# San Leandro Climate Hazard Assessment

Four Twenty Seven Climate Solutions

May 22, 2017

# Contents

# 1. Introduction

Changing climate conditions such as higher temperatures, more intense periods of rainfall, and sea level rise are expected to exacerbate existing challenges that California's cities and counties face as well as present new opportunities to bolster hazard mitigation and climate action efforts. State legislation seeks to promote the integration of climate change adaptation and resilience into local planning processes. *Assembly Bill No. 2140 General plans: safety element (Hancock)* enables local jurisdictions to adopt a local hazard mitigation plan with their Safety Element, facilitating integration of hazard mitigation into General Plans. *Senate Bill No. 379 Land Use: general plan: safety element (Jackson)* (SB 379) calls on local governments to incorporate adaptation and resilience strategies into Safety Elements of their General Plans as well as their local hazard mitigation plans. To support local governments' implementation of SB 379, the Governor's Office of Planning and Research recently issued draft guidelines for integrating climate considerations into Safety Elements. The draft guidelines build on the State's *Adaptation Planning Guide* (2012), emphasize the need for communities to adopt a longer-term perspective in preparing for climate risks, and highlight the importance of identifying linkages and complementarity across different elements of the General Plan as well as other relevant plans.

This climate change chapter was developed as part of an effort by StopWaste, Alameda County's waste authority, to assist seven of the County's cities[1], including the City of San Leandro, respond to SB 379 requirements and promote a consistent approach to incorporating adaptation and resilience into relevant local plans in Alameda County. The chapter's purpose is to describe projected changes in key climate hazards of concern for San Leandro and the citywide assets that these hazards are likely to affect as well as to present adaptation actions that the city may incorporate into relevant plans to address these hazards.

The content is intended to inform the city's efforts to incorporate climate hazards and adaptation strategies into its local hazard mitigation plan, General Plan Safety Element, and other relevant plans such as its climate action plan. In doing so, the content can also assist San Leandro in meeting requirements to position it for federal funding (e.g., Federal Emergency Management Agency (FEMA)) and to meet voluntary commitments (e.g., Compact of Mayors). However, the information in this document should be situated in the context of the City's other planning efforts and stakeholder inputs obtained through these other planning processes.

In the remainder of this section, we provide an overview of San Leandro. Section 2 presents the climate hazard analysis, which helps San Leandro answer the questions "What climate change effects will a community experience?" (exposure) and "What aspects of a community (people, structures, and functions) will be affected?" (sensitivity) identified in Steps 1 and 2 of the State's *Adaptation Planning Guide*[2]. The climate hazard analysis covers inland flooding, sea level rise, changes in temperature (including extreme heat) and precipitation, rainfall induced landslides, and wildfires, which align with the climate hazards prioritized in the Draft City of San Leandro 2015 Local Hazard Mitigation Plan. The analysis includes the probability of occurrence, extent of exposure, and assets affected by key climate

[1] The six participating cities are Albany, Emeryville, Fremont, Hayward, Livermore, Piedmont and San Leandro.

[2] This assessment focuses on the exposure of important assets to climate hazards of concern. Understanding vulnerability also requires an examination of the sensitivity of communities and functions as well as of adaptive capacity, which was outside the scope of this project, and for which the *Adaptation Planning Guide* describes a process.

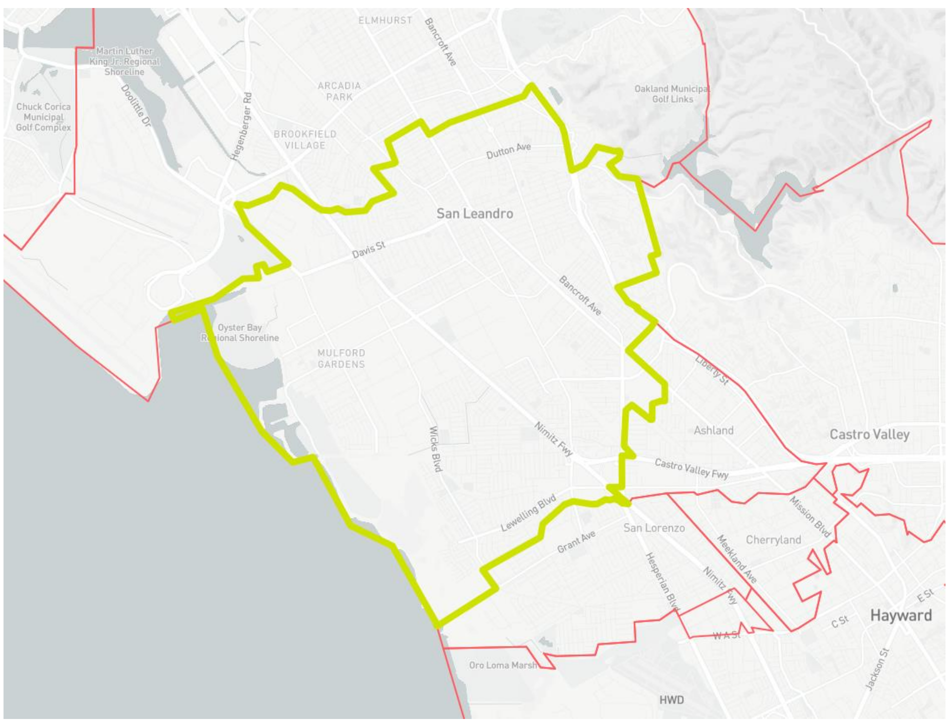
hazards in San Leandro. The methods used to assess the exposure of assets to the climate hazards as well as the data sources for each section are explained in Appendix A.

### San Leandro, California will be affected by Climate Change

San Leandro is located on the shoreline of the San Francisco Bay and sits at an average elevation of 56 feet. Located between Oakland and Hayward with a population of about 88,000 people, it is highly urbanized, made up of residential properties with industrial and manufacturing uses in the west, mixed use areas in the southern portions of the city, and the downtown core to the northeast. Due to its geographic span from the Bay into the hills, San Leandro is susceptible to a variety of climate hazards. See Figure 1 for a map of San Leandro.

As a result, San Leandro will likely be most affected by the combination of sea level rise, high tides and flooding along the shoreline and throughout the southwest portion of the city, which threaten to limit mobility and damage amenities and industry that are important to San Leandro and the regional economy. However, the most severe impacts will be seen in the long-term, when projected temperature increases and the frequency of very hot days will impact a broader set of the city's assets and population, resulting in greater occurrence of heat related illness.

Figure 1. Map of San Leandro




## 2. Climate Hazards Analysis

According to the analysis conducted for this report, San Leandro's climate is projected to grow hotter and experience fluctuations in precipitation patterns throughout the remainder of the 21st century. The climate hazards analysis also finds that rising sea levels threaten to inundate some of the city's critical sewer system and power line assets, facilities that use or contain hazardous materials, and shoreline neighborhoods by mid-century. Fortunately, San Leandro's core emergency response assets are located outside of the areas found to be exposed to projected rising sea levels. However, wildfire poses a substantial threat to the city, since a very high fire hazard severity zone is located just to the east of the city and increasingly dry, hot conditions may exacerbate wildfire risk. Figure 2 summarizes exposure to each of the hazards examined in this assessment.

Figure 2. Climate Hazards and Exposure

| **Climate Hazard** | **Exposure** | **Summary** |
|---|---|---|
| Inland Flooding | High | Significant exposure during 100-year storm (1 percent annual chance) with increasing exposure and risk during 500-year storm (0.2 percent annual chance) |
| Wildfire | High | Some emergency assets located in high fire hazard severity zones or in close proximity to very high fire hazard severity zones |
| Sea Level Rise | Medium | Significant exposure likely by mid-century with a 5-year, or 20 percent annual chance, storm surge (a combination of permanent and temporary inundation equivalent to 36 inches of sea level rise) |
| Temperature Change | Medium | Increase in the number of extreme heat days |
| Rainfall-Induced Landslides | Medium | Important assets located in the few landslide hazard zones |
| Precipitation Change | Low | Limited change in overall rainfall |

## Inland Flooding

### Climate change may increase flood risks in San Leandro

Many of San Leandro's citywide assets are vulnerable to flooding, including most notably Fire Station 13, Bayfair Center, the Bay Fair BART station, the Marina and parks along the shoreline, and the neighborhoods in southern San Leandro. This includes some essential emergency response, national shelter system and education assets. With more extreme precipitation events, the potential for more high intensity rainfall events may cause more frequent flooding of these and other assets. Flood events expected to have a 0.2 percent chance of occurring in a given year, or a 500-year recurrence interval, based on historical information may occur more often under changing climate conditions. [3] These changing conditions would translate to a shift in the FEMA maps of the 100- and 500-year floodplains, and have considerable economic consequences for the city in the event of a flood. Flooding already poses significant financial challenges to cities by incurring structural repair, transportation delay and utility service interruption costs.[4]

### San Leandro will potentially face more frequent, severe floods

Flood Insurance Rate Maps created by FEMA[5] were analyzed to identify exposed assets in the 100-year and 500-year floodplains. The 100-year floodplain includes land that has a one percent chance of flooding in a given year and therefore is expected to flood once every 100 years. The 500-year floodplain includes land that has a 0.2 percent chance of flooding in a given year. The flood maps are based on historical data and updated about every 10 years. Although they do not currently incorporate climate projections into the floodplain delineations, they provide an indication of where floodwaters are likely to concentrate, even if the probability of flooding changes with the climate.

