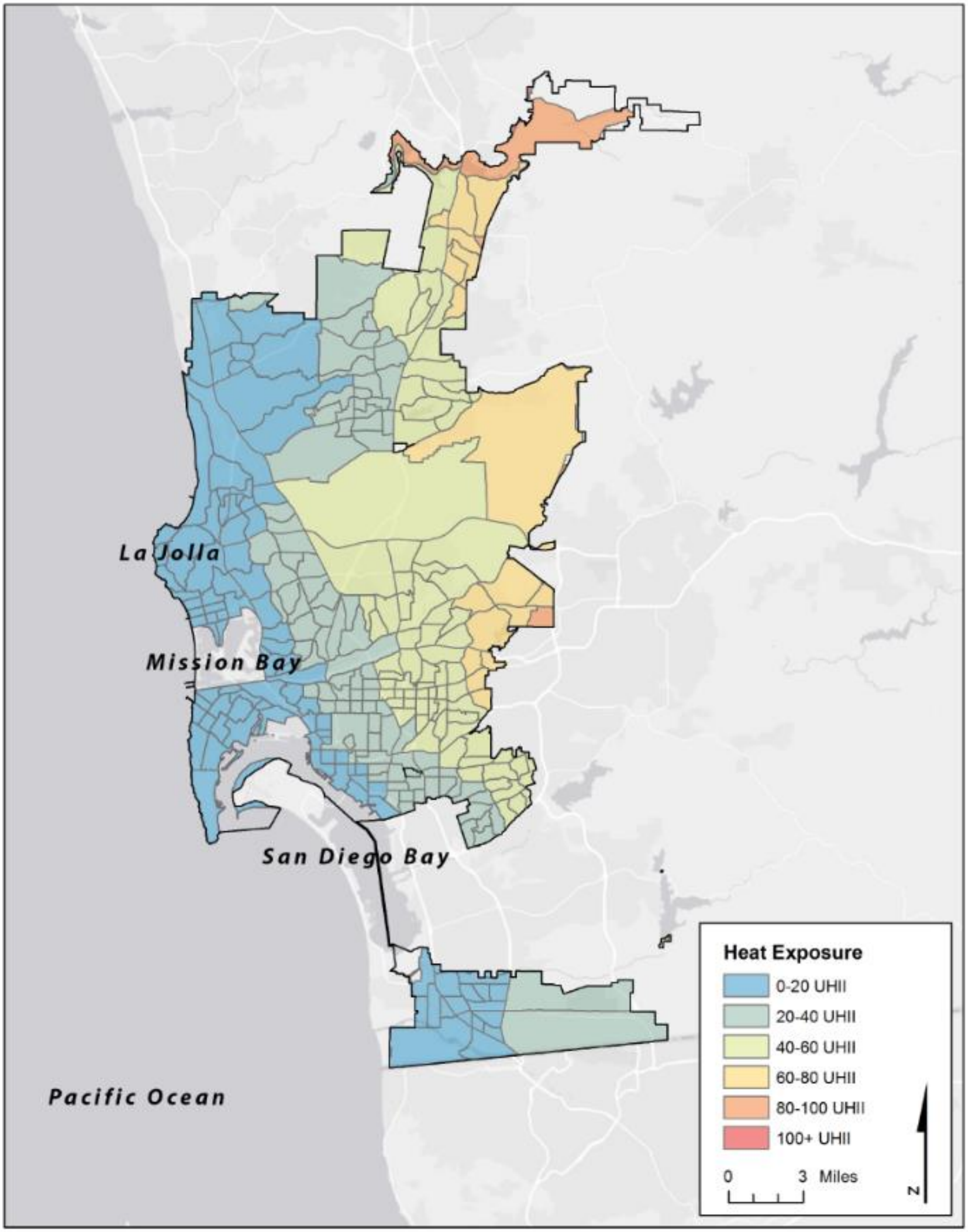

Figure 88. Heat exposure in the City of San Diego given CalEPA's Urban Heat Island Index. Heat exposure data obtained from CalEPA. Map created: 2019.

Appendix C: Exposure Data

This appendix provides more detailed information on the number of assets exposed to each of the climate change hazards.

