SECTION 4. RISK ASSESSMENT

4.2 Climate Change and Sea Level Rise

2018 HMP UPDATE CHANGES

- This profile now includes climate change with enhanced discussion and analysis on sea level rise. It has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, and probability of future occurrence for chronic coastal flooding and event-based coastal flooding.
- New and updated statistics and figures from federal, state, academic, and local agencies are incorporated.

4.2.1 Hazard Profile

Climate is defined as long-term averages and variations in weather measured over a period of time. A change in the state of the climate can be identified by changes in the mean and/or variability of its properties that persist for an extended period of time, typically decades or longer. Key indicators of the changing climate include rising carbon dioxide in the atmosphere, rising air and sea temperatures, rising sea levels and upper-ocean heat content, changing ocean chemistry and increasing ocean acidity, changing rainfall patterns, decreasing base flow in streams, changing wind and wave patterns, changing extremes, and changing habitats and species distributions (State of Hawai'i 2018).

Climate Change

A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer (IPCC 2007).

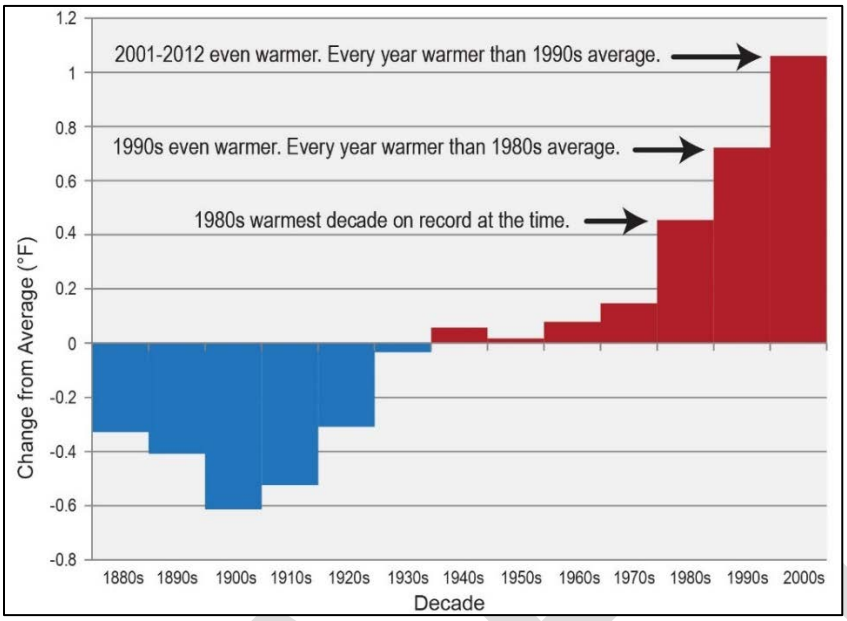
This section provides general information on the climate change hazard with an enhanced discussion on sea level rise. Chronic coastal flooding is discussed in Section 4.1 (Chronic Coastal Flood), flooding caused by dam failure is discussed in Section 4.3 (Dam Failure), event based flooding is discussed in Section 4.6 (Event-Based Flood), and storm surge is discussed in Section 4.10 (Hurricane).

HAZARD DESCRIPTION

Climate Change

In the last century, air temperatures have increased between one-half and one degree Fahrenheit (˚F). Figure 4.2-1 shows the last five decades of the Earth's average temperatures and how it is has increased each decade since the 1880s.

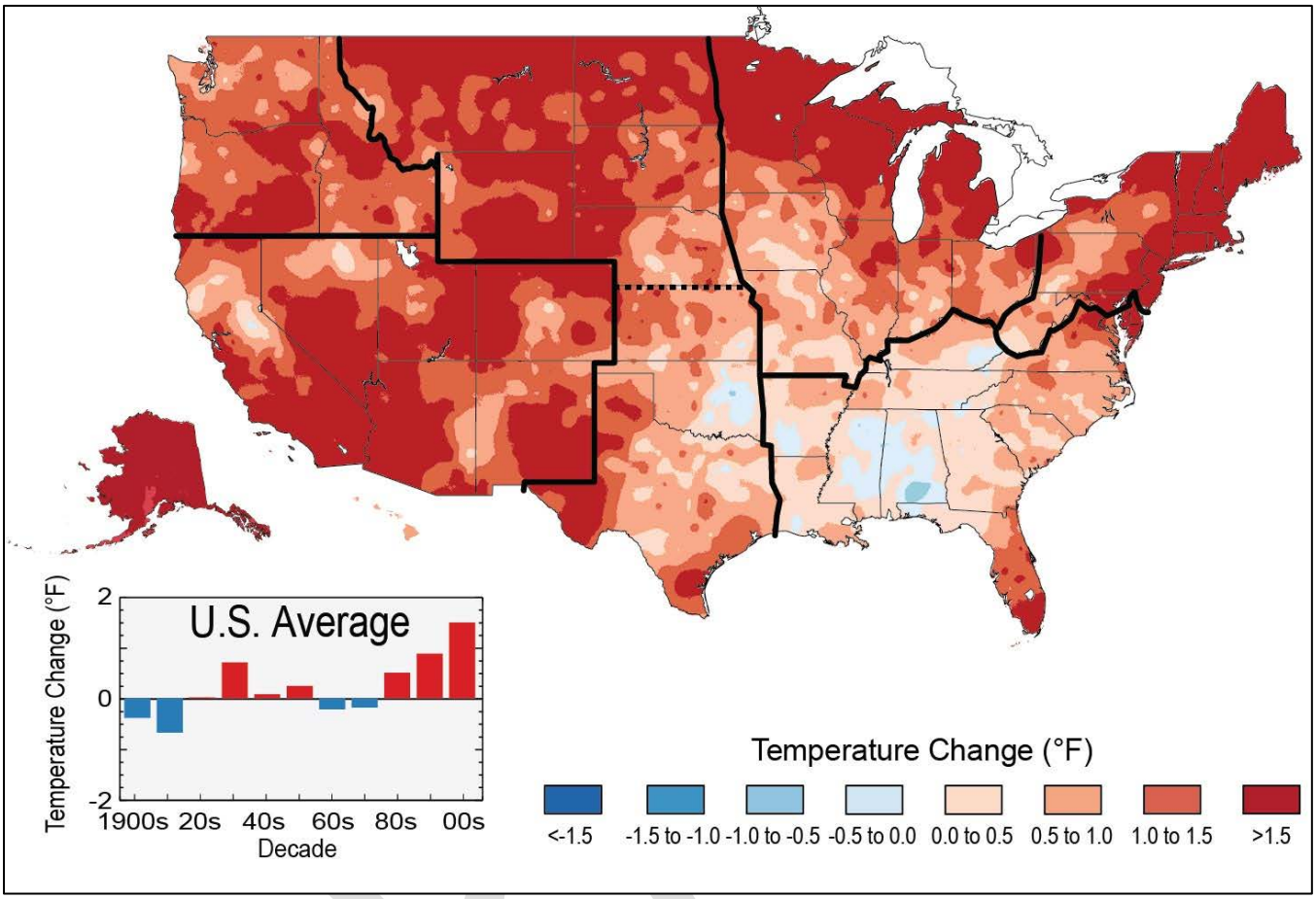
Figure 4.2-1. Global Temperature Change



Source: National Climate Assessment 2014

The planet’s average surface temperature has risen largely due to increased carbon dioxide and other human-made emissions into the atmosphere. Most of the warming occurred in the past 35 years, with 16 of the 17 warmest years on record occurring since 2001. Figure 4.2-2 shows temperature changes across the United States over the past 22 years, from 1991 to 2012, compared to the 1901 to 1960 average for the contiguous United States, and the 1951 to 1980 average for Alaska and the State of Hawai‘i. The bars on the graph show the average temperature changes by decade from 1901 to 2012 (relative to the 1901 to 1960 average). The far-right bar (2000s decade) includes 2011 and 2012. The period from 2001 to 2012 was warmer than any previous decade in every region (National Climate Assessment 2014).

Figure 4.2-2. Observed U.S. Temperature Change



Source: National Climate Assessment 2014

In the State of Hawai‘i, its climate is changing in ways that are consistent with the influence of global warming. The State of Hawai‘i has experienced rising air temperatures; decreased rainfall and stream flow; increased rain intensity; increased sea level and sea surface temperatures; and acidification of the ocean.

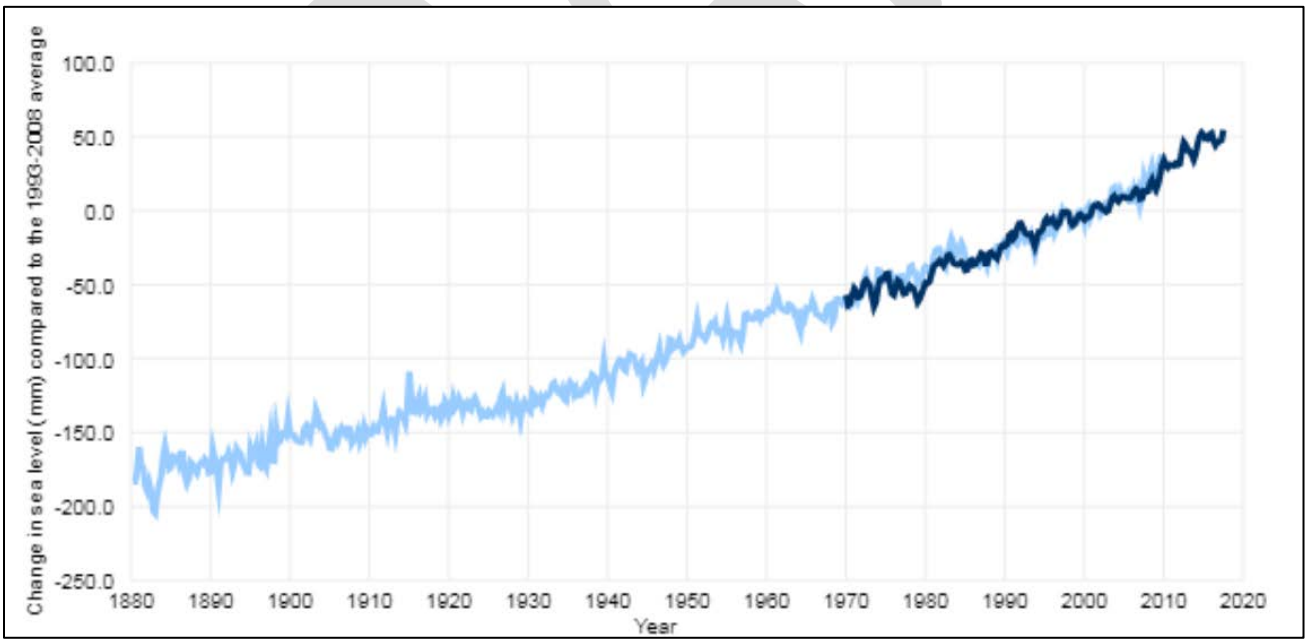
- **Surface Air Temperature**—Data has shown a rapid rise in air temperature in the past 30 years in the State of Hawai‘i, averaging 0.3°F per decade, with stronger warming at high elevations (above 2,600 feet). The rate of temperature rise at low elevations (below 2600 feet), 0.16°F per decade, is less than the global rate (about 0.36°F per decade). However, the rate of warming at high elevations in the State of Hawai‘i, 0.48°F per decade, is faster than the global rate.
- **Rainfall and Stream Discharge**—The State of Hawai‘i has seen an overall decline in rainfall in the last 30 years, with widely varying precipitation patterns on each island. Projections show that the State of Hawai‘i will see more drought and heavy rains. A decline in overall precipitation totals have caused a decrease in stream base flow, which may reduce aquifer discharge and freshwater supplies. This may also influence aquatic and riparian ecosystems and agriculture.