### Many citywide assets are exposed to flood risks

According to 2009 FEMA flood maps, San Leandro has many assets located in areas that have a one percent (Figures 3 and 4) and 0.2 percent (Figures 5 and 6) chance of flooding in a given year. Note that the citywide assets addressed in this report are limited to those available through open data sources and identified as important facilities by City staff. Important direct effects of inland flooding exist for other vital community assets such as business corridors, places of community assembly, and housing, but these are not necessarily all considered here.

Areas that have a one percent chance of flooding in a given year include the shoreline and southern edge of the city up to Bayfair Center. Most critically, sewer and transportation assets are exposed. The Livermore-Amador Valley Water Management Agency (LAVWMA) Valve Box, Roberts Landing Stormwater Pump Station, and the Marina Dechlorination Facility are all in the floodplain. In addition, the area between the Bay Fair BART station and Hesperian Boulevard is flooded under these conditions, including the BART parking lot, nearby retail locations and portions of the Caltrans East Bay Region Maintenance Station. The railways running through the center of the city and along the shoreline all cross the floodplain, as does a Pacific Gas and Electric Company (PG&E) powerline that runs through the marshlands.

A number of community assets[6] in the southwest part of San Leandro also have a one percent chance of flooding in a given year, including Dayton Elementary School which serves as a National Shelter System facility, James Madison School, the southeast corner of Saint Felicitas School, Washington Manor Middle School, and Woodroe Woods School. The Chinese Christian Church and Burbank Preschool are also close to the floodplain, and the Christ Presbyterian Church and New Life Church are in the floodplain.

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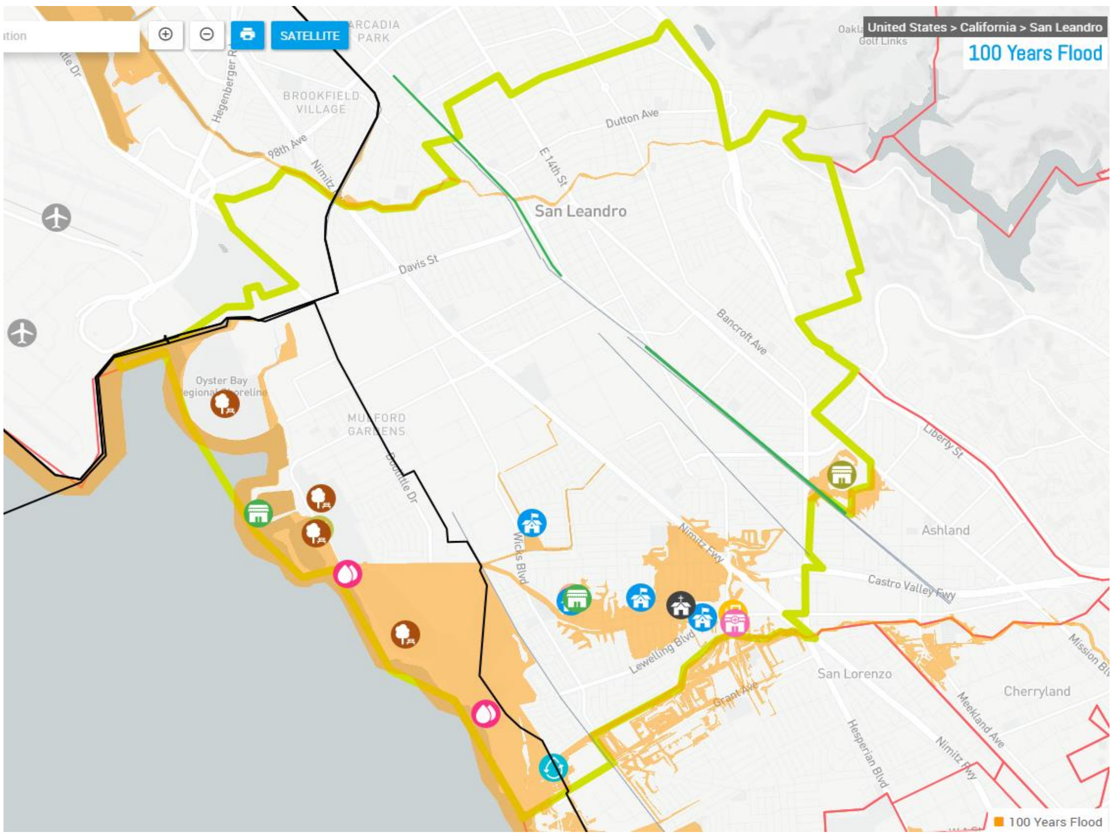
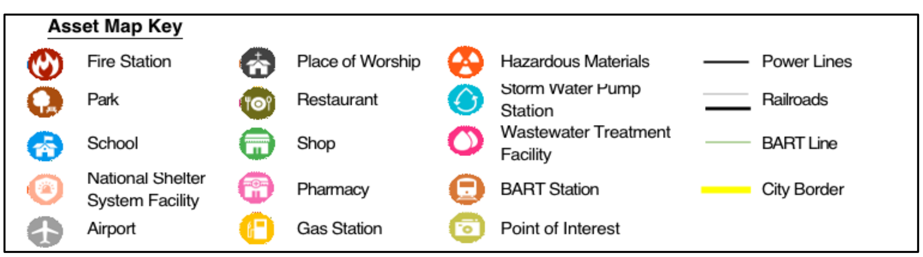
[3] Read, L. K., and R. M. Vogel. (2015). Reliability, Return Periods, and Risk under Nonstationarity. *Water Resources Research*, 51. doi:10.1002/2015WR017089.
[4] The Bay Area Council. (2015). *Surviving the Storm*. Accessed at: http://documents.bayareacouncil.org/survivingthestorm.pdf
[5] FEMA Flood Insurance Rate Map. (2009). 100 and 500-Year Floodplain. Alameda County. Effective August 3, 2009.
[6] Community assets include business corridors, places of community assembly, schools and neighborhoods that have value to the community but are not emergency assets or part of core infrastructure.

Other community assets with a one percent chance of flood exposure include the neighborhoods north of Lewelling Boulevard. Retail assets in this area include the pharmacy in the Walgreens on Washington Avenue and Lewelling Boulevard, the retail area between Washington Avenue and the I-880 freeway, and portions of the Bayfair Center Mall parking lot and north buildings. Parks in areas that have a one percent chance of flooding in a given year include the Tony Lema Golf Course and Marina Park. Flooding also affects Marina Golf Course and the Oyster Bay Regional Shoreline by inundating the area around the parks and possibly blocking access. See Figure 3 for a map of areas that have a one percent chance of flooding in a given year, and Figure 4 for a list of the key assets in areas with a one percent chance of flooding in a given year

Figure 3. San Leandro assets in areas that have a one percent chance of flooding in a given year




*Notes: The area shaded in orange is the 100-year floodplain and has a one percent chance of flooding in a given year based on historical data. Source: Local asset data provided by San Leandro City staff, OpenStreet Map, Open Data and FEMA [7] as represented on Vizonomy.*




[7] FEMA. Flood Insurance Rate Map. (2009). 100 Year Floodplain. Alameda County. Effective August 3, 2009.

Figure 4. List of Assets in areas that have a one percent chance of flooding in a given year

| Asset Type | Impact | Number of Assets |
|---|---|---|
| National Shelter System Facilities | H | 1 |
| BART Line | H | 1 |
| Railroads | H | 7 |
| Waste Water Facilities | H | 2 |
| Stormwater Pump Stations | H | 1 |
| Airports | M | 1 |
| Marina | M | 1 |
| Power Lines | M | 3 |
| Schools | M | 5 |
| Places of Worship | M | 1 |
| Pharmacies | L | 1 |
| Shops | L | 4 |
| Parks | L | 4 |
| Non-Residential Buildings | L | 9 |
| Roads | L | 265 |

*Notes: Exposed asset types and estimated level of impact. The "impact" ranking is based on a high, medium, low scale. High - Critical resources during a disaster or assets that could lead to immediate secondary hazards if damaged. Medium – Important assets or those that could lead to secondary hazards if damaged. Low – Assets that will not compound hazard effects or that do not house critical resources during an emergency. This distinction is based upon reasonable judgement and should be scrutinized by local officials for accuracy. Source of asset count: Local Asset Data provided by San Leandro City staff, OpenStreet Maps, Open Data, FEMA[8] as represented on Vizonomy.*

Exposed core assets in areas that have a 0.2 percent chance of flooding in a given year include Alameda County Fire Department Station 13 and the Bay Fair BART station. Increased flooding at Bayfair Center inundates the bus stations there, the ARCO gas station and the rail assets in the area. The Caltrans East Bay Region Maintenance Station is also affected, as are sewer assets Line D-1 and Line F. Three industrial sites that store hazardous materials, owned by the Coca Cola Bottling Company of California, XLC Corp and Foamex Innovations Operating Company are in the floodplain as well.

Exposed community assets include James Madison Elementary School - a National Shelter System facility - the Walgreens Pharmacy and Safeway on Washington Avenue, the International Christian School and the Hilton Garden Inn. On the waterfront, these assets include the Marina Golf Course, Marina Park, Marina Inn and Horatio's Restaurant. Figure 5 illustrates the core assets in areas with a 0.2 percent chance of flooding, and Figure 6 lists the key assets in areas with a one and 0.2 percent chance of flooding in a given year.

In addition to the assets in the FEMA flood maps, increased or higher intensity flooding due to climate change and/or high intensity storms could place strain on dams at the Lake Chabot or Upper San Leandro Reservoirs. Although unlikely, dam failure in either location would flood most of San Leandro

[8] FEMA Flood Insurance Rate Map. (2009). 100 and 500-Year Floodplain. Alameda County. Effective August 3, 2009.

and cause catastrophic damage.[9] Dam failure inundation maps pursuant to California Code Section 8589.5 are available from the Office of Emergency Services[10]. Although the dams are being seismically strengthened and are outside the FEMA designated floodplain, it may be pertinent for San Leandro to maintain a catastrophic emergency response plan for these conditions.