Sea Level Rise

- **Coastal Flooding**

  According to the November 2018 update to the California Coastal Commission's *Sea Level Rise Policy Guidance,* sea levels in San Diego may rise by 0.6 to 1.1 feet by 2030, 1.2 to 2.8 feet by 2050, and 3.6 to 10.2 feet by 2100 (California Coastal Commission 2018). The City used this information to select corresponding data from localized sea level rise modeling produced by CoSMoS, which were used to develop exposure maps. CoSMoS provides detailed projections of coastal flooding caused by sea level rise and storms while factoring in changes in beaches and the retreat of cliffs and bluffs along the California coast (USGS, n.d.). Table 78 shows how the CCC 2018 projections were translated to the closest data available from CoSMoS.

  Based on this data selection process, the City used the following sea level rise projections to estimate the exposure from daily average flooding and storm surge (100-year) flooding: 0.25 m of sea level rise (2030 timeframe), 0.5 m and 0.75 m of sea level rise (2050 timeframe), and 1.0 m, 1.5 m, and 2.0 m of sea level rise (2100 timeframe). Daily flooding was used to estimate exposure to chronic inundation, and storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding.

Table 78. Coastal Flooding Scenario Selection Based on CCC 2018 Projections and Closest CoSMoS Increments

Year	Low Risk Aversion Scenario[59] 17% probability SLR meets or exceeds		Medium-High Risk Aversion 0.5% probability SLR meets or exceeds		Extreme Risk Aversion Scenario H++ scenario, no assigned probability	
	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment
2030	0.6 ft.	0.25 m (0.8 ft.)	0.9	0.25 m (0.8 ft.)	1.1 ft.	0.25 m (0.8 ft.)
2050	1.2 ft.	0.25 m (0.8 ft.)	2.0 ft.	0.5 m (1.6 ft.)	2.8 ft.	0.75 m (2.5 ft.)
2100	3.6 ft.	1 m (3.3 ft.)	7.0 ft.	2 m (6.6 ft.)	10.2 ft.	2 m (6.6 ft.)

[59] The recent California Coastal Commission Sea Level Rise Policy Guidance November 2018 update provides three sets of sea level rise projections: low, medium-high, and extreme risk aversion. The sea level rise projections associated with low risk aversion should be used to inform planning for development with high adaptive capacity and relatively low associated consequences if impacted by sea level rise, such as temporary or seasonal development, or development that can be easily moved. The projections labeled “medium-high risk aversion” are appropriate for informing less adaptive, more vulnerable land uses that will experience medium to high consequences if impacted by sea level rise, including residential and commercial development. The projections labeled “extreme risk aversion” and “H++” are appropriate for development that, if impacted by sea level rise, would be irreversibly destroyed, would be significantly costly to repair, and/or would have considerable public health, public safety, or environmental impacts—such as critical infrastructure.

- Coastal Erosion
  The relatively soft sandstone bluffs that are common along the San Diego coast are prone to erosion from waves and from storm water runoff. In addition, sea level rise and increased storm frequency has the potential to accelerate beach and other shoreline erosion. The last City-wide coastal erosion assessment, consisting of geotechnical reports, site visits, and photographic documentation of erosion, was completed in 2003 (City of San Diego 2003). The City worked with consultants to update this coastal erosion assessment in 2018 and found that while the City has made improvements to pedestrian access and safety along the erosion sites, due to erosion, more sites pose threats to pedestrians now than in 2003.

  Based on this identified vulnerability, the City selected the best available localized modeling produced by CoSMoS for coastal erosion in the area, covering shoreline and cliff retreat under 2.0 m of sea level rise for four scenarios (USGS, n.d.):

  - Beach erosion:
    - "No hold no nourish" assumes the shoreline is allowed to retreat unimpeded and with no human increases in sediment (i.e., beach nourishment).
    - "Hold, continued nourish" assumes the shoreline retreat is limited to an urban boundary and sediment is increased.
  - Cliff retreat:
    - "Let it go" avoids coastal armoring and allows the cliff to retreat and cliff erosion rates to increase as sea level rises.

For the purpose of this assessment, beach erosion considers erosion of non-cliff shorelines, while cliff retreat considers erosion of cliffs along the coastline.