- **Rain Intensity**—Between 1958 and 2007, the amount of rain falling in the very heaviest downpours has increased by approximately 12%. These heavy rain events may lead to more flash flooding, damage to infrastructure, runoff, and sedimentation.
- **Sea Level**—Refer to the following subsection for information on sea level changes in the State of Hawai‘i.
- **Sea Surface Temperature**—At Station ALOHA, marine researchers at the University of Hawai‘i and cooperating institutions have measured an increase of sea surface temperature of 0.22°F per decade. With climate change impacts, this rate is likely to increase, potentially exposing coral reefs and other marine ecosystems to negative impacts related to increased temperatures including coral bleaching.
- **Ocean Acidification**—Rising carbon dioxide in the atmosphere mixes with seawater, causing the ocean to acidify. Measurements at Station ALOHA over the last 20 years have documented that the surface ocean around the State of Hawai‘i has grown more acidic (University of Hawai‘i at Mānoa Sea Grant College Program 2014; Fletcher 2010).

Sea Level Rise

Global mean sea level rise has been observed over the last century in tide station data from around the world and, more recently, in satellite-based ocean height measurements. The rate of global sea level rise has accelerated over the past century, as seen in Figure 4.2-2, and global mean sea level has risen by 8 to 9 inches since 1880, with a third of that rise occurring since 1993 (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017; Lindsey 2017).

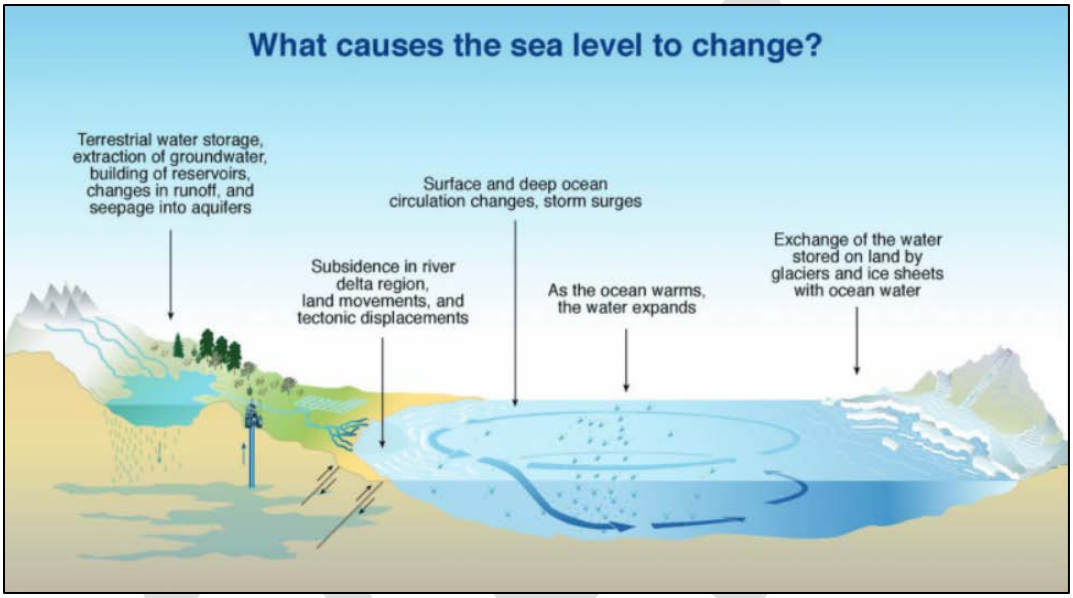
Figure 4.2-3. Global Sea Level Since 1880



Source: Lindsey 2017
Notes: The light blue line shows seasonal (3-month) sea level estimates from Church and White (2011). The darker line is based on University of Hawai‘i Fast Delivery sea level data.
mm Millimeter

There are two types of sea level rise: global and relative (local). Global sea level rise refers to the increase currently observed in the average global sea level trend. This is primarily attributed to changes in ocean volume due to ice melt and thermal expansion. The melting of glaciers and continental ice masses can contribute significant amounts of freshwater input to the earth’s oceans. In addition, a steady increase in global atmospheric temperature creates an expansion of salt water molecules, increasing ocean volume (NOAA Tides & Currents 2018).

Figure 4.2-4. Causes of Sea Level Change



Source: U.S. Climate Resilience Toolkit 2015

Relative (or local) sea level is affected by global sea level fluctuations, changes in land elevation, winds, and ocean circulation. It refers to the height of the water as measured along the coast relative to a specific point on land. Tide stations measure local sea level rise. Water measurements at the tide stations are referenced to stable vertical points on the land and a known relationship is established. Measurements at any given tide station include both global sea level rise and vertical land motion (subsidence, glacial rebound, or large-scale tectonic motion). Since the heights of both the land and water change, the land-water interface can vary spatially and temporally and must be defined over time. Depending on the rates of vertical land motion relative to changes in sea level, observed local sea level trends may differ greatly from the average rate of global sea level rise, and vary widely from one location to the next. Relative sea level trends reflect changes in local sea levels over time and are typically the most critical sea level trend for many coastal applications, including coastal mapping, marine boundary delineation, coastal zone management, coastal engineering, sustainable habitat restoration design, and the general public enjoying their favorite beach (NOAA Tides & Currents 2018).

Rising sea level and projections of stronger and more frequent El Niño events and tropical cyclones in waters surrounding the State of Hawai‘i all indicate a growing vulnerability to coastal flooding and erosion (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017; EPA 2018). Changing sea levels can affect human activities in coastal areas. The rising sea level inundates low-lying wetlands and dry land, erodes shorelines,

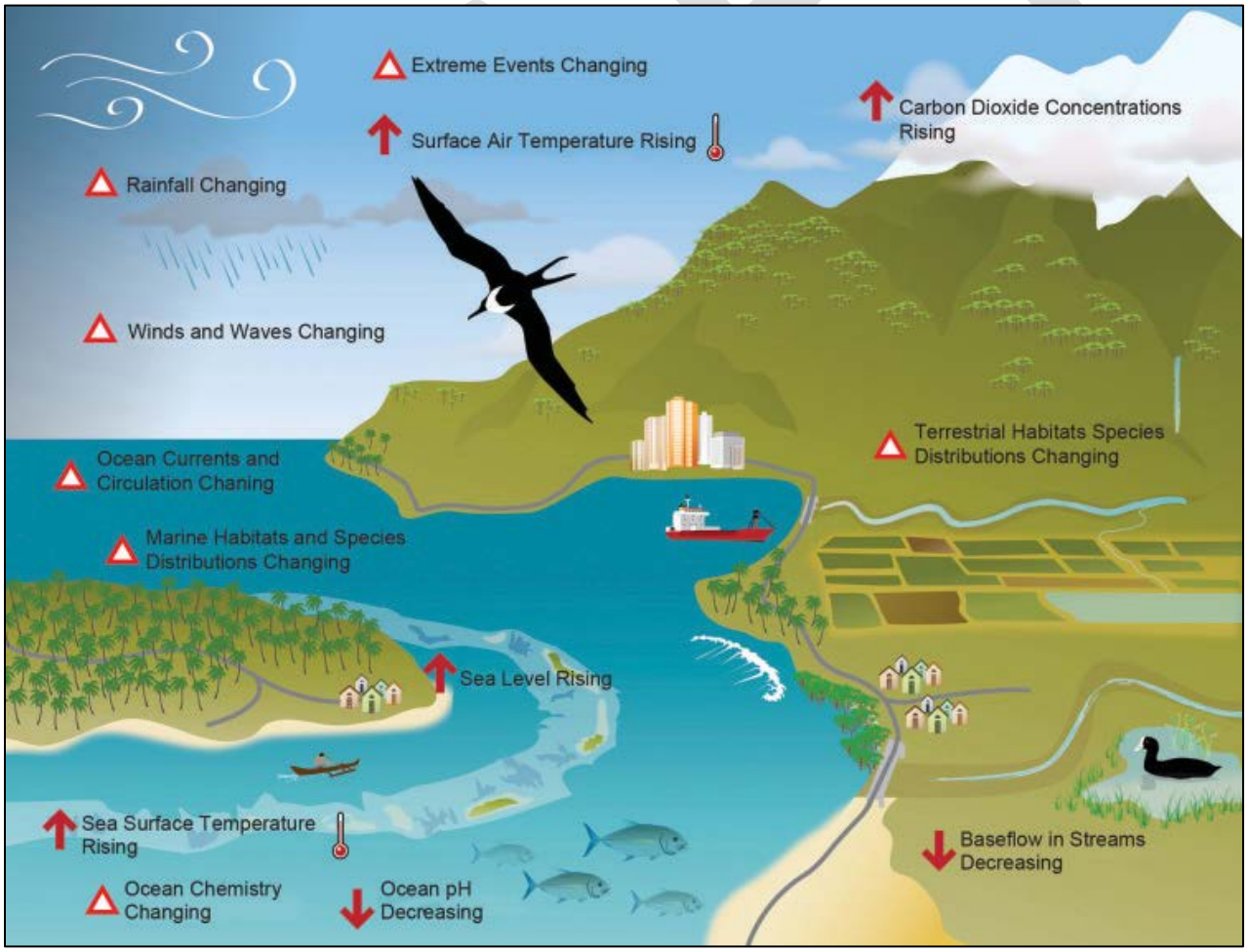
contributes to coastal flooding, and increases the flow of salt water into estuaries and nearby groundwater aquifers. Coastal areas become more vulnerable to damage from storms as well (EPA 2018).

LOCATION

The State of Hawai'i is experiencing climate change and sea level rise impacts in unique, region-specific ways. For example, the rapid acceleration observed in globally averaged rates of sea-level rise has not yet been observed in local sea-level data for the County of Hawai'i, whereas the Island of Oahu's daily temperature range is changing much more rapidly than the global mean. Climate change and sea level rise can impact marine ecosystems, coasts and the built environment, terrestrial ecosystems, freshwater resources, and human health. Some of these impacts have already been observed while others are projected to manifest in the coming years (University of Hawai'i at Mānoa Sea Grant College Program 2014).

Climate change will continue to be felt from the upper reaches of each island to the sea and throughout the entire archipelago including the main Hawaiian Islands and Northwestern Hawaiian Islands. Figure 4.2-5 shows the key indicators of climate change in the Hawaiian Islands and the relative location of these changes.