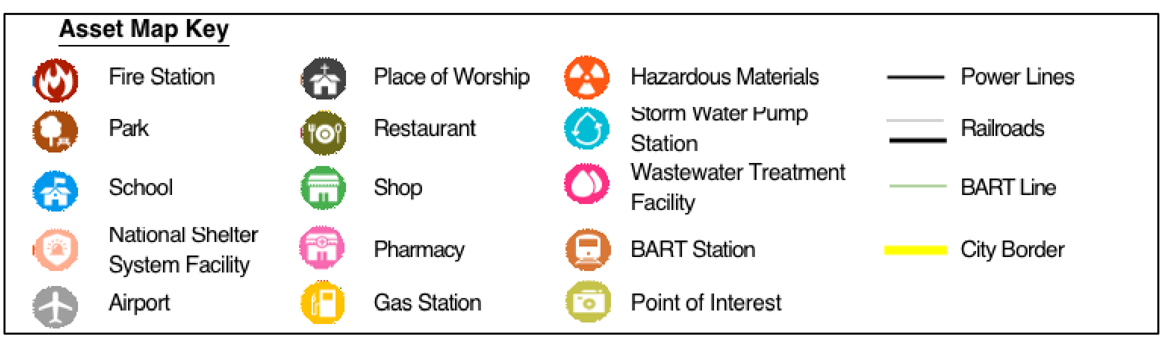
Even in a less catastrophic scenario, the considerable number of assets in areas with a one and 0.2 percent chance of flooding in San Leandro make flooding a noteworthy threat to the city. Economically, floods are costly. In addition to structural and contents damages caused by flood waters, the cost of transportation delays, utility service outages and lost economic activity can be significant.[11] City-wide preparedness can help minimize these impacts and even benefit public health, as flooding and the presence of standing water not only limit mobility by obstructing roads and disrupting utility service, but also increase the chance of public exposure to water-borne pathogens, toxic algae or chemicals that enter the water from spills.[12]

As sea level rise encroaches on the marshlands that help protect the city from coastal floods, it will become increasingly essential to minimize the contribution of land use change, site design and impervious cover to water runoff, which may cause flooding to affect a wider area and occur more frequently than historical records indicate. Exposed emergency and transportation assets such as Fire Station 13 and the Bay Fair BART Station will be critical to account for in future planning.

[9] Draft City of San Leandro 2015 Local Hazard Mitigation Plan.
[10] These maps have not been updated since the 1970s.
[11] The Bay Area Council. (2015). *Surviving the Storm*. Accessed at: http://documents.bayareacouncil.org/survivingthestorm.pdf
[12] U.S. Global Change Research Program (USGCRP). (2016). *Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. dx.doi.org/10.7930/J0R49NQX

Figure 5. San Leandro Assets in areas that have a 0.2 percent chance of flooding in a given year


*Notes: The area shaded in orange is the 100-year floodplain and has a one percent chance of flooding in a given year based on historical data. The area shaded in red is the 500-year floodplain and has a 0.2 percent chance of flooding in a given year based on historical data. Source: Local asset data provided by San Leandro City staff, OpenStreet Map, Open Data and FEMA* [13] *as represented on Vizonomy.*




[13] FEMA. Flood Insurance Rate Map. (2009). 100 Year Floodplain. Alameda County. Effective August 3, 2009.

Figure 6. List of Assets in areas that have a 0.2 percent chance of flooding in a given year

| Asset Type | Impact | Number of Assets |
|---|---|---|
| Fire Station | H | 1 |
| Bayfair BART Station | H | 1 |
| BART Line | H | 1 |
| Railroads | H | 8 |
| Stormwater Pump Stations | H | 2 |
| Airports | M | 1 |
| Marina | M | 1 |
| Hazardous Materials Sites | M | 4 |
| Power Lines | M | 2 |
| Schools | M | 2 |
| Gas Stations | L | 1 |
| Pharmacies | L | 1 |
| Restaurants | L | 1 |
| Shops | L | 2 |
| Parks | L | 3 |
| Non-Residential Buildings | L | 16 |
| Roads | L | 222 |

*Notes: See Figure 4 for an explanation of the asset impact ranking. The asset count for areas that have a 0.2 percent chance of flooding in a given year does not include the assets areas that have a one percent chance of flooding in a given year. Source of asset count: Local asset data provided by San Leandro City staff, OpenStreet Maps, Open Data and FEMA*[14] *as represented on Vizonomy.*

## Sea Level Rise

### San Leandro will experience sea level rise due to climate change

Sea levels are rising as a result of higher atmospheric and oceanic temperatures across the globe. The rate of sea level rise is expected to accelerate throughout the century, threatening coastal resources, but projections are complicated by the potential for a substantial acceleration of glacial ice melt, which is not currently accounted for in many global scenarios and may result in rapid sea level rise.[15]

The Bay Area is especially exposed to the impacts of sea level rise because of the large number of assets located on the coast that are significant to the local economy and communities. In San Leandro, the assets most at risk from sea level rise include transportation assets, powerlines and cultural amenities along the shoreline as well as the neighborhoods, parks and schools in the southwest portion of the city. While the downtown core and area surrounding the San Leandro BART station remain outside of the projected boundaries of sea level rise, the compounding effects of sea level rise could impede access to the city via I-880 and significantly impact San Leandro residents that live west of this freeway.

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[14] FEMA. Flood Insurance Rate Map. (2009). 100 and 500-Year Floodplain. Alameda County. Effective August 3, 2009.

[15] M. K. Buchanan, R. E. Kopp, M. Oppenheimer, and C. Tebaldi. (2016). Allowances for evolving coastal flood risk under uncertain local sea-level rise. *Climatic Change* 137, 347-362. doi:10.1007/s10584-016-1664-7.

## Sea level rise is a certainty

Sea level rise is occurring and is expected to accelerate throughout the 21st century. However, it is uncertain how much and how quickly sea levels will rise in the Bay Area. Considered the best available science, the National Research Council (NRC) identified likely sea level rise estimates for the west coast of the United States. [16] These values are accompanied by ranges of possible sea levels based on low and high emissions scenarios and ice melt scenarios. Figure 7 summarizes these projections: six inches of sea level rise by 2030 (range: 2-12 in), 11 inches by 2050 (range: 5-24 in), and 36 inches by 2100 (range: 17-66 in) relative to the year 2000.

Figure 7. Sea Level Rise Estimates Relative to the Year 2000

| Year | Projections | Ranges |
|---|---|---|
| **2030** | 6 ± 2 in | 2 to 12 in |
| **2050** | 11 ± 4 in* | 5 to 24 in |
| **2100** | 36 ± 10 in | 17 to 66 in |

*Source: NRC, 2012.* [17]

These projections characterize the estimated timeline for permanent increases in water levels. However, the conditions may occur sooner on a temporary basis under a number of different circumstances given the combination of permanent sea level rise and temporary extreme tides resulting from the additive impact of high tides and storm surge. For example, water levels could reach the equivalent of 48 inches of inundation by 2050 in the event of a 50-year storm, or a storm that has a two percent chance of occurring in a given year, even though that level of sea level rise is not projected to occur by the end of the century (See Appendix A, Figure A2).

In the 2035 General Plan, the City of San Leandro adopted a sea level rise scenario of 55 inches by 2100[18] according to conservative estimates in the San Francisco Bay Conservation and Development Commission (BCDC) report *Living with a Rising Bay*. [19] City planning and projects in San Leandro will work to account for the threats posed by this estimate of sea level rise over the remainder of the century. In order to provide a wider lens to evaluate near and long term sea level rise relative to the established planning horizon of 55 inches, this climate hazard assessment explores the exposure of assets to sea level rise of 12 to 96 inches as presented in the *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment,* which was conducted as part of a related effort by BCDC and provides more localized sea level rise projections.[20] See Appendix A for further information on the data used in this analysis.

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[16] National Research Council. (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Report. DOI: 10.17226/13389
[17] National Research Council. (2012).
[18] City of San Leandro. (2016). San Leandro 2035 General Plan. Adopted September 19, 2016.
[19] San Francisco Bay Conservation and Development Commission (BCDC). (2011). *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline*.
[20] Alameda County Flood Control and Water Conservation District and the San Francisco Bay Conservation and Development Commission (BCDC). (2015). *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment Final Report*.