Coastal Flooding

Table 79. City Critical Asset Type Exposure to Sea Level Rise and Storm Surge

	SLR Scenario	0.25 m		0.5 m		0.75 m		1.0 m		1.5 m		2.0 m	
	Flooding Scenario	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge
Public Safety Assets	Fire Stations (50)	0	0	0	0	0	0	0	0	0	0	0	2
	Police Stations (12)	0	0	0	0	0	0	0	0	0	0	0	0
	Lifeguard Stations (10)	1	1	0	0	0	1	0	1	0	1	1	0
	Fire Logistics and Dispatch	0	0	0	0	0	0	0	0	0	0	0	0

	SLR Scenario	0.25 m		0.5 m		0.75 m		1.0 m		1.5 m		2.0 m	
	Flooding Scenario	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge
	(2)												
	Maintenance Facilities (15)	0	0	0	0	0	0	0	0	0	0	0	0
	Police Patrol and Specialty Vehicles (4)	0	0	0	0	0	0	0	0	0	0	0	0
	Other Public Safety (8)	0	0	0	0	0	1	1	1	1	1	1	1
Water Assets	Dams (7)	0	0	0	0	0	0	0	0	0	0	0	0
	Water Pipes (107,697)	363	428	233	190	197	524	165	280	843	1,131	1,195	991
	Wastewater Pipes (71,563)	330	272	0	264	80	169	554	0	455	516	395	292
	Water Pump Stations (54)	0	0	0	0	0	0	0	0	0	0	0	0
	Wastewater Pump Stations (8)	0	4	0	0	0	0	7	0	0	0	0	1
	Distribution Reservoirs (27)	0	0	0	0	0	0	0	0	0	0	0	0
	Water Treatment Plants (3)	0	0	0	0	0	0	0	0	0	0	0	0
	Wastewater Treatment Plants (4)	0	0	0	0	0	0	0	0	0	0	0	0
Transportation and	Airports (2)	0	0	0	0	0	0	0	0	0	0	0	0
	Bridges (379)	4	4	0	0	0	1	0	2	3	4	4	1

	SLR Scenario	0.25 m		0.5 m		0.75 m		1.0 m		1.5 m		2.0 m	
	Flooding Scenario	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge	Avg. Daily	Storm Surge
	Major Arterials (2,602)	32	44	0	13	2	43	25	23	71	88	117	112
	Drain Pump Stations (14)	1	5	2	0	1	1	1	0	2	0	1	6
	Outfalls (562)	150	202	16	34	29	26	22	18	43	28	25	21
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land (118,568 acres)	327.8	178.5	249.6	214.0	220.4	286.3	217.0	278.0	495.1	433.1	558.3	356.8
	Community Parks (11,324 acres)	43.9	67.3	40.4	99.8	72.2	144.9	110.1	136.1	294.8	269.8	259.2	302.4
	Miramar Landfill (1)	0	0	0	0	0	0	0	0	0	0	0	0
	CNG Fueling Station (1)	0	0	0	0	0	0	0	0	0	0	0	0
	Beaches (481.4 acres)	186.6	287.3	24.2	23.5	30.0	28.1	20.5	20.0	47.1	40.3	35.2	30.1
Additional Assets	Recreation Centers (57)	0	0	0	0	0	0	0	0	1	1	0	0
	Libraries (37)	0	0	0	0	0	0	0	0	0	0	0	0
	City buildings (14)	0	0	0	0	0	0	0	0	0	0	0	0
	Historical, Tribal Cultural, and Archaeological Resources (1,375)	7	11	1	1	3	0	0	2	2	3	4	8

Table 80. City Critical Asset Type Exposure to Cliff and Beach Erosion

		Cliff Let It Go	Shoreline Hold, Continued Nourish	Shoreline No Hold, No Nourish
Public Safety Assets	Fire Stations (50)	0	0	0
	Police Stations (12)	0	0	0
	Lifeguard Stations (10)	3	1	3
	Fire Logistics and Dispatch (2)	0	0	0
	Maintenance Facilities (15)	0	0	0
	Police Patrol and Specialty Vehicles (4)	0	0	0
	Other Public Safety (8)	0	0	0
Water Assets	Dams (7)	0	0	0
	Water Pipes (107,697)	89	1	116
	Wastewater Pipes (71,563)	1,221	1,001	67
	Water Pump Stations (54)	0	0	0
	Wastewater Pump Stations (8)	1	2	0
	Distribution Reservoirs (27)	0	0	0
	Water Treatment Plants (3)	0	0	0
	Wastewater Treatment Plants (4)	0	0	0
Transportation and Storm Water Assets	Airports (2)	0	0	0
	Bridges (379)	0	1	0
	Major Arterials (2,602)	1	0	1
	Drain Pump Stations (14)	0	0	0
	Outfalls (562)	85	7	40
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land (118,568 acres)	282.2	22.5	85.3
	Community Parks (11,324 acres)	89	26.6	57.2
	Miramar Landfill (1)	0	0	0
	CNG Fueling Station (1)	0	0	0