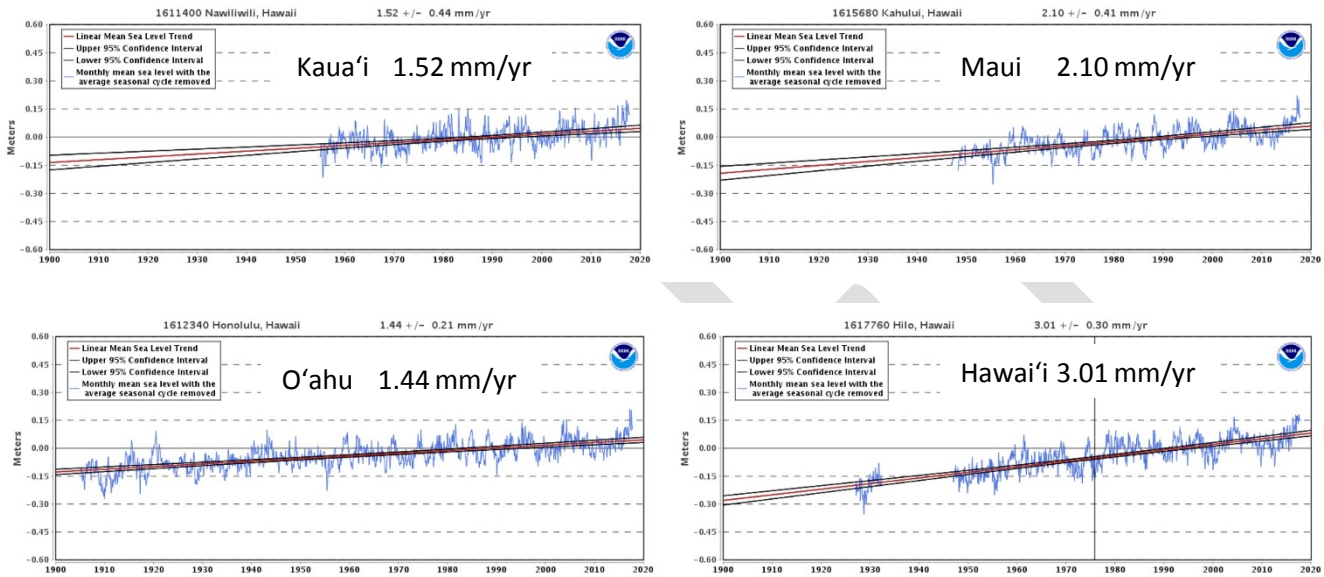
Figure 4.2-5. Indicators of Climate Change in the Pacific Islands Region



Source: National Climate Assessment 2014

The local relative rates of sea level rise vary among the Hawaiian Islands due to varying rates of subsidence along the volcanic island chain and possibly, in part, due to oceanic variability. As seen in Figure 4.2-5, the relative rate of sea level rise on the Island of Hawai‘i is almost twice the rate on the Island of Kaua‘i. This is due to the fact that the Island of Hawai‘i is slowly subsiding as it gains mass from active volcanoes, resulting in a higher relative rate of sea level rise while the Islands of Kaua‘i and O‘ahu, which are older islands, are relatively stable (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017; NOAA 2018).

Figure 4.2-6. Observed Mean Sea Level Rise Trends and Rates of Rise in the Hawaiian Islands



Source: NOAA 2018
Notes: mm/y Millimeters per year
NOAA National Oceanic and Atmospheric Administration

Modeling was conducted using the best available data and methods to determine the potential future exposure of the State of Hawaii to multiple coastal hazards as a result of sea level rise (Hawai‘i Climate Mitigation and Adaptation Commission 2017*)*. Chronic and event-based coastal flooding were modeled using the IPCC worst case scenario of 3.2 feet of sea level rise by the year 2100. As noted in the 2017 *Hawaii Sea Level Rise Vulnerability and Adaptation Report* and discussed in Section 4.2 (Chronic Coastal Flood), current or near-term exposure to coastal hazards is assessed using the Sea Level Rise Exposure Area with 1.1 feet of sea level rise (SLR-XA-1.1). To assess mid- to late century sea level rise on chronic coastal flooding, the Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLR-XA-3.2) is used for the 2018 HMP Update. These maps may be seen on the Hawai‘i Sea Level Rise Viewer.

The 1% annual chance coastal flood zone (V-zones, referred to as the 1%CFZ) will expand with sea level rise meaning that more land area will be exposed to damaging wave impacts from a 100-year flood event. The 1%CFZ with 3.2 feet of sea level rise (1%CFZ-3.2) was utilized to assess mid- to late century sea level rise on coastal event-based flooding. It is important to note that the event-based flood hazard discussed in Section 4.6 assesses the entire Special Flood Hazard Area (V- and A-zones). Sea level rise on event-based flooding only includes the coastal V-zone with sea level rise. The 1%CFZ-3.2 areas are shown in Figure 4.2-6 through Figure 4.2-9.

Table 4.2-1 shows the estimated square miles of potential land loss/impact due to 3.2 feet of sea level rise for each County. The State's total potential lost area due to chronic coastal flooding with seal level rise will amount to an estimated 0.5% of the State's total land area; however, it comprises of some of the most developed and valued land. When examining the 1% annual chance coastal flood event with 3.2 feet of sea level rise, 1.7% of the State's land will be impacted. The City and County of Honolulu, with its expansive coastal plains, will have the most land unusable due to sea level rise, followed by the Counties of Kaua'i and Maui.

Summary of Key Terms

SLR-XA – *The SLR-XA represents the area exposed to chronic coastal flooding and land loss based on modeling of passive flooding, annual high wave flooding and coastal erosion (refer to Section 4.0 for further details).*

Chronic Coastal Flood – *The SLR-XA with 1.1 feet of sea level rise (SLR-XA-1.1) approximates current or near-term exposure to chronic coastal flooding discussed in Section 4.2.*

SLR-XA-3.2 – *The SLR-XA with 3.2 feet of sea level rise was used to assess mid- to late century exposure to chronic coastal flooding.*

Event-Based Flood – *The 1% annual chance flood as depicted on the FEMA Flood Insurance Rate Maps, also known as the Special Flood Hazard Area (inclusive of V- and A-zones), was assessed in Section 4.6.*

1%CFZ-3.2 –*The 1% annual chance coastal flood zone (V zones only) with 3.2 feet of sea level rise was used to assess mid- to late century event-based coastal flooding.*

Table 4.2-1. Sea Level Rise Hazard Areas by County

County	Area				
	Total Area (square miles)	SLR-XA-3.2 (square miles)	SLR-XA-3.2 as % of Total Area	1%CFZ-3.2 (square miles)	1%CFZ-3.2 Area as % of Total Area
County of Kaua'i	630.3	8.8	1.4%	32.8	5.3%
City and County of Honolulu	600.2	13.0	2.2%	41.2	6.9%
County of Maui	1,174.6	7.8	0.7%	15.7	1.3%
County of Hawai'i	4,027.8	4.3	0.1%	19.4	0.5%
Total	**6,432.9**	**33.9**	**0.5%**	**109**	**1.7%**

Source: State of Hawai'i GIS layers, State of Hawai'i GIS Program Geospatial Data Portal; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Note: Total area for each County calculated using coastline spatial layer downloaded from State of Hawai'i GIS Program Geospatial Data Portal

GIS Geographic Information System

SLR-XA-3.2 Sea Level Rise Exposure Area with 3.2 feet of sea level rise.

1%CFZ-3.2 1% Annual Chance Coastal Flood with 3.2 feet of sea level rise (V-zones only).

Figure 4.2-7. 1% Annual Chance Coastal Flood Event with 3.2-feet of Sea Level Rise (1%CFZ-3.2) for the County of Kaua‘i

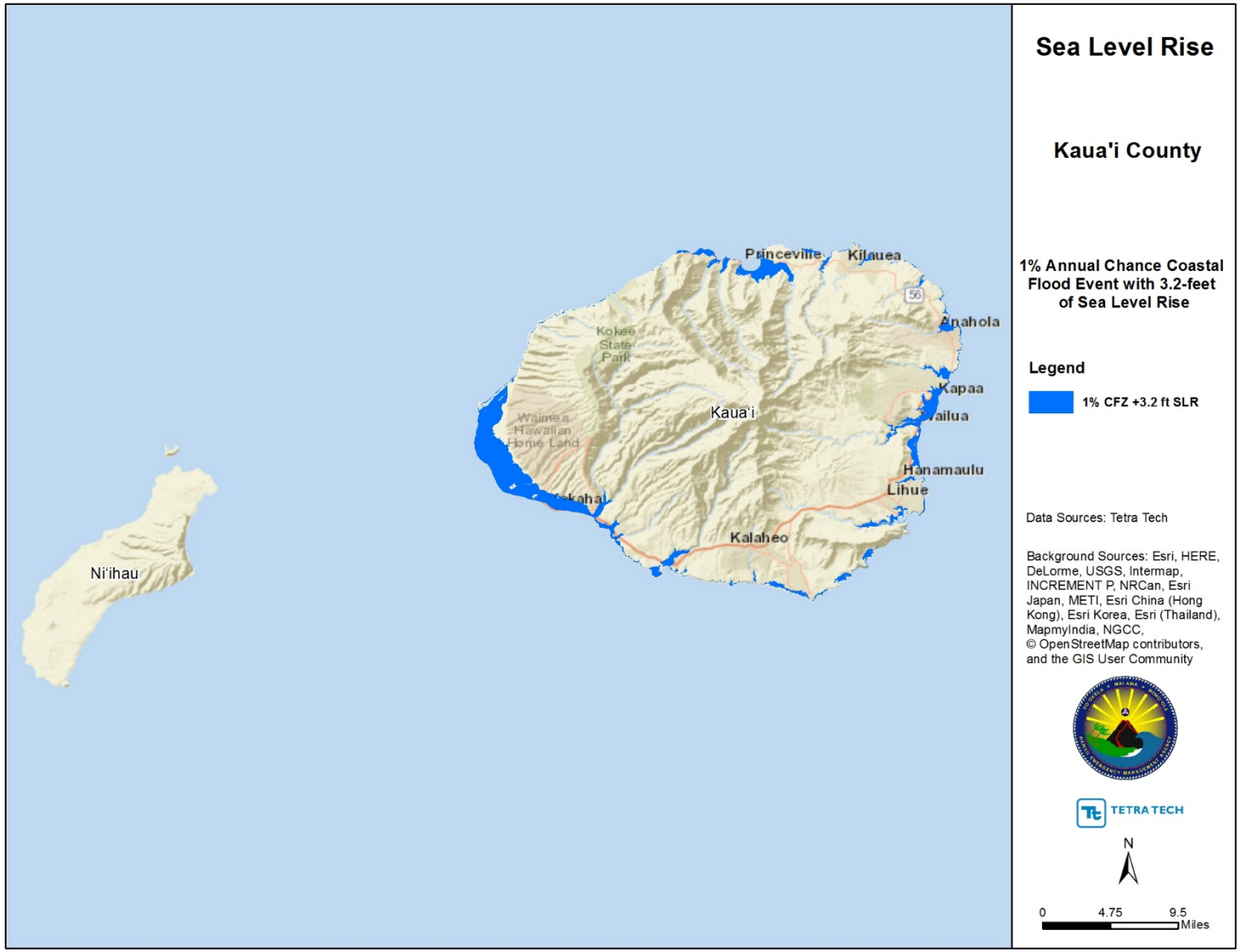


Figure 4.2-8. 1% Annual Chance Coastal Flood Event with 3.2-feet of Sea Level Rise(1%CFZ-3.2) for the City and County of Honolulu