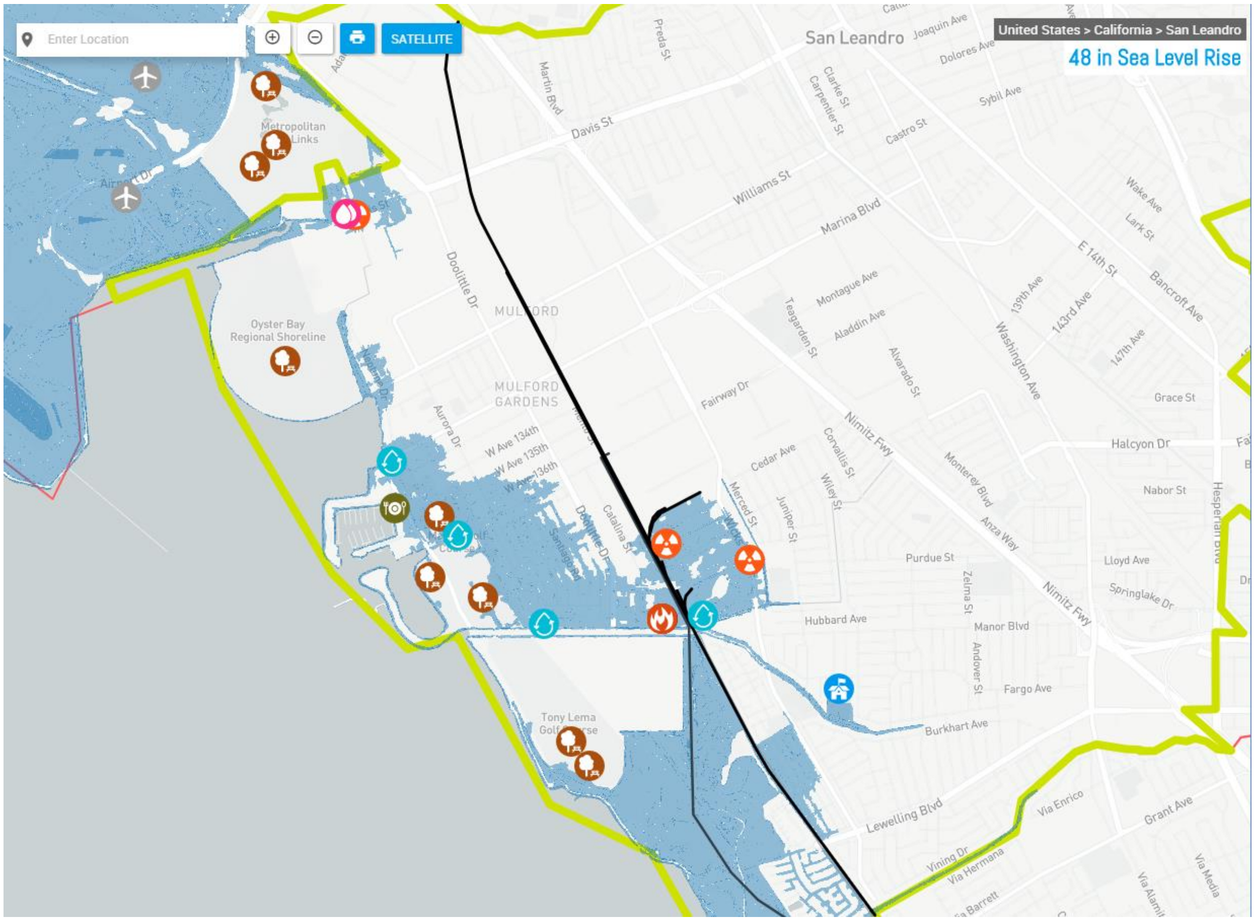
## Sea level rise will mean floods affect more assets over time

Sea level rise associated flooding will first affect marshlands and eventually threaten property and assets in southwest San Leandro, reaching the neighborhoods east of Wicks Boulevard in some areas. By mid-century, about 12 inches of sea level rise is projected to permanently inundate the marshlands, eroding the southern portion of the city's defense to storm surge and high tides. Assets flooded under these conditions include a powerline that runs through marshlands and the coastal boundaries of the city's shoreline parks. As water levels reach 24 inches, which is possible as soon as 2030 with a two-year extreme tide, the Union Pacific Railroad along the coast may experience flooding. At this level, water begins to encroach on the Oyster Bay Regional Shoreline, and creep up the Estudillo Channel and the edges of Marina Park, Marina Golf Course, and Tony Lema Golf Course.

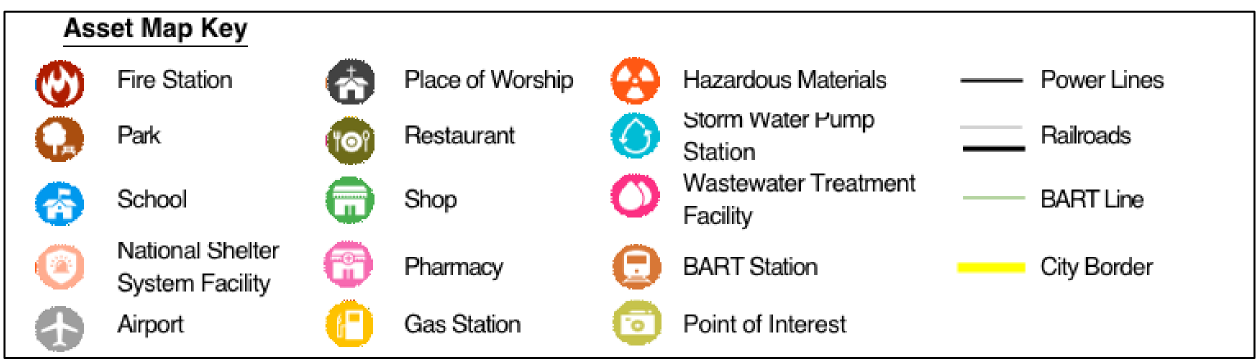
At 36 inches of sea level rise, water begins to flood into the neighborhoods between Wicks Boulevard and the railroad, and affects the Wicks Boulevard bridge where it crosses the Estudillo Channel. At this height, water levels reach the San Leandro Water Pollution Control Plant. These assets could be temporarily inundated by a five-year recurrence interval storm by mid-century and will potentially be permanently inundated by the end of the century. Although the Port of Oakland plans to raise levees in the area, which will increase protections along the southern border of the Water Pollution Control Plant and decrease projected flooding, some of the plant will remain exposed to rising sea levels.

The consequences of sea level rise escalate quickly once water levels reach 48 inches, likely by the end of the century when combined with average yearly storm surge. At this level of inundation, Alameda County Fire Department Station 11 is exposed, as is more of the San Leandro Water Pollution Control Plant. Other sewer assets are exposed as well, namely, Line D-1, Belvedere, Line F, Line H, and the San Leandro Effluent Pump Station on Davis Street. These assets support sewer function and their proper functioning is critical to protect public health throughout San Leandro. Dayton Elementary School, which serves as a national shelter system facility, and three industrial facilities with hazardous materials onsite, owned by Davis Street Smart, US Printing Ink Corporation, and the Coca Cola Bottling Plant of California respectively are also at risk. There is also an increase in exposed power line and rail assets that could negatively affect commerce and the availability of resources and electricity in the city. See Figure 8 (on following page) for a map of areas inundated by 48 inches of sea level rise.

Figure 8. San Leandro Assets Exposed to 48 Inches of Sea Level Rise




*Notes: The area shaded in blue indicates the area inundated by 48inches of sea level rise. Source: Local asset data provided by San Leandro City staff, OpenStreet Maps, Open Data, and Alameda County Flood Control and Water Conservation District and BCDC* [21] *as represented on Vizonomy.*




In the worst-case scenario, with predicted end-of-century sea level rise compounded by glacial melting and/or seasonal King tides and storm surge, there is the possibility that the Bay Area may experience sea

[21] Alameda County Flood Control and Water Conservation District and BCDC. (2015). *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment Final Report*.

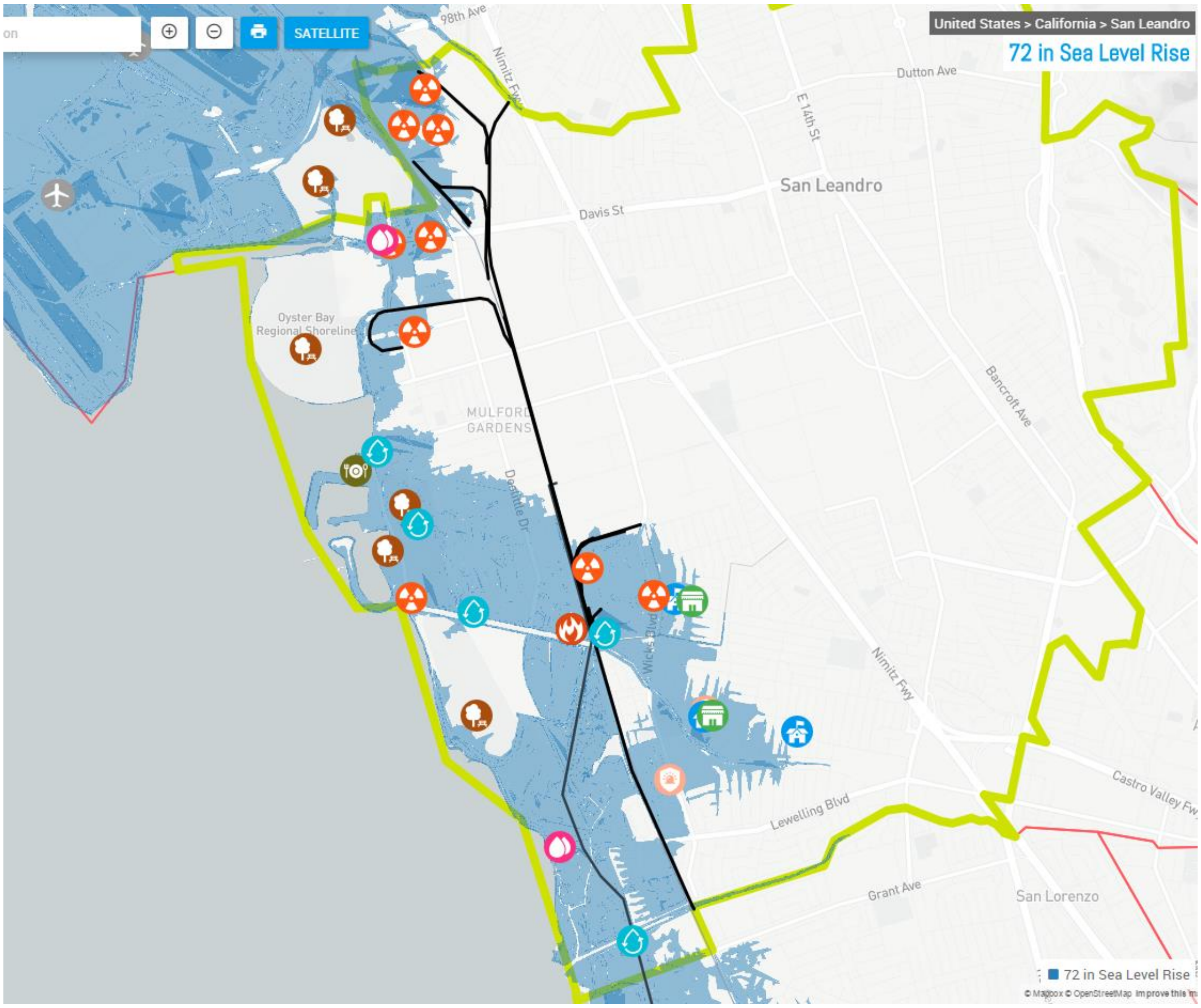
level rise related flooding of up to 72 inches or more. See Figure 9 for a map of areas inundated by 72 inches of sea level rise, and Figure 10 for a list of key exposed assets under different levels of sea level rise. At 72 inches, the Marina and neighborhoods east of it are completely inundated. This includes Mulford Gardens and Marina Faire neighborhoods, as projected flooding reaches most of the area west of the railroad and extends out into the neighborhoods east of the railroad and south of Fairway Drive. Exposed assets include two non-emergency ambulance facilities located on Wicks Boulevard, Washington Manor Middle School, James Madison Elementary School, St. Felicitas School, and the Marina Community Center, which also serves as a National Shelter Service facility.