		Cliff Let It Go	Shoreline Hold, Continued Nourish	Shoreline No Hold, No Nourish
	Beaches (481.4 acres)	71.6	65.6	31.8
Additional Assets	Recreation Centers (57)	0	0	0
	Libraries (37)	0	0	0
	City buildings (14)	0	0	0
	Historical, Tribal Cultural, and Archaeological Resources (1,375)	6	0	7

Table 81. Private Parcel Exposure to Sea Level Rise and Storm Surge

	2030		2050		2100	
Resource (parcels)	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge	Sea Level Rise	Storm Surge
Agricultural (1,514)	2	4-5	2-3	5	3-8	8-11
Commercial (8,165)	96-145	159-175	166-175	184-240	188-510	257-618
Community (850)	4-6	6-7	6-7	20-21	20-33	23-36
Cemetery (51)	0	0	0	0	0	0
Entertainment (134)	8	10	8	10	8-14	10-16
Health (512)	0-1	1	1	1-2	1-13	2-19
Hotel/motel (850)	32-35	40-43	37-44	44-491	48-524	495-533
Industrial (3,433)	57	55-56	58-61	58-63	62-169	67-178
Institutional (149)	1	3	1-2	3	3-6	4-9
Marina docks (45)	41	41-42	41-42	42	42	42
Office space (964)	2-6	7-10	10	10	10-11	10-15
Open space (2,375)	2	2	2	2-4	2-9	4-9
Residential (333,199)	1,098-1,848	1,849-2,573	2,223-2,955	3,171-4,228	3,189-5,554	4,875-8,944
Restaurant (706)	27-30	36-37	32-35	40-46	36-81	49-100
Rural land (298)	0	0	0	0	0	0
Not defined (29,956)	521-612	503-580	668-713	619-1,182	734-1,318	1,256-1,546
Vacant (5,457)	49-70	76-84	81-92	88-102	93-161	107-190

Table 82. Private Parcel Exposure to Cliff and Beach Erosion

Resource (Parcels)	Cliff Let it Go	Shoreline No Hold, No Nourish	Shoreline Hold, Continued Nourish

Agricultural (1,514)	3	5	1
Commercial (8,165)	5	3	1
Community (850)	1	0	0
Cemetery (51)	0	0	0
Entertainment (134)	2	2	2
Health (512)	0	0	0
Hotel/motel (850)	3	5	3
Industrial (3,433)	1	0	0
Institutional (149)	3	4	3
Marina docks (45)	0	0	0
Office space (964)	0	0	0
Open space (2,375)	0	0	0
Residential (333,199)	2,504	557	94
Restaurant (706)	4	4	3
Rural land (298)	0	0	0
Not defined (29,956)	50	45	8
Vacant (5,457)	15	18	10

Precipitation

Annual average precipitation projections from Cal-Adapt and other sources suggest only modest changes in total annual precipitation in the decades ahead (Seager, 2015), but there is expected to be more variability in rainfall from year to year and more intense transitions between droughts and deluges (Swain, 2018). To examine potential flooding vulnerabilities from intense precipitation events, the City selected the best available spatial data that reflect current, highly localized precipitation-driven flood vulnerability: the 100-year floodplain and 500-year floodplain from the Federal Emergency Management Agency Flood Rate Insurance Maps (FEMA, 2016). These reflect 2012 FIRMs for all of the City except South Bay, for which the FIRM was last updated in 2016.