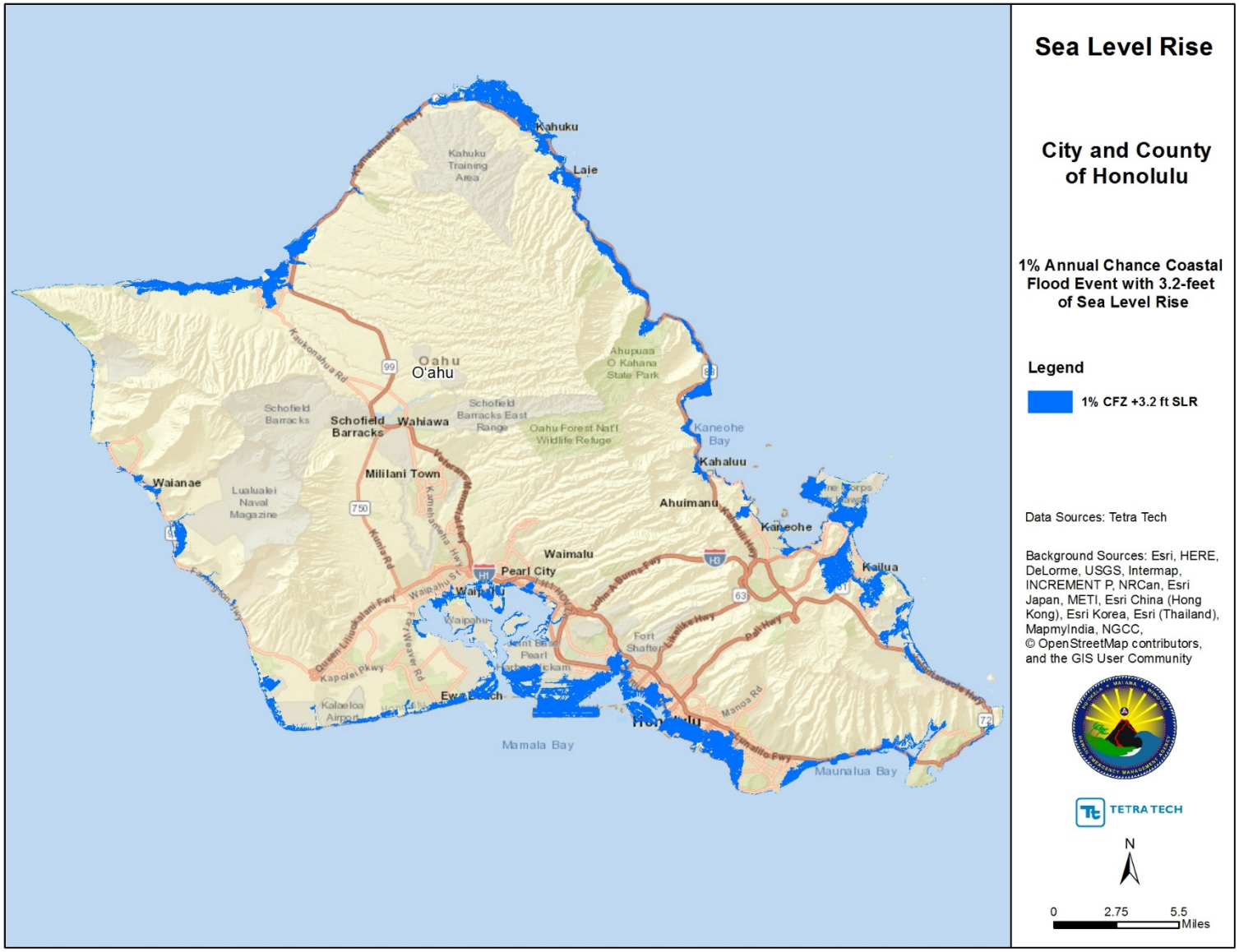


Figure 4.2-9. 1% Annual Chance Coastal Flood Event with 3.2-feet of Sea Level Rise (1%CFZ-3.2) for the County of Maui

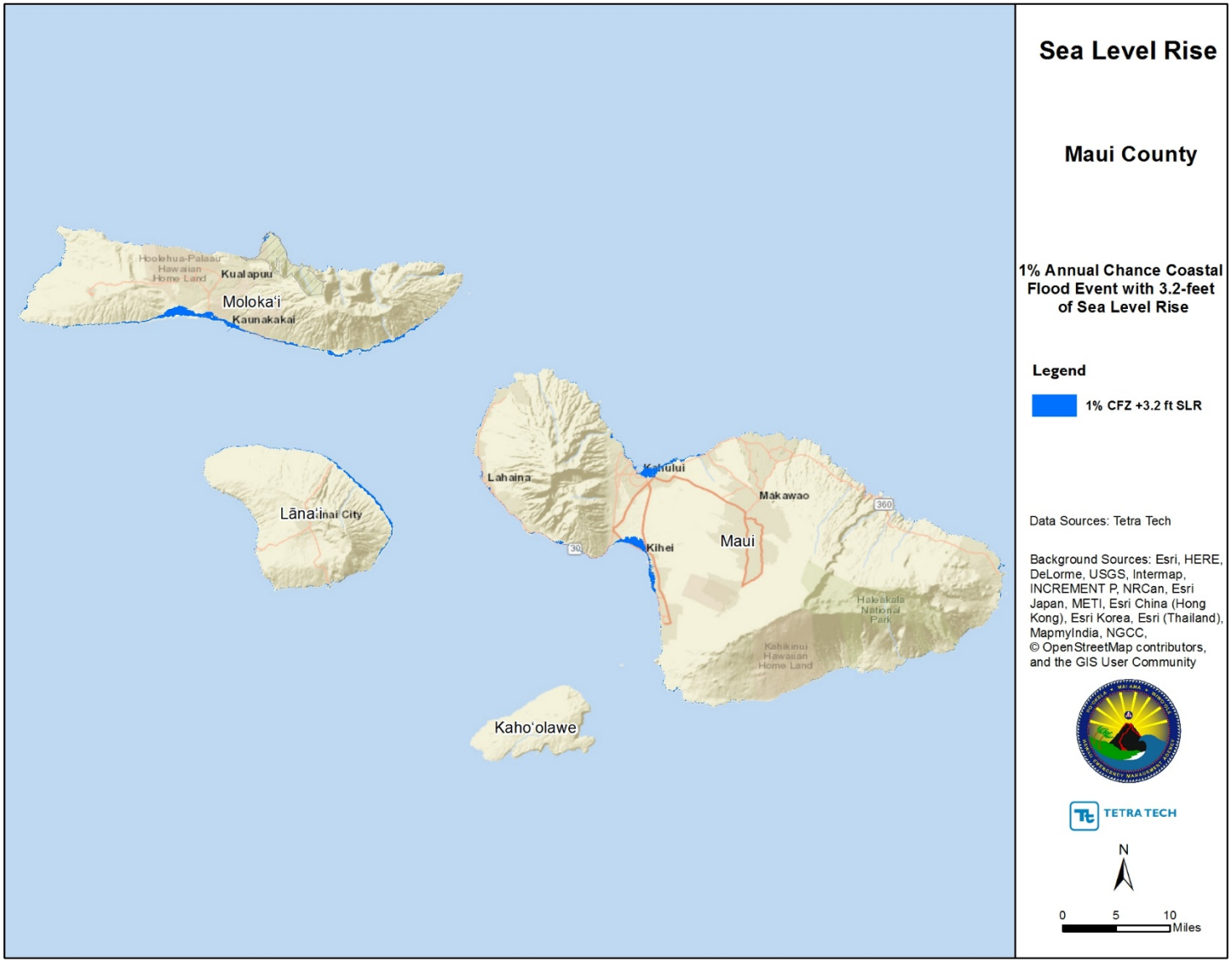
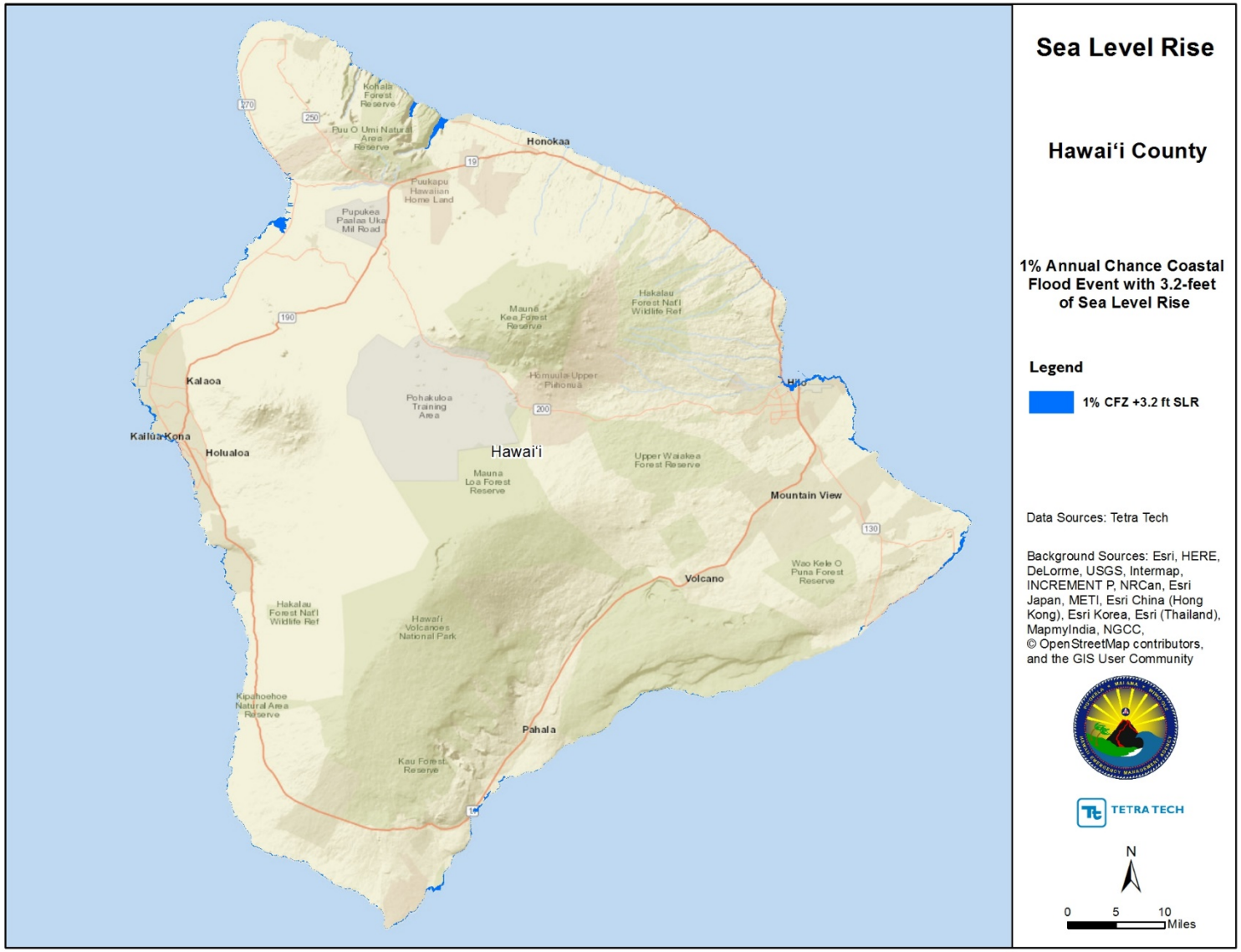


Figure 4.2-10. 1% Annual Chance Coastal Flood Event with 3.2-feet of Sea Level Rise(1%CFZ-3.2) for the County of Hawai‘i