To the north, additional flooding occurs behind the Oyster Bay Regional Shoreline. Ten facilities that use or contain hazardous materials onsite are inundated at this magnitude of sea level rise throughout the city, with five facilities clustered inland of the Oyster Bay Regional Shoreline and the Oakland Metropolitan Golf Links. These include the Davis Street Smart, Copper Harbor Company, Foamex Innovations Operating Company, Safeway Milk Plant, Benkiser Electric, Cast Aluminum and Brass Corporation, and the Wyman Gordon Company properties. To the south, the East Bay Dischargers Authority Joint Outfall and facilities owned by the US Printing Ink Corporation, Coca Cola Bottling Company of California are also exposed.

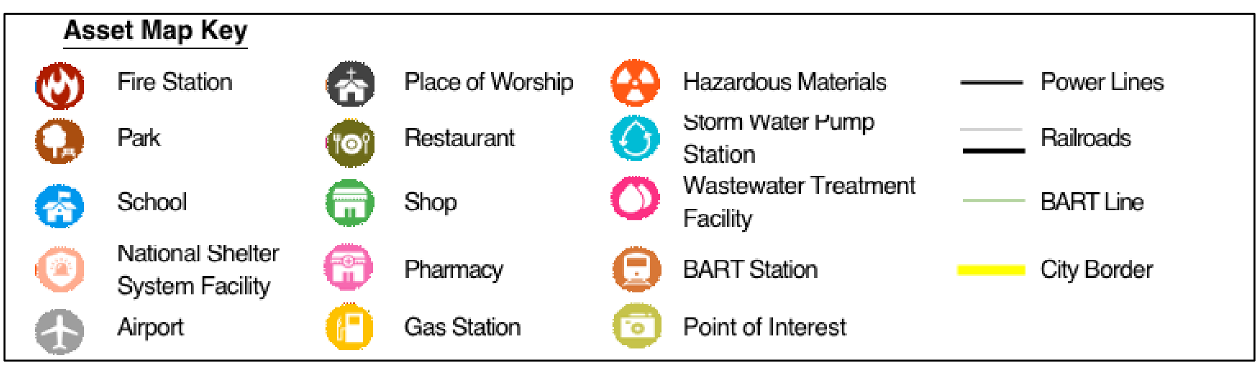
By 96 inches, flooding creeps further into the neighborhood south of Cedar Avenue and west of the I-880 by another two or three blocks. While few additional critical assets are immediately impacted as water levels rise above 72 inches, the number of people affected will continue to increase significantly.

Overall, the potential impacts to the sewer system and the number of schools threatened by sea level rise flooding will increase threats to public health from sewer overflows and backups, mold and rust, limit the number of community resources available to use as shelters, and threaten vulnerable neighborhoods in the southwest regions of the city. In addition, as water levels encroach on shoreline amenities along the Bay and into the industrial and manufacturing areas slightly inland, many of the resources that the city depends on to thrive economically may be challenged and forced to close or relocate outside the city. Appropriate planning and adaptive measures focused on mitigating these impacts will be essential for the City of San Leandro.

Figure 9. San Leandro Assets Exposed to 72 Inches of Sea Level Rise




*Notes: The area shaded in blue indicates the area inundated by 72 inches of sea level rise. Source: Local asset data provided by San Leandro City staff, OpenStreet Maps, Open Data, and Alameda County Flood Control and Water Conservation District and BCDC* [22] *as represented on Vizonomy.*




[22] Alameda County Flood Control and Water Conservation District and BCDC. (2015). *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment Final Report*.

Figure 10. List of Assets Exposed to Sea Level Rise

| Asset Type | Impact | 12in | 24in | 36 in | 48 in | 72 in | 96 in |
|---|---|---|---|---|---|---|---|
| Fire Station | H | | | | 1 | 1 | 1 |
| National Shelter System Facilities | H | | | | | 2 | 3 |
| Water Pollution Control Plant | H | | | 1 | 1 | 1 | 1 |
| Waste Water Facilities | H | | | 1 | 1 | 2 | 3 |
| Stormwater Pump Stations | H | | | | 4 | 5 | 5 |
| Ambulence Services | H | | | | | 2 | 2 |
| Railroads | H | 2 | 4 | 4 | 1 | 19 | 25 |
| Airports | M | 1 | 1 | 1 | 1 | 1 | 1 |
| Marina | M | 1 | 1 | 1 | 1 | 1 | 1 |
| Hazardous Materials Sites | M | | | 1 | 3 | 10 | 10 |
| Power Lines | M | 1 | 1 | 1 | 1 | 2 | 2 |
| Schools | M | | | | 1 | 4 | 5 |
| Places of Worship | M | | | | | | 1 |
| Libraries | L | | | | 1 | 1 | 1 |
| Gas Stations | L | | | | | 1 | 2 |
| Restaurants | L | | | | 1 | 2 | 3 |
| Parks | L | 2 | 3 | 3 | 4 | 5 | 5 |
| Non-Residential Buildings | L | 1 | 1 | 1 | 3 | 6 | 9 |
| Roads | L | 19 | 25 | 46 | 179 | 357 | 490 |

*Notes: See Figure 4 for an explanation of the asset impact ranking. The asset counts for increasing levels of sea level rise are cumulative. Source of asset count: Local asset data provided by San Leandro City staff, OpenStreet Maps, Open Data, FEMA,[23] and Alameda County Flood Control and Water Conservation District and BCDC [24] as represented on Vizonomy.*

## Temperature Changes and Precipitation Events

### Climate Change may increase temperatures in San Leandro, but impacts on rainfall are unclear

As greenhouse gas emissions increase, temperatures are expected to warm globally. San Leandro's climate is no exception and temperatures are projected to increase throughout the city with the number of days over 90 ˚F increasing from a model history baseline average[25] of less than once a year to 11 days per year by the end of century[26]. The impact of climate change on precipitation is more ambiguous, and

[23] FEMA Flood Insurance Rate Map. 2009. 100 and 500-Year Floodplain. Alameda County.

[24] Alameda County Flood Control and Water Conservation District and BCDC. (2015). *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment Final Report*.

[25] The climate model history is intended to capture climate conditions experienced from 1970-2000, but not to predict the weather conditions on any given day, month, or year. For this baseline period, the climate models were run with an emissions scenario representative of the observed history from those past years but with the same physics and configurations as in future-year runs. This enables comparison of like historical and future model data to better establish the magnitude of likely future changes. This climate modeled history is referred to here as the historical baseline.

[26] Reclamation. (2013). 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado.

although precipitation patterns are expected to become more variable, projections of annual totals show no clear signal of significant directional change.

## San Leandro may experience higher average daily temperatures and more extreme heat days

Temperature and precipitation projections were provided by Four Twenty Seven using scenarios from the Intergovernmental Panel on Climate Change (IPCC). The Representative Concentration Pathway (RCP) 8.5 is characterized by a minimal greenhouse gas mitigation effort and high emissions scenario, resulting in the largest increase in radiative forcing and warming, while RCP 4.5 is considered a moderate mitigation scenario where climate action limits the amount of global emissions.[27] Future temperature rise scenarios vary based on which government policies and commercial and human actions are actually implemented in the coming years and how well these climate change mitigation efforts work cumulatively. While, temperatures in San Leandro are projected to increase under both scenarios, daily average temperatures are projected to increase by about twice as much under the RCP 8.5 (high emissions) scenario than under the RCP 4.5 (lower emissions) scenario by the end of the century. (RCP 8.5 leads to a 6.9 to 8.8 ˚F increase in daily average temperature, compared to 3.2 to 4.9 ˚F increase under RCP 4.5.)