Table 83. City Critical Asset Type Exposure to Precipitation-driven Flooding

		FEMA 100-Year Floodplain	FEMA 500-Year Floodplain
Public Safety	Fire Stations (50)	0	1
	Police Stations (12)	0	0
	Lifeguard Stations (10)	1	1
	Fire Logistics and Dispatch (2)	0	0
	Maintenance Facilities (15)	1	1
	Police Patrol and Specialty Vehicles (4)	0	1
	Other Public Safety (8)	0	0
Water	Dams (7)	2	0
	Water Pipes (107,697)	2,299	2,626
	Wastewater Pipes (71,563)	3,328	2,120
	Water Pump Stations (54)	0	1
	Wastewater Pump Stations (8)	2	0
	Distribution Reservoirs (27)	0	0
	Water Treatment Plants (3)	0	0
	Wastewater Treatment Plants (4)	0	0
Transportation and Storm Water	Airports (2)	0	0
	Bridges (379)	15	2
	Major Arterials (2,602)	240	186
	Drain Pump Stations (14)	5	1
	Outfalls (562)	207	76
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land (118,568 acres)	12,360.7	1,011.5
	Community Parks (11,324 acres)	573.4	875.3
	Miramar Landfill (1)	0	0
	CNG Fueling Station (1)	0	0
	Beaches (481.4 acres)	92.4	64.3
Additional Assets	Recreation Centers (57)	0	1
	Libraries (37)	0	0

		FEMA 100-Year Floodplain	FEMA 500-Year Floodplain
	City buildings (14)	0	0
	Historical, Tribal Cultural, and Archaeological Resources (1,375)	8	11

Table 84. Private Parcel Exposure to Precipitation-driven Flooding

Resource (parcels)	FEMA 100-year Floodplain	FEMA 500-year Floodplain
Agricultural (1,514)	55	56
Commercial (8,165)	323	706
Community (850)	43	63
Cemetery (51)	5	5
Entertainment (134)	42	42
Health (512)	22	29
Hotel/motel (850)	59	89
Industrial (3,433)	390	552
Institutional (149)	17	21
Marina docks (45)	39	40
Office space (964)	36	59
Open space (2,375)	97	137
Residential (333,199)	6,960	15,087
Restaurant (706)	40	79
Rural land (298)	21	21
Not defined (29,956)	1,489	2,535
Vacant (5,457)	317	481

Temperature

The City used urban heat island index data from the CalEPA to project areas that could be exposed to extreme heat. These data were the best available spatial information for heat within the City at the time of the vulnerability assessment. The geographic patterns revealed by CalEPA's urban heat island data are likely to persist even as temperatures change over time. This source thus identifies areas of the City that are likely to be more or less vulnerable to future extreme heat events. The heat island scenarios are represented as zones with scores of 0 to 100+, with higher scores denoting hotter areas (CalEPA, 2019).[60]

Table 85. City Asset Exposure to Heat. The column ranges represent exposure to different ranges in the UHI index, with higher UHI values denoting hotter areas and therefore increased exposure to heat.

		0-20	20-40	40-60	60-80	80-100	100+
Public Safety Assets	Fire Stations (50)	20	13	12	5	0	0
	Police Stations (12)	6	2	4	0	0	0
	Lifeguard Stations (10)	10	0	0	0	0	0
	Fire Logistics and Dispatch (2)	0	0	2	0	0	0
	Maintenance Facilities (15)	6	2	6	1	0	0
	Police Patrol and Specialty Vehicles (4)	1	1	2	0	0	0
	Other Public Safety (8)	3	1	4	0	0	0
Water Assets	Dams (7)	0	1	3	2	0	2
	Water Pump Stations (54)	7	10	23	13	1	0
	Wastewater Pump Stations (8)	0	1	0	0	0	0
	Distribution Reservoirs (27)	11	3	9	4	1	0
	Water Treatment Plants (3)	0	0	2	1	0	0

[60] The urban heat island index is calculated as a temperature differential over time between an urban Census tract and nearby upwind rural reference points. The index is reported in degree-hours per day on a Celsius scale, a measure of heat intensity over time. An increase of one degree over an eight-hour period would equal eight degree-hours, as would an increase of two degrees over a four-hour period.

		0-20	20-40	40-60	60-80	80-100	100+
	Wastewater Treatment Plants (4)	2	1	1	0	0	0
Transportation and Storm Water Assets	Airports (2)	0	1	1	0	0	0
	Bridges (379)	180	115	77	4	3	0
	Major Arterials (2,602 segments)	2,480	1,728	1,224	753	458	879
	Drain Pump Stations (14)	14	0	0	0	0	0
	Outfalls (562)	417	77	48	15	1	0
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land (118,568 acres)	20,689.2	15,883.6	26,876.6	16,181.6	11,236.6	3,320.9
	Community Parks (11,324 acres)	5,931.3	2772.3	1093	1359.5	91.2	0
	Miramar Landfill (1)	0	0	1	0	0	0
	CNG Fueling Station (1)	0	1	0	0	0	0
	Beaches (481.4 acres)	457.9	0	0	0	0	0
Additional Assets	Recreation Centers (57)	20	20	15	0	1	0
	Libraries (37)	12	11	10	4	0	0
	City buildings (14)	6	1	7	0	0	0
	Historical, Tribal Cultural, and Archaeological Resources (1,375)	832	397	121	1	5	0