EXTENT

Climate Change

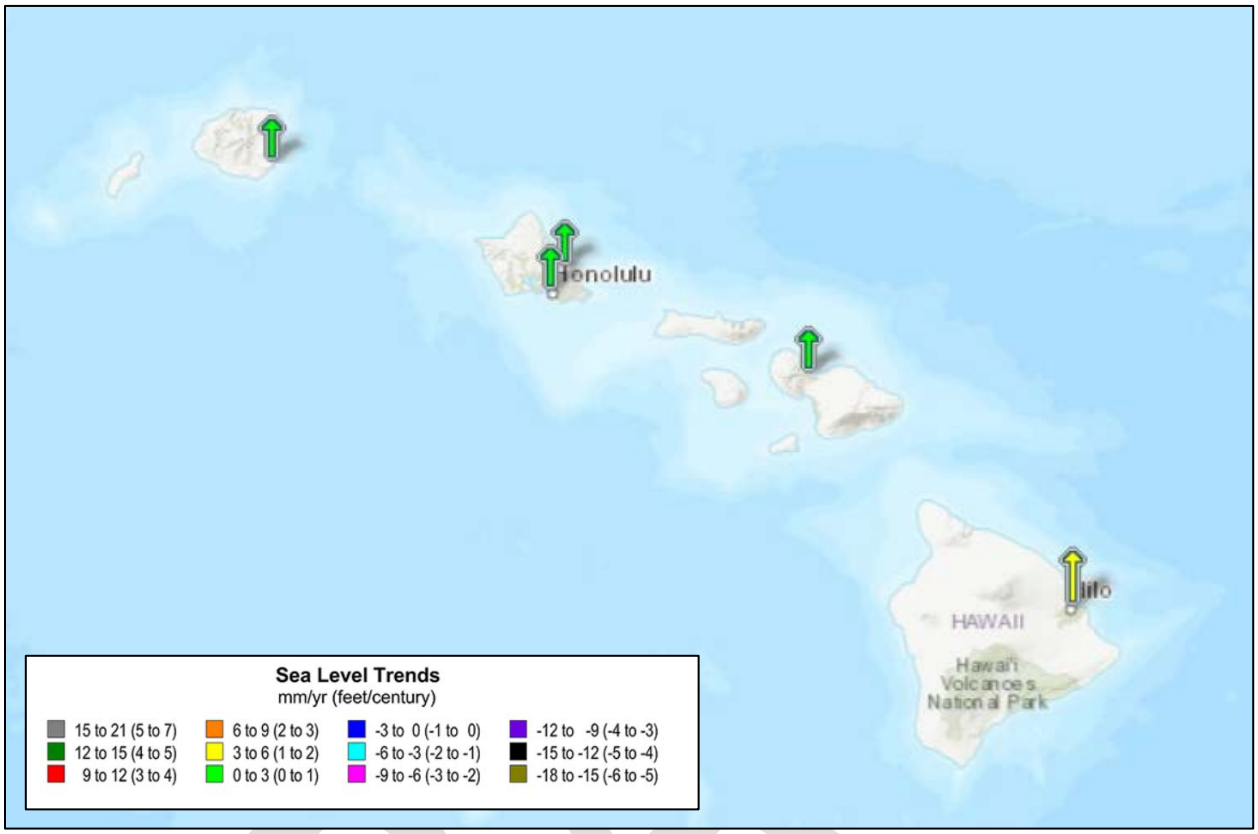
Increasing temperatures, and in some areas reduced rainfall, will stress native plants and animals, especially in high-elevation ecosystems with increasing exposure to invasive species, increasing the risk of extinctions (Leong et al 2014). Freshwater supplies are already constrained and will become more limited on many Hawaiian Islands (Leong et al 2014). Saltwater intrusion associated with sea level rise will reduce the quantity and quality of freshwater in coastal aquifers, especially on low islands. In areas where precipitation does not increase, freshwater supplies will be adversely affected as the air temperature rises.

Sea Level Rise

Rising sea levels, coupled with high water levels caused by storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism (Leong et al 2014). Global average sea levels are expected to continue to rise—by at least several inches in the next 15 years and by 1 to 4 feet by 2100. A rise of as much as 8 feet by 2100 cannot be ruled out (Wuebbles et al. 2017).

Sea level is measured by two main methods: tide gauges and satellite laser altimeters. Tide gauge stations from around the world have measured the daily high and low tides for over a century. Using data from these stations, scientists can calculate a global average of change. Since the early 1990s, the sea level has been measured from space using laser altimeters. This method determines the height of the sea surface by measuring the return speed and intensity of a laser pulse directed at the ocean. The higher the sea level, the faster and stronger the return signal (Lindsey 2017). Figure 4.2-10 illustrates the regional trends in sea level rise for the State of Hawai'i. The arrows represent the direction and magnitude of change. Sea level trends in the State of Hawai'i are on the rise and range between 0 millimeters per year (mm/yr) to 6 mm/yr. Table 4.2-2 discusses these changes for the State of Hawai'i.

Figure 4.2-11. Sea Level Trends in the State of Hawai‘i



Source: NOAA 2018
Notes: mm/year millimeter per year
NOAA National Oceanic and Atmospheric Administration

Table 4.2-2. Linear Mean Sea Level Trends and 95% Confidence Intervals

Station Name	First Year	Year Range	MSL Trend (mm/year)	+/- 95% Confidence Interval	Equivalent To
Nāwiliwili	1955	61	1.52	0.44	0.50 feet in 100 years
Mokuolo‘e	1957	59	1.26	0.52	0.14 feet in 100 years
Honolulu	1905	111	1.44	0.21	0.47 feet in 100 years
Kahului	1947	69	2.1	0.41	0.69 feet in 100 years
Hilo	1927	89	30.1	0.3	0.99 feet in 100 years

Source: NOAA 2018
Notes mm/year millimeter per year
MSL Mean Sea Level

Previous Occurrences and Losses

The sea level has been rising in the State of Hawai‘i for the past century or more (refer to Figure 4.1-3). Rates of rise vary amongst the islands due to differing rates of subsidence based on distance from actively-growing Island

of Hawai‘i. Rates of sea level rise in the State of Hawai‘i ranged from 0.6 inches on the Islands of O‘ahu and Kaua‘i, to 1.3 inches on the Island of Hawai‘i per decade over the last century. Other observations related to climate change and sea level rise in the State of Hawai‘i include 70% of the beaches in the State of Hawai‘i have eroded and over 13 miles of beach have been completely lost to erosion over the past century. This dominant trend of beach erosion could be driven by local sea level rise. Additionally, shoreline retreat, averaging one-foot per year statewide, wetland migration, and cliff collapse due to erosion are occurring now on many of the coastlines in the State of Hawai‘i. Elevated groundwater tables, due in part to sea level rise, are contributing to chronic coastal flooding and flooding from heavy rainfall events (University of Hawai‘i at Mānoa Sea Grant College Program 2014).

Probability of Future Hazard Events

The State of Hawai‘i is currently experiencing the impacts of climate change: surface temperatures are rising, rainfall and stream flow have decreased, rain intensity is increasing, sea level and sea surface temperatures have increased and the ocean is acidifying. It is anticipated that these trends will continue causing further increases in temperature, extreme variation in precipitation (resulting in droughts or flooding), potential changes in storm systems (possibly more frequent or increased magnitude), and continued rise in sea levels, impacting the State of Hawaii’s water resources and forests, coastal communities, and marine ecology (Fletcher 2010).

As global temperatures continue to increase, sea level will also continue to rise. The rate of future carbon dioxide emissions and future climate change determines how much the sea level will rise. The speed at which it rises depends mostly on the rate of glacier and ice sheet melting (Lindsey 2017). The sea level is projected to rise 3.2 feet by year 2060 and impacts are assessed further in the Vulnerability Assessment below (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017). In summary consequences of sea level rise for the State of Hawai‘i are severe compared to many other coastal states, as the majority of the population, public infrastructure, and economic sectors exist on low-lying coastal plains which are highly susceptible to coastal hazards (State of Hawai‘i 2018).

The impacts of El Niño may exacerbate the consequences of sea level rise. El Niño events in the tropical Pacific Ocean can cause sea levels to rise 6 to 12 inches above mean conditions in some areas (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017).

4.2.2 Vulnerability Assessment

A statewide sea level rise exposure analysis was conducted for two flood scenarios, chronic coastal flooding and event-based coastal flooding with 3.2-feet of sea level rise. The data used was generated for the Hawai‘i Climate Mitigation and Adaptation Commission. Overall, vulnerability to SLR-3.2 is the potential permanent loss of assets and displacement of population located in the SLR-XA-3.2 hazard area. Land that is flooded in the 1%CFZ-3.2 is not considered ‘lost’, because it is assumed the flooding is temporary and the floodwaters

Sea Level Rise Hazard Area Definitions

SLR-XA-3.2 – *To assess chronic coastal flood with mid- to late century sea level rise, the SLR-XA with 3.2 feet of sea level rise was used. The hazard area is called SLR-XA-3.2.*

1%CFZ-3.2 –*To assess the 1% annual chance coastal flood in mid- to late century, the 1% annual chance coastal flood (V-zones only) with 3.2 feet of sea level rise was used. The hazard area is called 1%CFZ-3.2.*

would recede. However, buildings and natural resources on that land may be damaged or destroyed as a result the event. Therefore, vulnerability to the 1%CFZ-3.2 is the potential damage to assets as a result of the event-based coastal flooding exacerbated by sea level rise.

Assessment of State Vulnerability and Potential Losses

This section discusses statewide vulnerability of exposed state assets (state buildings and state roads) and critical facilities to the climate change and sea level rise hazards.

State Assets

Across the State, there are 55 state buildings that may be compromised or lost due to sea level rise (SLR-XA-3.2). Almost all of these buildings are located in the City and County of Honolulu (52 of the 55 buildings with a replacement cost value of $55 million). Only replacement cost value was available for state buildings and reported as the total economic loss. However, a more accurate reflection of loss to the SLR-XA-3.2 hazard would be the combined value of the land and structure.

Table 4.2-3 summarizes the state buildings located in the SLR-XA-3.2 by county. The Department of Education has the greatest number of buildings (37) in the SLR-XA-3.2 hazard area as seen in Table 4.2-4. The loss of these structures may result in the interruption and/or relocation of state services if they remain in their present locations. Appendix X summarizes the state buildings by state agency.

Table 4.2-3. Estimated State Building Loss from Sea Level Rise (SLR-XA-3.2) by County

County	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-3.2	Percent (%) of Total Buildings	Total Value of State Buildings in SLR-XA-3.2	Percent (%) of Total Value
County of Kaua'i	531	$957,679,537	1	0.2%	$219,408	0.02%
City and County of Honolulu	3,472	$16,750,785,426	52	1.5%	$55,249,138	0.3%
County of Maui	831	$2,862,316,819	2	0.2%	$370,372	0.01%
County of Hawai'i	1,261	$4,209,774,236	0	0.0%	$0	0.0%
Total	**6,095**	**$24,780,556,017**	**55**	**0.90%**	**$55,838,918**	**0.23%**

Source: Hawai'i State Risk Management Office 2017; 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report
Notes: Value Replacement Cost Value of state building; this does not include land value and may be underestimating the total loss.