## Temperatures in San Leandro may be two to four degrees higher

According to the model baseline (1970-2000), San Leandro's climate has been characterized by a daily average temperature of about 58.6 ˚F, an average maximum temperature of 67 ˚F, and an average minimum temperature of 50.2 ˚F.[28] Temperature projections exhibit a clear trend toward warmer average temperatures and more frequent occurrence of high or even extreme temperature events. Under RCP 8.5 (a high emissions scenario), daily average temperatures are projected to increase from the model baseline by as much as 2.5 ˚F to 3.5 ˚F, daily minimum temperatures by about 2.5 ˚F to 3.5 ˚F, and daily maximum temperatures by about 2.5 ˚F to 4 ˚F between now and mid-century. Even under RCP 4.5 (a lower emissions scenario), temperature increases are anticipated, and projections range between an average daily increase of as much as 2.5 ˚F and 3.5 ˚F by mid-century. By the end of the century, temperature changes are estimated to be substantial, for daily average, minimum, and maximum temperatures with the high-end of the range of RCP 8.5 temperature increase projections suggesting increases from about 7 ˚F to 9 ˚F.[29] This means that San Leandro's average maximum temperature would be comparable to current levels in San Luis Obispo, California. These projections do not indicate seasonal fluctuations, but yearly averages.

The greatest potential impact of temperature increases lies in the relative increase in the severity of extreme heat and the frequency of hot days. According to the modelled historical baseline of San Leandro's climate, the occurrence of temperatures exceeding 90 ˚F is rare.[30] The average number of days over 90 ˚F is projected to rise significantly after mid-century. Under RCP 4.5, 90 ˚F days in San Leandro are projected to double by mid-century, with a threefold increase under RCP 8.5 over the same period.

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[27] IPCC. (2014). Scenario Process for AR5. Accessed at: http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html

[28] Reclamation. (2013).

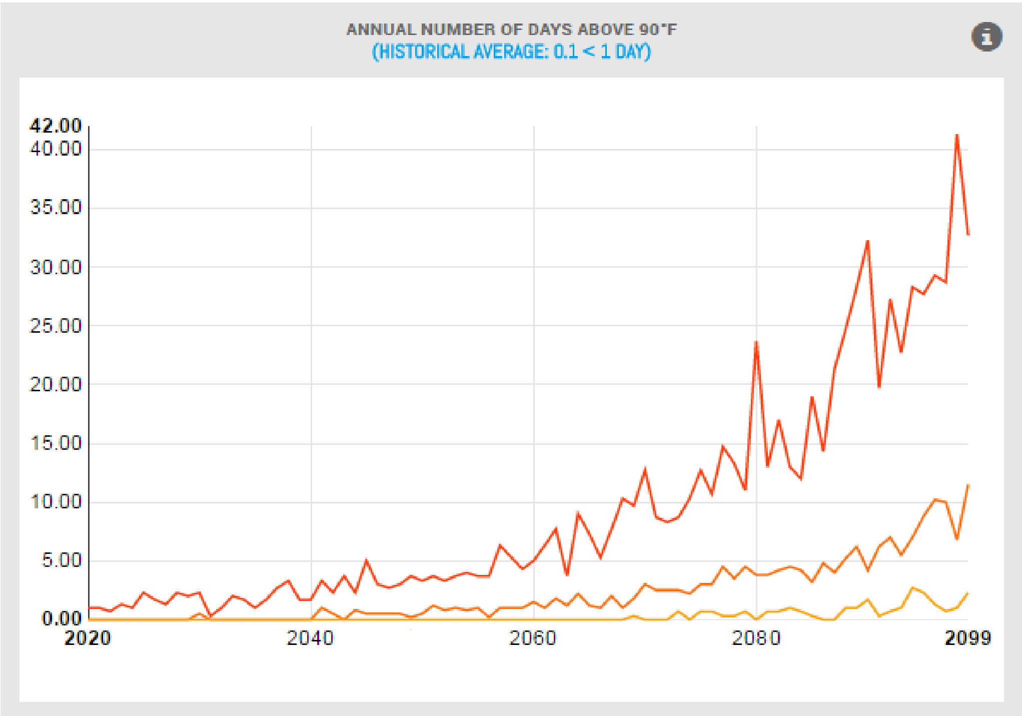
[29] Reclamation. (2013).

[30] Reclamation. (2013). 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado.

By century's end, the increase in the number of days per year above the 90 °F mark could reach fivefold under RCP 4.5, but be as much as 41 times higher in a business-as-usual scenario. However, mid-range RCP 8.5 projections indicate the number of days may be closer to 11 times higher (see Figure 11).[31]

Higher temperatures will likely increase the magnitude of heat hazards in the city, for instance, heat stroke or exhaustion among local residents, workers and visitors, or raised demand for power during peak periods which could affect the frequency of outages. Since San Leandro residents are unlikely to have air conditioning units in their homes,[32] residents, especially the elderly, disabled or socially isolated, will be more vulnerable to extreme heat events.[33] These high temperatures and the associated hazards may be exaggerated by local conditions, such as the urban heat island effect, where buildings and pavement absorb heat during the day and then radiate that heat at night, limiting nighttime cooling and amplifying daytime high temperatures.[34]

Figure 11. Projected Extreme Heat Days in San Leandro




*Notes: RCP 8.5 projected annual number of days above 90 °F throughout the 21st century. Lines represent low-end (light orange), mid-range (dark orange) and high-end (red) model results. Source: Reclamation[35] as represented on Vizonomy.*

[31] Reclamation. (2013).
[32] Pacific Institute. (2012). Social Vulnerability Index. Percent of Households without Air Conditioning. Accessed at: http://pacinst.org/publication/study-maps-social-vulnerability-to-climate-change-in-california-and-identifies-need-for-adaptation-planning/
[33] USGCRP. (2016). *Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. dx.doi.org/10.7930/J0R49NQX
[34] USGCRP. (2016).
[35] Reclamation. (2013). 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado.

According to the historical baseline (1970-2000), San Leandro's climate trends suggest that temperatures drop below freezing on average two days per year. Based on climate scenarios, the number of very cold days is expected to decrease and minimum temperatures gradually to rise. Under RCP 8.5, mid-range projections show no days below freezing after 2035 and even the high-range scenario drops to zero days per year by 2095. Even under RCP 4.5, it would be unlikely for San Leandro to experience a day below 32 °F after 2064.[36]

### The impacts of climate change on rainfall are ambiguous

During the model baseline period of 1970-2000, San Leandro's typical climate conditions resulted in approximately 18 inches of rainfall per year. By mid-century, under RCP 8.5 (a high emissions scenario), the percent change in total precipitation varies widely between a decrease of 19.6 percent and an increase of 35.8 percent, indicating that no clear directional change in cumulative precipitation volumes is expected by the end of the century. Under both RCP 8.5 and 4.5, mid-range projections of maximum five-day precipitation totals estimate an increase in rainfall of only 15 percent by the end of the century.[37] Thus, annual precipitation totals may remain analogous to present conditions in all but the high-end model projections. Figure 12 depicts the projected occurrence of heavy rainfall events in San Leandro between 2020 and 2099.

These extreme rainfall event projections may not account for rare, but increasingly intense events such as atmospheric rivers (i.e., Pineapple Express). [38] Studies using computational models suggest that climate change will cause the most intense atmospheric river storms hitting California to become more frequent and last longer by the end of the century.[39]

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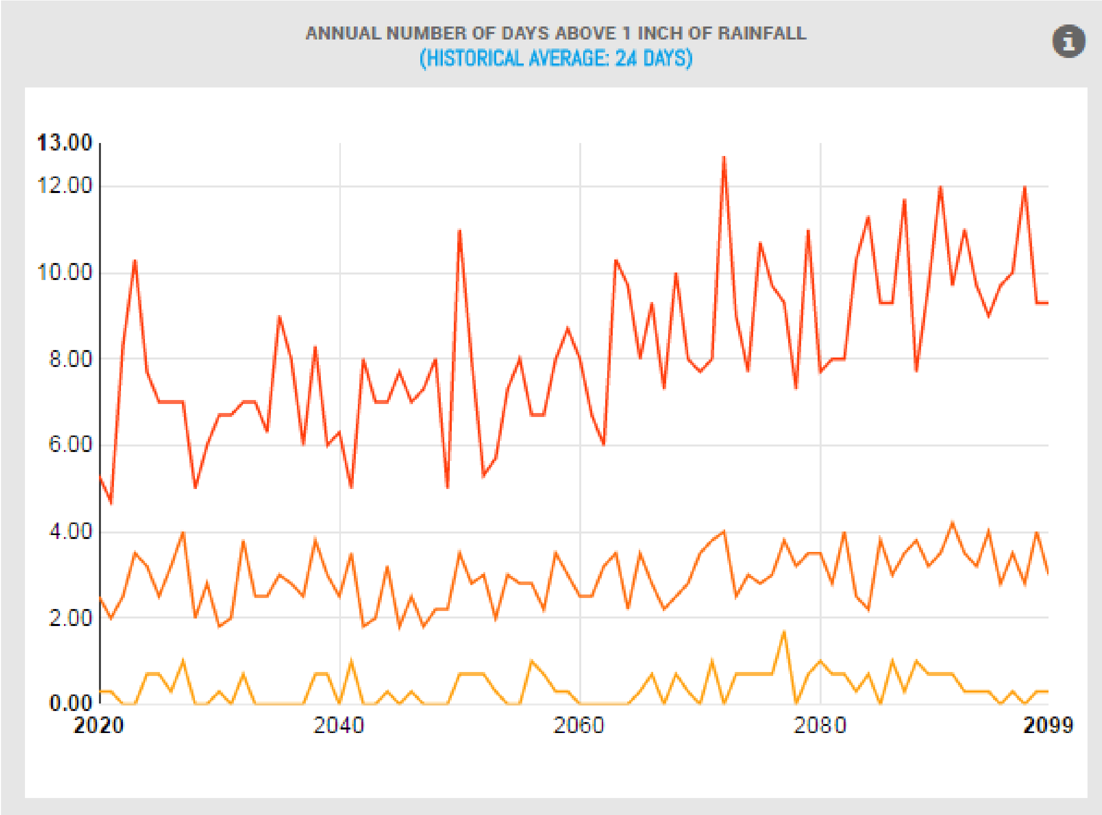
[36] Reclamation. (2013).
[37] Reclamation. (2013). 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado.
[38] Shields, C. A., and J. T. Kiehl. (2016). Simulating the Pineapple Express in the half degree Community Climate System Model, CCSM4, *Geophysical Research*. Letters, 43, 7767–7773, doi: 10.1002/2016GL069476
[39] Shields, C. A., and J. T. Kiehl. (2016).