Wildfire

Due to uncertainty in the Cal-Adapt wildfire projections, and uncertainty surrounding changes in wildfire drivers, such as fuel availability, fuel moisture, and the Santa Ana winds, the City of San Diego used a conservative approach to plan for a future wildfire risk of equal or greater severity than that of recent decades. The City based its wildfire vulnerability assessment on its four current measures of fire risk: The City's brush management zone, a 100-foot and 300-foot buffer around the brush management zone, and the fire hazard severity zone. These areas indicate where fuel for potential wildfires exists within the City.

Table 86. City Critical Asset Type Exposure to Wildfire

		Native Vegetation	100-ft Setback	300-ft Setback	Fire Hazard Zone
Public Safety	Fire Stations (50)	0	4	5	3
	Police Stations (12)	0	1	1	0
	Lifeguard Stations (10)	0	0	3	0
	Fire Logistics and Dispatch (2)	0	0	0	0
	Maintenance Facilities (15)	0	0	5	2
	Police Patrol and Specialty Vehicles (4)	0	0	1	0
	Other Public Safety (8)	0	0	0	0
Water	Dams (7)	0	1	3	0
	Water Pump Stations (54)	14	18	14	5
	Wastewater Pump Stations (8)	0	0	0	0
	Distribution Reservoirs (27)	2	13	7	1
	Water Treatment Plants (3)	0	0	0	1
	Wastewater Treatment Plants (4)	0	0	3	1
Transportation and Storm Water	Airports (2)	0	1	0	0
	Bridges (379)	73	113	47	10
	Major Arterials (2,602 segments)	24	1,024	527	135
	Drain Pump Stations (14)	0	3	1	1
	Outfalls (562)	85	78	31	22
Open Space and Environment Assets	Conservation Areas/Open Space/Source Water Land (118,568 acres)	69340.2	5616.3	4960.6	6698.9
	Community Parks (11,324 acres)	4,718.3	879	1,071.5	263.9
	Miramar Landfill (1)	1	0	0	0
	CNG Fueling Station (1)	0	0	0	1
	Beaches (481.4 acres)	117.1	23.7	19.4	7.3
Additional Assets	Recreation Centers (57)	1	6	16	4
	Libraries (37)	2	3	2	0
	City buildings (14)	0	2	1	0

		Native Vegetation	100-ft Setback	300-ft Setback	Fire Hazard Zone
	Historical, Tribal Cultural, and Archaeological Resources (1,375)	87	133	268	117

Table 87. Private Parcel Exposure to Wildfire

Resource (parcels)	Native Vegetation/100-ft buffer	300-ft buffer	Fire Hazard Zone
Agricultural (1,514)	307	588	570
Commercial (8,165)	1,279	1,491	1,377
Community (850)	207	290	364
Cemetery (51)	13	22	19
Entertainment (134)	77	75	113
Health (512)	126	154	140
Hotel/motel (850)	86	81	80
Industrial (3,433)	1,246	1,232	1,413
Institutional (149)	40	63	87
Marina docks (45)	0	0	0
Office space (964)	329	369	338
Open space (2,375)	622	1,703	2,616
Residential (333,199)	77,735	152,688	150,821
Restaurant (706)	138	139	127
Rural land (298)	32	128	377
Not defined (29,956)	4,501	6,459	6,724
Vacant (5,457)	949	2,507	3,749

Appendix D: Energy Efficient Buildings

The following buildings have been identified by the City of San Diego as LEED certified (and therefore energy efficient):

Table 88. City-Owned Buildings Identified as LEED Certified

Facility Number	Description	Street	Department Name	Year Built
F2204	Library-New Skyline	7900 Paradise Valley Rd	Library	2016
F2176	Fire Station 17	4206 Chamoune Ave	Fire and Life Safety	2017
F2214	Fire Station 2	825 West Cedar St	Fire and Life Safety	2018
F2224	Fire Station 22	1055 Catalina Blvd	Fire and Life Safety	2018
F2231	Fire Station 5	3902 Ninth Ave.	Fire and Life Safety	2018
F2273	Mission Hills Hillcrest Library	215 W. Washington St.	Library	2018