Table 4.2-4. Estimated State Building Loss from Sea Level Rise (SLR-XA-3.2) by Agency

Agency	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-3.2	Percent (%) of Total Buildings	Total Value in SLR-XA-3.2	Percent (%) of Total Value
Dept of Accounting & General Services	66	$946,504,656	0	0.0%	$0	0.0%
Dept of Agriculture	70	$133,065,375	1	1.4%	$2,040,456	1.5%
Dept of Attorney General	15	$95,151,863	0	0.0%	$0	0.0%
Dept of Budget & Finance	16	$26,624,294	0	0.00%	$0	0.00%

Agency	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-3.2	Percent (%) of Total Buildings	Total Value in SLR-XA-3.2	Percent (%) of Total Value
Dept of Business, Economic Development and Tourism	25	$612,574,032	1	4.0%	$2,300,000	0.4%
Dept of Commerce & Consumer Affairs	2	$35,611,360	0	0.0%	$0	0.0%
Dept of Defense	69	$246,099,477	0	0.0%	$0	0.0%
Dept of Education	4,090	$9,604,111,443	37	0.9%	$16,732,208	0.2%
Dept of Hawaiian Home Lands	12	$100,471,477	1	8.3%	$4,748,597	4.7%
Dept of Health	44	$387,068,440	0	0.0%	$0	0.0%
Dept of Human Resources Development	1	$5,523,320	0	0.0%	$0	0.0%
Dept of Human Services	130	$420,004,555	2	1.5%	$2,839,820	0.7%
Dept of Labor and Industrial Relations	22	$79,322,626	0	0.0%	$0	0.0%
Dept of Land and Natural Resources	90	$98,666,185	8	8.9%	$1,195,202	1.2%
Dept of Public Safety	154	$427,884,909	0	0.0%	$0	0.0%
Dept of Taxation	1	$6,864,408	0	0.0%	$0	0.0%
Dept of Transportation	68	$2,912,510,888	1	1.5%	$3,368,912	0.1%
Hawai‘i State Ethics Commission	1	$891,212	0	0.0%	$0	0.0%
Hawai‘i Health Systems Corporation	106	$1,223,962,810	0	0.0%	$0	0.0%
Hawai‘i Housing Finance & Development Corporation	86	$333,526,064	0	0.0%	$0	0.0%
Hawai‘i Public Housing Authority	273	$933,255,767	1	0.4%	$5,340,000	0.6%
Hawai‘i State Legislature	2	$43,024,855	0	0.0%	$0	0.0%
Hawai‘i State Public Library System	53	$525,584,082	0	0.0%	$0	0.0%
Judiciary	41	$511,093,204	0	0.0%	$0	0.0%
Legislative Reference Bureau	1	$2,686,408	0	0.0%	$0	0.0%
Office of Hawaiian Affairs	11	$53,991,251	1	9.1%	$219,408	0.4%
Office of the Auditor	2	$1,789,788	0	0.0%	$0	0.0%
Office of the Governor	1	$2,686,408	0	0.0%	$0	0.0%

Agency	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-3.2	Percent (%) of Total Buildings	Total Value in SLR-XA-3.2	Percent (%) of Total Value
Office of the Lieutenant Governor	2	$3,977,640	0	0.0%	$0	0.0%
Office of the Ombudsman	1	$1,620,944	0	0.0%	$0	0.0%
Research Corporation of the University of Hawai'i	3	$3,713,497	0	0.0%	$0	0.0%
University of Hawai'i	637	$5,000,692,783	2	0.3%	$17,054,314	0.3%
Total	**6,095**	**$24,780,556,017**	**55**	**0.9%**	**$55,838,918**	**0.2%**

Source: Hawai'i State Risk Management Office 2017; 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report
Note: Dept Department
Value Replacement Cost Value of state building; this does not include land value and may be underestimating the total loss.

Event-based coastal flooding from waves generated by infrequent but severe storms and other coastal hazards could occur at any time but will be exacerbated by sea level rise. There are 642 state buildings located in the 1%CFZ-3.2 area; of which the majority are in the City and County of Honolulu (454 buildings with a replacement cost value of $1.745 billion). Table 4.2-5 summarizes the state buildings located in the 1%CFZ-3.2 area by county. The Department of Education occupies the greatest number of buildings (392) that may be impacted as seen in Table 4.2-6.

Table 4.2-5. State Buildings Located in the 1%CFZ-3.2 by County

County	Total Number of State Buildings	Total Replacement Cost Value	Number of State Buildings Exposed	Percent (%) of Total Buildings	Total RCV Exposed	Percent (%) of Total RCV
County of Kaua'i	531	$957,679,537	112	21%	$190,039,468	20%
City and County of Honolulu	3,472	$16,750,785,426	454	13%	$1,745,537,900	10%
County of Maui	831	$2,862,316,819	50	6%	$156,360,444	5%
County of Hawai'i	1,261	$4,209,774,236	26	2%	$107,083,808	3%
Total	**6,095**	**$24,780,556,017**	**642**	**11%**	**$2,199,021,620**	**9%**

Source: Hawai'i State Risk Management Office 2017; 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report
Notes: RCV Replacement Cost Value

Table 4.2-6. State Buildings Located in the 1%CFZ-3.2 by Agency

Agency	Total Number of State Buildings	Total Replacement Cost Value	Number of State Buildings Exposed	Percent (%) of Total Buildings	Total RCV Exposed	Percent (%) of Total Value
Dept of Accounting & General Services	66	$946,504,656	9	13.6%	$80,340,824	8.5%
Dept of Agriculture	70	$133,065,375	13	18.6%	$24,524,445	18.4%
Dept of Attorney General	15	$95,151,863	4	26.7%	$27,412,721	28.8%
Dept of Budget & Finance	16	$26,624,294	4	25.00%	$20,193,447	75.9%

Agency	Total Number of State Buildings	Total Replacement Cost Value	Number of State Buildings Exposed	Percent (%) of Total Buildings	Total RCV Exposed	Percent (%) of Total Value
Dept of Business, Economic Development and Tourism	25	$612,574,032	4	16.0%	$15,583,469	2.5%
Dept of Commerce & Consumer Affairs	2	$35,611,360	0	0.0%	$0	0.0%
Dept of Defense	69	$246,099,477	9	13.0%	$26,767,373	10.9%
Dept of Education	4,090	$9,604,111,443	392	9.6%	$808,930,258	8.4%
Dept of Hawaiian Home Lands	12	$100,471,477	1	8.3%	$4,748,597	4.7%
Dept of Health	44	$387,068,440	5	11.4%	$9,525,587	2.5%
Dept of Human Resources Development	1	$5,523,320	0	0.00%	$0	0.0%
Dept of Human Services	130	$420,004,555	30	23.1%	$155,178,145	36.9%
Dept of Labor and Industrial Relations	22	$79,322,626	4	18.2%	$4,677,116	5.9%
Dept of Land and Natural Resources	90	$98,666,185	32	35.6%	$15,104,751	15.3%
Dept of Public Safety	154	$427,884,909	15	9.7%	$32,889,853	7.7%
Dept of Taxation	1	$6,864,408	0	0.0%	$0	0.0%
Dept of Transportation	68	$2,912,510,888	39	57.4%	$234,861,971	8.0%
Hawai‘i State Ethics Commission	1	$891,212	0	0.0%	$0	0.0%
Hawai‘i Health Systems Corporation	106	$1,223,962,810	1	0.9%	$829,553	0.07%
Hawai‘i Housing Finance & Development Corporation	86	$333,526,064	5	5.8%	$118,247,972	35.5%
Hawai‘i Public Housing Authority	273	$933,255,767	34	12.5%	$35,788,719	3.8%
Hawai‘i State Legislature	2	$43,024,855	0	0.0%	$0	0.0%
Hawai‘i State Public Library System	53	$525,584,082	11	20.8%	$25,026,076	4.8%
Judiciary	41	$511,093,204	5	12.2%	$72,969,084	14.3%
Legislative Reference Bureau	1	$2,686,408	0	0.0%	$0	0.0%
Office of Hawaiian Affairs	11	$53,991,251	6	54.6%	$42,915,963	79.5%
Office of the Auditor	2	$1,789,788	0	0.0%	$0	0.0%
Office of the Governor	1	$2,686,408	0	0.0%	$0	0.0%
Office of the Lieutenant Governor	2	$3,977,640	0	0.0%	$0	0.0%
Office of the Ombudsman	1	$1,620,944	0	0.0%	$0	0.0%
Research Corporation of the University of Hawai‘i	3	$3,713,497	0	0.0%	$0	0.0%
University of Hawai‘i	637	$5,000,692,783	19	3.0%	$442,505,696	8.9%
Total	**6,095**	**$24,780,556,017**	**642**	**10.5%**	**$2,199,021,620**	**8.9%**

Source: Hawai‘i State Risk Management Office 2017; 2017 Hawai‘i Sea Level Rise Vulnerability and Adaptation Report
Note: Dept Department
RCV Replacement Cost Value

Approximately 39.2 miles of State roads could be chronically flooded with 3.2 feet of sea level rise; with the majority of these roads located in the City and County of Honolulu (19.7 miles). The flooding may cause these roads to be impassible which would jeopardize critical access to many communities, and eventually lead to permanent road closures.

Statewide, there is greater than 100 miles of State roads exposed to event-based coastal flooding in the 1%CFZ-3.2 hazard area. Many state roads serve as evacuation routes to higher ground. Not only will these roads be closed during coastal flood events and potentially isolating communities, the flood waters may accelerate the degradation of these roads leading to increased repair and replacement costs. The City and County of Honolulu has the greatest number of State road miles (51.3 miles) exposed to the 1%CFZ-3.2, followed by the Counties of Kaua'i and Maui, respectively. Greater than 25% of the County of Kauai's State roads are located in the 1%CFZ-3.2 hazard area. Table 4.2-7 shows the length of State roads exposed to sea level rise by county. A complete list of State roads exposed is included in Appendix X.

Table 4.2-7. State Roads Located in the Sea Level Rise Hazard Areas by County

County	Total Length (miles)	Miles of State Road in the SLR-XA-3.2	Percent (%) of Total Length	Miles of State Road in the 1%CFZ-3.2	Percent (%) of Total Length
County of Kaua'i	104.0	7.4	7.1%	27.0	25.9%
City and County of Honolulu	375.3	19.7	5.2%	51.3	13.7%
County of Maui	238.6	12.0	5.0%	20.1	8.4%
County of Hawai'i	378.7	0.2	0.1%	2.8	0.7%
Total	**1,096.5**	**39.2**	**3.6%**	**101.1**	**9.2%**

Source: State of Hawai'i DOT State Routes GIS layer 2017; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017
Notes: 1%CFZ 1% Annual Chance Coastal Flood Zone
GIS Geographic Information System
DOT Department of Transportation
SLR-XA-3.2 Sea Level Rise Exposure Area with 3.2 feet of sea level rise.
1%CFZ-3.2 1% Annual Chance Coastal Flood with 3.2 feet of sea level rise (V-zones only)

Critical Facilities

Sea level rise may result in the permanent loss of critical facilities including roads, airports, harbors, utility infrastructure, water/wastewater facilities and conveyance systems and other public service facilities with cascading impacts statewide. There are 33 critical facilities located in the SLR-XA-3.2 hazard area (see Table 4.2-8). The County of Maui has the greatest number of critical facilities (14) exposed with the majority of the facilities being water, waste, and wastewater systems. Table 4.2-9 summarizes the number and percentage of exposed critical facilities by core category. Water, waste, and wastewater systems have nearly 5% of their facilities located the SLR-XA-3.2 hazard area statewide. It is recognized that replacement cost value listed in Table 4.2-9 does not depict an accurate loss estimate; however, this was the best available data for the 2018 HMP Update. A more accurate reflection of loss to the SLR-XA-3.2 would be the combined value of the land and structure using tax-assessed data. In addition to land and structural loss, the loss of service by that critical facility would further increase the total loss as a result of sea level rise.

Table 4.2-10 summarizes the total number of critical facilities by core category located in the 1%CFZ-3.2 area by county. The City and County of Honolulu has the greatest number of critical facilities (121) within the hazard area with

the majority of the facilities being water, waste, and wastewater systems. Table 4.2-11 summaries the number and percentage of exposed critical facilities by core category. Transportation services have 12.5% of their facilities within the hazard area.