Figure 12. Projected Occurrence of Heavy Rainfall Events in San Leandro




*Notes: RCP 8.5 projected percent changes in heavy precipitation throughout the 21st century. Lines represent low-end (light orange), mid-range (dark orange) and high-end (red) model results. Source: Reclamation[40] as represented on Vizonomy.*

## Rainfall Induced Landslides

### Areas where landslides have already occurred are at greatest risk

Landslides are considered to be most likely to occur in and around the places where they have previously taken place. Wildfire and high-intensity rainfall events, both anticipated to occur with greater frequency due to climate change, increase the risk of inland flooding.[41] Secondary impacts associated with flooding include landslides, subsidence, slippage, creep or sinkholes. Cities with hilly terrain can experience increased risk of these events. Due to San Leandro's location and topography, there is a medium risk of experiencing landslides in the hills to the east.

[40] Reclamation. (2013).
[41] USGS. (2005). "Southern California – Wildfires and Debris Flows" Fact Sheet 2005–3106.

### San Leandro is at a medium risk for landslides

As defined by the United States Geological Survey (USGS),[42] most of the city of San Leandro is in a zone that experiences “very few landslides.” However, Bay-O-Vista, a neighborhood located east of I-580, has experienced recent landslides, and Lake Chabot Road and the area near Kindred Hospital are also vulnerable to instability. While these assets are located in a USGS zone designated as experiencing “few landslides” the consequences of a potential landslide affecting the hospital and surrounding neighborhoods makes this area a concern for hazard mitigation and response as climate conditions and flood risks change.

## Wildfires

### Climate change may increase wildfire risk

Extreme temperatures and increased variability in rainfall will likely cause dry conditions in California, exacerbating the risk of wildfire throughout the state. Large areas east of the I-580 freeway and throughout the hills adjacent to San Leandro are at risk of high to very high hazard severity in the event of a wildfire. This includes areas with increased exposure along the eastern edge of the city where San Leandro borders Lake Chabot Regional Park, which is designated as a very high hazard severity zone. While these zones do not affect the city’s key emergency response or transportation assets, a couple of regional hospital facilities are exposed which may challenge the city’s contracted fire agency’s, the Alameda County Fire Department, capacity to respond to wildfire impacts.

### Wildfires may become more common or severe

According to the California Department of Forestry and Fire Protection (CAL FIRE) Fire Hazard Severity Zone maps,[43] San Leandro has moderate to very high wildfire severity zones in many areas of the city, primarily east of the MacArthur Freeway, but with some high severity areas in the Oyster Bay Regional Shoreline and the inland areas of the marshlands near the shoreline. Fire hazard severity is a metric of the potential exposure of wildland and urban properties to wildfire based on vegetation, topography, and dangerous fire characteristics. The extent of these zones will therefore depend on land use change, but the occurrence of fire within these zones may increase due to climate change impacts such as more frequent droughts. Figure 13 depicts the geographic distribution of fire hazard severity risk throughout San Leandro.

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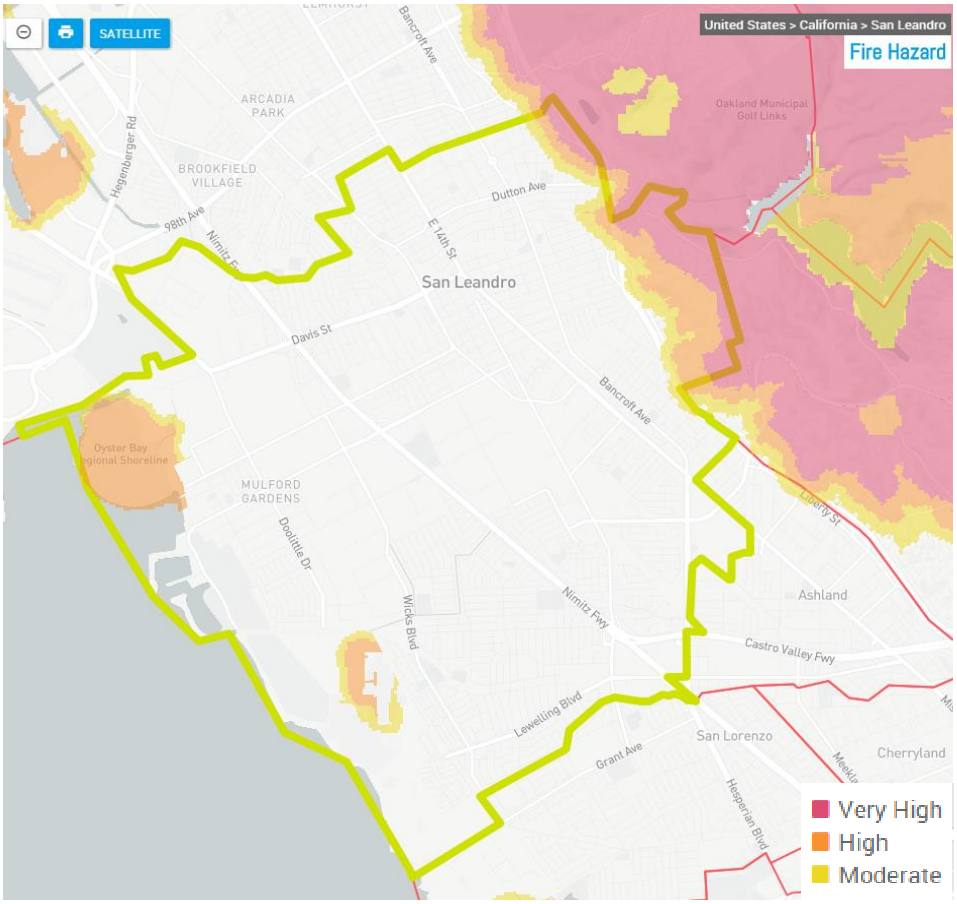
[42] Pike, R.J. (1997). San Francisco Bay Region Landslide Folio Part D. USGS. Accessed at: http://pubs.usgs.gov/of/1997/of97-745/of97-745d.html

[43] CalFIRE. Wildland Hazard and Building Codes: Fire Hazard Severity Zone Development. Accessed at: http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development

Figure 13. Fire Hazard Severity Zones within and near San Leandro




*Source: Open Data, OpenStreet Map and USGS [44] as represented on Vizonomy.*

## Many assets are already exposed to wildfire risks

Fire risk in San Leandro is low throughout most of the city, however, the city borders a very high fire severity zone to the east and is therefore exposed to potentially higher severity fires in the event of a wildfire. San Leandro assets in the designated high hazard severity zone include Kindred Hospital, Fair Haven Bible Chapel, Creekside Community Church, and the San Leandro Church of Christ on MacArthur, and the assets in the moderate zone include Grand Gas Station and Rite Aid pharmacy on Grand and MacArthur. Two power lines also run right through the very high hazard severity zone in Anthony Chabot Regional Park and could affect power service in the city if damaged. Along the coast, the Oyster Bay Regional Shoreline is at a moderate level of fire risk.

Community assets in the city located near fire hazard severity zones include Roosevelt Elementary School, which serves as a National Shelter System facility, and St. James Lutheran Church. Relevant assets located outside the city border but in very high hazard severity zones include the Chabot Dam,

[44] CalFIRE. Wildland Hazard and Building Codes: Fire Hazard Severity Zone Development. Accessed at: http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development

Fairmont Hospital, including John George Psychiatric Hospital and George Mark Children's House, and Sheffield Village Clubhouse and Pre-School.

Since the area exposed to wildfire risk overlaps with areas that are at a medium risk for landslides, especially those surrounding Kindred Hospital, an emergency asset, special attention should be paid to preventing wildfire in San Leandro. Wildfire damages soil and can diminish its water-absorbing capacity, leading to increased runoff, debris flows and exacerbated landslide risk post-fire.[45]

[45] USGS. (2005). "Southern California – Wildfires and Debris Flows" Fact Sheet 2005–3106.

# Appendix A: Methods & Data Sources

## Methods

The San Leandro climate hazards analysis was conducted using a digital mapping tool called the Vizonomy Climate Risk Platform (Vizonomy). This platform overlays geographical representations of sea level rise and rainfall-induced inland flooding with the location of citywide assets throughout San Leandro, creating a visual representation of the spatial extent and the number of specific assets that could be affected by each hazard throughout the city. The asset data was collected from open data sources available through various federal agencies, OpenStreet Map and local data provided by the City of San Leandro and Alameda County. Hazard projections and data were collected from the data sources explained in the next section of this appendix. In addition, statistical analysis of downscaled climate models and graphical representations of projected temperature and precipitation changes throughout the 21st century were provided by Four Twenty Seven.