Table 4.2-8. Critical Facilities Located in the SLR-XA-3.2 by County

County	Core Category of Critical Facilities										
	Commercial Facilities	Communications	Emergency Services	Energy	Food and Agriculture	Government Facilities	Healthcare and Public Health	Mass Care Support Services	Transportation Services	Water, Waste, and Wastewater Systems	Total in the SLR-XA-3.2
County of Kaua'i	0	0	3	0	0	1	0	0	0	2	6
City and County of Honolulu	0	0	2	1	0	1	2	0	0	6	13
County of Maui	0	0	2	1	0	1	0	0	2	7	14
County of Hawai'i	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**7**	**2**	**0**	**3**	**2**	**0**	**2**	**15**	**33**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Table 4.2-9. Critical Facilities Located in the SLR-XA-3.2 by Core Category

Core Category	Total Number of Critical Facilities	Total Value	Number of Critical Facilities in SLR-XA-3.2	Percent (%) of Total Facilities	Value in the SLR-XA-3.2	Percent (%) of Total Value
Commercial Facilities	60	$206,894,206	0	0.0%	$0	0.0%
Communications	130	$523,848,060	0	0.0%	$10,739,055	2.1%
Emergency Services	149	$1,017,628,710	7	4.7%	$53,490,530	5.3%
Energy	90	$2,591,975,628	2	2.2%	$63,264,080	2.4%
Food & Agriculture	39	$829,869,410	0	0.0%	$0	0.0%
Government Facilities	100	$399,781,575	3	3.0%	$11,718,135	2.9%
Healthcare & Public Health	193	$3,399,521,375	2	1.0%	$8,734,005	0.3%
Mass Care Support Services	353	$11,497,547,155	0	0.0%	$0	0.0%
Transportation Services	56	$1,739,256,960	2	3.6%	$61,916,160	3.6%
Water, Waste, & Wastewater Systems	305	$9,481,445,760	15	4.9%	$465,972,480	4.9%
Total	**1,475**	**$31,687,768,838**	**33**	**2.2%**	**$675,834,445**	**2.1%**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Value Replacement Cost Value of state building; this does not include land value and may be underestimating the total loss.

Table 4.2-10. Critical Facilities Located in the 1%CFZ-3.2 by County

County	Core Category of Critical Facilities										Total in the 1%CFZ-3.2
	Commercial Facilities	Communications	Emergency Services	Energy	Food and Agriculture	Government Facilities	Healthcare and Public Health	Mass Care Support Services	Transportation Services	Water, Waste, and Wastewater Systems	
County of Kaua'i	1	1	6	3	2	2	1	7	2	11	36
City and County of Honolulu	7	20	11	19	1	9	5	9	1	39	121
County of Maui	0	3	4	0	0	4	4	3	8	17	43
County of Hawai'i	1	1	0	2	6	1	0	2	5	11	29
Total	**9**	**25**	**21**	**24**	**9**	**16**	**10**	**21**	**16**	**78**	**229**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Table 4.2-11. Critical Facilities Located in the 1%CFZ-3.2 by Core Category

Category	Total Number of Critical Facilities	Total Replacement Cost Value	Number of Critical Facilities in 1%CFZ-3.2	Percent (%) of Total Facilities	Value in the 1%CFZ-3.2	Percent (%) of Total Value
Commercial Facilities	60	$206,894,206	9	15.0%	$22,504,941	10.9%
Communications	130	$523,848,060	25	19.2%	$65,306,105	12.5%
Emergency Services	149	$1,017,628,710	21	14.1%	$104,301,910	10.3%
Energy	90	$2,591,975,628	24	26.7%	$693,960,408	26.8%
Food & Agriculture	39	$829,869,410	9	23.1%	$113,819,680	13.7%
Government Facilities	100	$399,781,575	16	16.0%	$62,863,955	15.7%
Healthcare & Public Health	193	$3,399,521,375	10	5.2%	$112,373,350	3.3%
Mass Care Support Services	353	$11,497,547,155	21	5.9%	$365,143,365	3.2%
Transportation Services	56	$1,739,256,960	16	28.6%	$496,129,920	28.5%
Water, Waste, & Wastewater Systems	305	$9,481,445,760	78	25.6%	$2,430,743,040	25.6%
Total	**1,475**	**$31,687,768,838**	**229**	**15.5%**	**$4,467,146,674**	**14.1%**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Critical transportation hubs and critical infrastructure located on the coast are exposed to the sea level rise hazard. The primary transportation arteries for the entry of people and goods to the State is the Daniel K. Inouye International Airport and Honolulu Harbor. The International Airport serves more than 19 million passengers and receives more than 228,000 tons of cargo annually. More than 14.6 million tons of commodities and an estimated 400,000 cruise ship passenger sailing pass through Honolulu Harbor each year. In addition, each island has critical points of entry for people and goods which are considered vulnerable to sea level rise if located along the coast.

Interruption of interisland and transoceanic shipping and travel would impact residents, visitors and all forms of economic activity (Hawai'i Climate Mitigation and Adaptation Commission 2017).

Assessment of Local Vulnerability and Potential Losses

This section provides a summary of vulnerability and potential losses to population, general building stock, environmental assets and cultural resources by county. Similar to the analysis for state assets, a spatial exposure analysis was conducted. As noted above, vulnerability to SLR-3.2 is the potential permanent loss of assets and displacement of population located in the SLR-XA-3.2 hazard area. Vulnerability to the 1%CFZ-3.2 is the potential damage to assets as a result of event-based coastal flooding exacerbated by sea level rise.

Population

Climate Change

As the climate changes in the State of Hawai'i, residents will face natural hazard threats just as plants and animals will be impacted. With increased temperatures, vulnerable populations could face increased vulnerability to extreme heat and its associated illnesses such as heatstroke and cardiovascular and kidney disease. The State of Hawai'i may also see an increase in levels of vector-borne diseases, water-borne diseases such as cholera, fish poisoning, heat-related illnesses, mental health problems, respiratory diseases and other non-communicable diseases, and injury and death from tropical storms and cyclones. Inundation and flooding has led to contamination of surface water and groundwater. Polluted runoff associated with excessive stormwater can contain sewage from overflowing manholes or chemicals from commercial and industrial facilities and has already caused the closure of the beaches around the State of Hawai'i annually (University of Hawai'i at Mānoa Sea Grant College Program 2014).

Additionally, climate change can threaten food and water security, infrastructure, and public health and safety. All of which is expected to increase human migration from low to high elevation islands and continental sites. This will make it increasingly difficult for residents to sustain the many unique customs, beliefs, and languages of the Pacific Islanders (National Climate Assessment 2014).

Sea Level Rise

People living and working in the SLR-XA-3.2 hazard area may be displaced as homes and businesses become flooded and permanently lost. According to the 2017 *Hawai'i Sea Level Rise Vulnerability and Adaptation Report*, statewide, the loss of structures in this area may result in nearly 20,000 displaced residents, both homeowners and renters, in need of new homes statewide (Table 4.2-12). The greatest number of people that may be displaced by mid- to late century are located in the City and County of Honolulu (13,300 people). The people displaced would include a range of incomes and living situations.

Table 4.2-12. Estimated Population Displaced by Sea Level Rise (SLR-XA-3.2) by County

County	Total Population	Displaced Population	Percent (%) of Total Population
County of Kaua'i	67,091	3,370	1.5%
City and County of Honolulu	953,207	13,300	<1%
County of Maui	154,924	2,160	<1%
County of Hawai'i	185,079	1,000	<1%
Total	**1,360,301**	**19,830**	**<1%**

Source: Hawai'i Climate Mitigation and Adaptation Commission 2017

Over 145,000 residents are vulnerable to temporary flooding from the 1%CFZ-3.2 if a severe coastal flood event impacts the entire state (Table 4.2-13). This represents the added risk of event-based coastal flooding from severe waves resulting from hurricanes and tropical cyclones that poses a potential for loss of human life and property and for severe and long-term economic disruption.

Table 4.2-13. 2010 U.S. Census Population Located in the 1%CFZ-3.2 by County

County	Population						
	Total Population	Population in 1%CFZ-3.2	Population Exposed as Percent (%) of Total	Population Over 65 in 1%CFZ-3.2	Population Over 65 Exposed as Percent (%) of Total	Population with Income <$30K/yr in 1%CFZ-3.2	Population with Income <$30K/year as Percent (%) of Total
County of Kaua'i	67,091	10,710	16.0%	1,634	2.4%	3,702	5.5%
City and County of Honolulu	953,207	126,460	13.3%	18,105	1.9%	39,480	4.1%
County of Maui	154,924	6,373	4.1%	904	0.6%	1,680	1.1%
County of Hawai'i	185,079	2,405	1.3%	469	0.3%	1,482	0.8%
Total	**1,360,301**	**145,948**	**10.7%**	**21,112**	**1.6%**	**46,344**	**3.4%**

Source: U.S. Census 2010; Draft Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017
The poverty threshold for the State is $24,000/year (Federal Register 2017). Utilizing the demographic layer in Hazus, the total households with an income of $30,000 or less was calculated. Per the U.S. Census Bureau QuickFacts, the average number of persons per household (2012-2016) is 3.03 for the State of Hawaii. To convert households to residents, three people per household was used.

Land Use Districts

Table 4.2-14 shows the number of square miles and percent of total acres in each State Land Use District statewide; refer to Appendix X for results by County. Statewide, 35 square miles of land are exposed to 3.2 feet of sea level rise. Conservation Districts lands, which contain valuable environmental resources, have the most area exposed, statewide; however, the exposure accounts for less than 1% of the total Conservation District land in the State. Additional discussion of exposure and vulnerability of environmental resource areas can be found in the Environmental Resources section below. Urban District lands have the second highest area exposed accounting for 3.7% of total Urban District land in the State. This is significant as development in these areas would need to be adapted in place to chronic flood conditions or moved elsewhere, which may result in encroachment or conversion of agricultural or conservation district lands. The City and County of Honolulu has the greatest number of square miles of land in the SLR-XA-3.2 of any County and almost 60% of this area is in low lying Urban Districts, which are highly developed.

The 1%CFZ will expand with sea level rise meaning that more land area will be exposed to damaging wave impacts from a 1% Annual Chance Flood event. This is of particular concern for Urban Districts, which have the greatest share of developed land. With 3.2 feet of sea level rise, more than 13% of the State's Urban Districts are projected to be exposed to wave heights of more than 3 feet from a 1% Annual Chance Storm. It should be noted that this does not include exposure to wave heights of between 1.5 feet and 3 feet, which can also include significant structural damage.

Table 4.2-14. State Land Use Districts within the Sea Level Rise Hazard Areas

Land Use District	Total (square miles)	Square miles in SLR-XA-3.2	Percent (%) of Total Area	Square miles in 1%CFZ-3.2	Percent (%) of Total Area
Agricultural	2,942.8	9.0	0.3%	36.0	1.2%
Conservation	3,156.3	13.3	0.4%	29.8	0.9%
Rural	16.1	0.6	3.7%	2.2	13.3%
Urban	319.7	11.8	3.7%	42.0	13.2%
Total	**6,434.9**	**35.0**	**0.5%**	**110.0**	**1.7%**

Source: State of Hawai'i GIS layers, State of Hawai'i GIS Program Geospatial Data Portal, 2017
Total area may differ slightly between this and other calculations due to slight differences in the shoreline geography.
Notes: 1%CFZ-3.2 — 1% Annual Chance Coastal Flood Zone with 3.2 Feet of Sea Level Rise
GIS — Geographic Information System
SLR — Sea Level Rise
SLR-XA-3.2 — Sea Level Rise Exposure Area with 3.2 Feet of Sea Level Rise

General Building Stock

To further assess what is at risk, each County's general building stock's exposure was examined. Table 4.2-15 summarizes buildings that may be permanently lost due to sea level rise. These vulnerable structures include residential structures, hotels and businesses. Due to the high concentration of development along the coast, the City and County of Honolulu has the greatest potential economic loss of the Counties.