The spatial evaluation of hazards and assets limited this analysis to the consideration of asset exposure. In order to assess vulnerability to climate change hazards, more information is needed on the sensitivity and adaptive capacity of affected communities and assets. This analysis provides a thorough examination of the city's potential spatial exposure to a variety of climate hazards and is meant to complement further analysis of overall vulnerability and the appropriate adaptive responses.

## Data Sources

### Rainfall Induced Inland Flooding

FEMA creates Flood Insurance Rate Maps as part of the National Flood Insurance Program to determine flood insurance requirements and inform local hazard mitigation actions that address flood risks. These flood maps incorporate statistical information on river flow, storm surge, hydrology and topography in order to delineate 100-year and 500-year floodplains, or areas that will experience floods with a one percent or 0.2 percent chance respectively of being exceeded in a given year. The statistical information and associated maps are based on historical data and do not incorporate climate projections into floodplain delineations, yet do provide an accurate depiction of where floodwaters are likely to concentrate, even if recurrence intervals change.

### Sea Level Rise

The 2012 NRC Report *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* identified likely sea level rise estimates throughout the 21st century for the west coast of the United States based on moderate greenhouse gas emissions and continued acceleration of glacial melt patterns. These values are accompanied by ranges of possible sea levels based on low and high emissions scenarios and ice melt scenarios. Figure A1 presents these projections: six inches of sea level rise by 2030 (range: 2-12 in), 11 inches by 2050 (range: 5-24 in), and 36 inches by 2100 (range: 17-66 in) relative to the year 2000.

Figure A1. Sea Level Rise Estimates Relative to the Year 2000

| Year | Projections | Ranges |
|---|---|---|
| **2030** | 6 ± 2 in | 2 to 12 in |
| **2050** | 11 ± 4 in* | 5 to 24 in |
| **2100** | 36 ± 10 in | 17 to 66 in |

*Source: NRC. 2012.* [46]

In the report *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment*, these projections inform a sea level rise analysis for Alameda County. Four inundation maps were created which incorporate remote sensing data using light detection and ranging (LiDAR) methods to depict the elevation on natural and hard structures and determine the level of "overtopping" at five-meter resolution. Each map represents a range of scenarios that are possible given different combinations of sea level rise and extreme tides. Extreme tides are caused by the additive impact of unusually high tides, or King tides, which happen twice per year, and storm surge, which results from the high winds and low atmospheric pressure associated with storm conditions.

The analysis includes maps of water levels increasing by 12 inches, 24 inches, 36 inches and 48 inches over the Mean Higher High Water (MHHW), or the average height of the higher high tide of each day. (Refer to Figure A2.) Based on the likely sea level rise projections within climate scenarios, the areas flooded in the map depicting 36 inches of sea level rise are likely to be permanently inundated by 2100. However, this same water level could occur temporarily on an annual basis by mid-century with high tides and storm surge.

Two additional maps of water level increases at 72 and 96 inches illustrate flooding that can potentially take place under the circumstances that sea level rise is combined with higher than projected glacial melt and extreme tides. For example, a 72-inch scale flood is possible with 36 inches of sea level rise and a 50-year extreme tide. A 95-inch scale flood, which would inundate half the city, is possible with 54 inches of sea level rise and a 100-year storm event.

[46] National Research Council. (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Report. DOI: 10.17226/13389

Figure A2. Sea Level Rise and Extreme Tide Matrix (Hydrodynamic Zone 3)

| Sea Level Rise Scenario | Daily Tide *Permanent Inundation* | Extreme Tide (Storm Surge) *Temporary Flooding* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | +SLR | 1-yr | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| | Water Level above MHHW (in) | | | | | | | |
| **Existing Conditions** | 0 | 15 | 20 | 24 | 27 | 32 | 36 | 41 |
| MHHW + 6 inch | 6 | 21 | 26 | 30 | 33 | 38 | 42 | 47 |
| MHHW +12 inch | 12 | 27 | 32 | 36 | 39 | 44 | 48 | 53 |
| MHHW +18 inch | 18 | 33 | 38 | 42 | 45 | 50 | 54 | 59 |
| MHHW +24 inch | 24 | 39 | 44 | 48 | 51 | 56 | 60 | 65 |
| MHHW +30 inch | 30 | 45 | 50 | 54 | 57 | 62 | 66 | 71 |
| MHHW +36 inch | 36 | 51 | 56 | 60 | 63 | 68 | 72 | 77 |
| MHHW +42 inch | 42 | 57 | 62 | 66 | 69 | 74 | 78 | 83 |
| MHHW +48 inch | 48 | 63 | 68 | 72 | 75 | 80 | 84 | 89 |
| MHHW +54 inch | 54 | 69 | 74 | 78 | 81 | 86 | 90 | 95 |
| MHHW +60 inch | 60 | 75 | 80 | 84 | 87 | 92 | 96 | 101 |
| **HYDRODYNAMIC ZONE 3** | | | | | | | | |

*Source: Alameda County Flood Control and Water Conservation District and BCDC, 2015.* [47]

## Temperature and Precipitation

Temperature and precipitation projections were derived from a statistically downscaled Bias Corrected Constructed Analog (BCCA) dataset,[48] from which Four Twenty Seven extrapolated temperature and precipitation indices. Statistically downscaled data was used to better represent local conditions, and an ensemble of 19 global circulation models was used to reduce individual model uncertainties. Probabilistic estimates were generated for extreme indicators using Gaussian distribution, with the most likely value falling between the 25th and 75th percentiles. For indicators showing changes to average precipitation and temperature, an envelope-based approach was used by bounding the range of models based on their departure from the historical mean. Temperature and precipitation indicators have been parametrized to show future trends in terms of averages and extremes at the city-level (approximately 12 x 12 km). All future values (2020-2060) were amended with probabilistic estimates and compared to a historical baseline (1970-2000).

The historical baseline is a climate model history intended to capture climate conditions experienced from 1970-2000, but not to predict the weather conditions on any given day, month, or year. For this baseline period, the climate models were run with an emissions scenario representative of the observed history from those past years but with the same physics and configurations as in future-year runs. This

[47] Alameda County Flood Control and Water Conservation District and BCDC. (2015). *Adapting to Rising Tides: Alameda County Shoreline Vulnerability Assessment Final Report.*

[48] Reclamation. (2013). 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado.

enables comparison of like historical and future model data to better establish the magnitude of likely future changes.

The models used scenarios from the IPCC. The RCP 8.5 represents the most minimal greenhouse gas mitigation effort and high emissions, resulting in the largest increase in radiative forcing and warming, while RCP 4.5 is considered a moderate greenhouse gas mitigation scenario where climate action limits the amount of global emissions.[49]

## Rainfall Induced Landslides

The USGS conducted a survey of landslide risk in the San Francisco Bay Area leading up to the 1997-1998 El Niño event. Today, these maps are used to predict future landslides since these events are generally believed likely to occur within and around the places where they have previously taken place.[50] Geographic locations are assigned risk based on a five-point scale from surficial deposits (low risk) to mostly landslide (high risk). Areas which have experienced few landslides have a mid-level risk for landslide events.

## Wildfires

CAL FIRE produces Fire Hazard Severity Zone maps to determine the potential exposure of wildland and urban properties to wildfire based on vegetation, topography, and dangerous fire characteristics such as crown fire potential and ember production and movement. Fire hazard is a metric for determining physical fire behavior in order to predict the amount of damage a fire in a certain location is likely to cause and is classified as Very High, High or Moderate. The Fire Hazard Severity Zones are based on the evaluation of the likelihood that an area will burn and how, without consideration of the risk for property damage.[51]

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[49] IPCC. (2014). Scenario Process for AR5. Accessed at: http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html
[50] Pike, R.J. (1997). San Francisco Bay Region Landslide Folio Part D. USGS. Accessed at: http://pubs.usgs.gov/of/1997/of97-745/of97-745d.html
[51] CalFIRE. Wildland Hazard and Building Codes: Fire Hazard Severity Zone Development. Accessed at: http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development

# Appendix B: Calculated Priority Risk Index

The Calculated Priority Risk Index in Figure B1 is informed by FEMA's guidelines for comparing hazards, as described in the *Local Mitigation Planning Handbook* (2013). The focus here, based on available data, is on the types of assets exposed to a given hazard and the magnitude of the impact. The rankings for types of assets exposed to a given hazard are: low – only assets that will not compound hazard effects or that are replaceable are subject to the hazard, medium – important assets or those that could lead to secondary hazards if damaged are subject to the hazard, and high – critical assets that could lead to immediate secondary hazards if damaged are subject to the hazard. For magnitude, the rankings are: low – no critical assets are affected, medium – some critical assets and/or a large number of important assets are affected, and high – several critical assets are affected.

FEMA defines critical facilities as "all public and private facilities deemed by a community to be essential for the delivery of vital services, protection of special populations, and the provision of other services of importance for that community."[52] This includes emergency response facilities, healthcare facilities, transportation infrastructure, schools, emergency shelters, utilities, communications facilities and other assets important to maintaining the health and safety of city residents.

Figure B1. Calculated Priority Risk Index[53]

| Hazard | Types of Assets Exposed to Hazard | Magnitude | Rank |
|---|---|---|---|
| Inland flooding | H | M | H |
| Wildfires | M | H | H |
| Sea level rise | M | M | M |
| Temperature change | M | M | M |
| Rainfall-Induced Landslides | H | L | M |
| Precipitation Change | L | L | L |

[52] FEMA. (2007). *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings,* FEMA 543. Accessed at: https://www.fema.gov/media-library/assets/documents/8811
[53] FEMA. (2013). Local Mitigation Planning Handbook.