To more fully understand the potential economic loss to 3.2 feet of sea level rise, both the value of the land and structure must be considered. According to the 2017 *Hawaii Sea Level Rise Vulnerability and Adaptation Report*, the value of projected flooded structures, combined with the land value projected to be flooded, amounts to over $19 billion across the State. The economic loss due to chronic flooding of roads, utilities and other public infrastructure was not analyzed, but will likely amount to a far greater loss. Utilities, such as water, wastewater and electrical systems, often run parallel underneath roadways, making lost road mileage a good indication of extent of lost utilities. This chronically flooded infrastructure would have significant impacts on local communities as well as reverberating effects around each island through loss of commerce, loss of access to emergency services, and increased traffic on other roads and highways. Repair and relocation of vulnerable roadways are already costly efforts for the State and Counties, which will only worsen as the sea level rises. Harbors and airports, often located in low-lying coastal areas in the State, face chronic flooding. For this reason, the economic loss due to flooded critical infrastructure is expected to be an order of magnitude greater than the potential economic loss from land and structures. Refer to the 2017 *Hawaii Sea Level Rise Vulnerability and Adaptation Report* for more detailed discussion on vulnerable areas by island.

Damages to buildings as a result of a 1% annual chance coastal flood event may also displace people from their homes, threaten life safety and impact a community's economy and tax base. Table 4.2-15 lists the estimated cost to repair or replace flooded structures and their contents in the 1%CFZ-3.2. Statewide, this would be greater than $125 billion, of which 94% would occur in the City and County of Honolulu. This figure does not include the cost of damage to roads or utilities, which would be considerable. Areas with the highest potential economic loss resulting from a flood event are low-lying urban areas.

Table 4.2-15. Estimated Potential Structure and Property Value (Structure and Land) Loss from Sea Level Rise (SLR-XA-3.2)

County	Number of Structures	Estimated Structure and Land Value Loss
County of Kaua'i	940	$2,600,000,000
City and County of Honolulu	3,800	$12,900,000,000
County of Maui	1,553	$3,490,000,000
County of Hawai'i	130	$430,000,000
Total	**6,423**	**$19,420,000,000**

Source: Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017

Table 4.2-16. Estimated General Building Stock Loss (Structure and Contents) to the 1%CFZ-3.2

County	Number of Structures Impacted	Potential Damages
County of Kaua'i	5,360	$5,700,000,000
City and County of Honolulu	17,700	$120,000,000,000
County of Maui	2,830	$7,880,000
County of Hawai'i	470	$110,000,000
Total	**26,360**	**$125,817,880,000**

Source: *Draft 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report*
Notes: 1% CFZ 1% Annual Chance Coastal Flood Zone
GIS Geographic Information System

Environmental Resources

The observed and projected influences of climate change on global and local ecosystems are diverse and often detrimental. Some of the changes likely to impact the State of Hawaii's ecosystems include accelerated sea level rise, ocean and atmospheric warming, increased flooding, ocean acidification, changing distributions of terrestrial and marine biota, and changing intensity and frequency of storms among others (University of Hawai'i at Mānoa Sea Grant College Program 2014).

Climate Change

Hawaiian ecosystems will be challenged by increasing frequency and severity of climate-related disturbances (for example, storms, flooding, drought, wildfire, invasive species, and ocean acidification) and continued pressure from anthropogenic influences, such as change in land use, pollution, fragmentation of natural systems, and overexploitation of resources. Evidence of many of these climate-related impacts has already been observed in the State of Hawai'i (University of Hawai'i at Mānoa Sea Grant College Program 2014). The following provides details on how the ecosystems in the State of Hawai'i may be impacted by climate change.

- **Open Ocean**—The physical, chemical, and biological characteristics of the ocean are shifting around the State of Hawai'i under the influence of climate change. The ocean is getting warmer and more acidic which has the potential to drive changes in circulation. This could disrupt the timing of feeding and spawning of marine species and reduce primary productivity and fish catches around the Hawaiian Islands. Acidification of the oceans threaten some calcifying plankton, corals, and other species. Ocean warming

could also lead to a more favorable environment for pathogens and invasive species, threatening native and endemic species of the State of Hawai‘i (University of Hawai‘i at Mānoa Sea Grant College Program 2014).

- **Coral Reefs and Nearshore Habitats**—Coral reefs and other nearshore habitats face degradation from both climate change and localized anthropogenic influences, including but not limited to, sedimentation, direct physical impacts, overfishing, nutrient loading from runoff, and erosion. Warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of tuna fisheries (Leong et al 2014). Hawaiian reefs experienced statewide bleaching events in 2014 and 2015. Ocean acidification can cause a variety of responses in marine organisms, including inhibited development of calcium carbonate shells or skeletons in corals, shellfish, and plankton, and impaired physiological functions of some reef fish. Changing precipitation patterns over the Hawaiian Islands influence the quantities and concentration of stormwater runoff that enters coastal waters. Ocean acidification will reduce coral growth and health. Warming and acidification, combined with existing stresses, will strongly affect coral reef fish communities (University of Hawai‘i at Mānoa Sea Grant College Program 2014).
- **Coasts and the Built Environment**—The coastline of the State of Hawai‘i is comprised of a diverse mixture of environments, including sandy carbonate beaches, steep bluffs, densely-developed lowlands, lava benches, marshes and fishponds, many of which are eroding due to natural and anthropogenic causes (University of Hawai‘i at Mānoa Sea Grant College Program 2014).
- **Terrestrial Ecosystems**—A changing climate can alter the habitats and conditions of endemic Hawaiian species, such as the Hawaiian honeycreeper and the Haleakalā silversword. Warmer temperatures could lead to a shift in the habitat ranges of native plants like the Haleakalā silversword, which is only found at high elevations on Mount Haleakalā and has experienced a decline in population over the last 20 years that is connected to temperature increase. Endemic bird species, such as the Hawaiian honeycreeper, could decline in population due to the warming of high-elevation forests where risk of avian disease transmission was previously low. Ranges for pests, diseases, and invasive species may expand as a result of warming temperatures. The higher elevations in the State of Hawai‘i are bearing the brunt of impacts and lower elevations are seeing new habitats emerge that previously did not exist in the archipelago (University of Hawai‘i at Mānoa Sea Grant College Program 2014).
- **Freshwater Resources**—Climate change can lead to a decrease in precipitation, streamflow, and groundwater levels and increase the number of and duration of droughts. All of these factors can impact the water table of the State of Hawai‘i. Groundwater provides a majority of drinking water in the State of Hawai‘i and a lower water table will reduce the amount of water available. If drought events continue to increase, dry areas could see more fire and problems with stressed water supplies (University of Hawai‘i at Mānoa Sea Grant College Program 2014).

Sea Level Rise

The loss of natural and cultural resources statewide resulting from sea level rise is difficult to quantify; however, their loss would deeply cost the State. Sea level rise would take its toll on the State’s world-famous beaches, including such iconic stretches of beaches such as Oahu’s North Shore “Seven Mile Miracle,” the beaches of Kauai’s North Shore, and West Maui beaches (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017).

Over the past century, 70% of the beaches in the State have eroded and over 13 miles of beach have been completely lost to erosion. This trend of beach erosion could be driven by local sea level rise. Shoreline retreat, averaging 1 foot per year (0.3 meters/year) statewide, and wetland migration and cliff collapse due to erosion are occurring now on many of the State of Hawaii's coastlines. Sea level rise can increase saltwater intrusion in aquifers and cause the groundwater table to rise, resulting in inundation of low-lying areas and infrastructure (University of Hawai‘i at Mānoa Sea Grant College Program 2014).

Sea level rise and coastal inundation will change the coral reefs and nearshore habitats of the State of Hawai‘i and may result in a shift or loss of ecosystems. Beach and wetland systems may not be able to adapt to rising sea levels and could be lost if not allowed to migrate landward. The loss of wetlands could reduce the coast's ability to buffer impacts from storms and flooding (University of Hawai‘i at Mānoa Sea Grant College Program 2014).

Additionally, sea level rise has the potential to impact facilities that could release wastewater or hazardous materials and waste to nearshore waters and coastal habitats. Septic tanks, cesspools, and other on-site sewage disposal systems (OSDS) as well as other hazard materials/waste storage and disposal sites are located along the coast. The OSDS exposed to chronic flooding in the SLR-XA with 3.2 feet of sea level rise area would not only result in system failures to operate properly but would also degrade nearshore water quality. In the County of Hawai‘i, the OSDS are located along many urban and rural shoreline areas, such as along the shoreline of Kapoho. Releases from these OSDS may change disease risk for coral reefs and negatively impacting nearby coral resources, such as those off the coast of Puakō (Hawai‘i Climate Change Mitigation and Adaptation Commission 2017).

Environmental resources, including critical habitat (or habitats that are known to be essential for an endangered or threatened species), wetlands, parks and reserves located in the assessed hazard areas are summarized in Table 4.2-16. It is important to note that wetlands and coral reefs provide protection from rising sea levels and damaging wave action (Carey 2018).

Table 4.2-17. Environmental Resources Located in the Sea Level Rise Hazard Areas

Environmental Asset	Total Square Miles of Asset	SLR-XA-3.2 Area	Percent (%) of Total Asset Area	1%CFZ-3.2 Area	Percent (%) of Total Asset Area
Critical Habitat[a]	915.2	1.6	0.2%	2.2	0%
Wetlands	260.0	15.7	6.1%	31.1	12%
Parks and Reserves	2,607.7	7.2	0.3%	17.7	1%
Total[b]	**3,837.6**	**79.3**	**2.1%**	**105.7**	**2.8%**

Source: State of Hawai‘i GIS layers, State of Hawai‘i GIS Program Geospatial Data Portal
Notes: 1% CFZ 1% Annual Chance Coastal Flood Zone
GIS Geographic Information System
SLR Sea Level Rise
SLR-XA Sea Level Rise Exposure Area
a. Critical habitat area mileage includes the combined area of coverage of individual critical habitat areas
b. Total square miles may be over reported as some environmental asset areas may overlap.
Reefs were excluded from the analysis because they are under water and thus 100% exposed to a flood hazard.

Cultural Assets

Many Native Hawaiian cultural resources would be impacted by sea level rise as well due to the number of cultural sites located within the SLR-XA-3.2. Cultural practices including fishing, gathering, and other cultural practices that require shoreline access would be impacted (Hawai'i Climate Change Mitigation and Adaptation Commission 2017). Table 4.2-17 summarizes the Hawaiian Home Lands square miles vulnerable to sea level rise and exacerbated impacts from coastal event-based flood events due to sea level rise.

Table 4.2-18. Hawaiian Home Lands Vulnerable to Sea Level Rise

County	Area (in square miles)				
	Total Area	SLR-XA-3.2 Hazard Area	Hazard Area as Percent (%) of Total Area	1%CFZ-3.2 Hazard Area	Hazard Area as Percent (%) of Total Area
County of Kaua'i	32.0	0.1	0.5%	0.7	2.1%
City and County of Honolulu	10.9	0.1	0.6%	0.2	1.8%
County of Maui County	92.6	0.8	0.8%	1.8	1.9%
County of Hawai'i	190.3	0.1	0.1%	1.1	0.6%
Total	**325.8**	**1**	**0.3%**	**4**	**1.2%**

Source: State of Hawai'i GIS layer Trust Land, State of Hawai'i GIS Program Geospatial Data Portal
Notes: 1%-CFZ-3.2 1% Annual Chance Coastal Flood Zone with 3.2 Feet of Sea Level Rise
GIS Geographic Information System
SLR Sea Level Rise
SLR-XA-3.2 Sea Level Rise Exposure Area with 3.2 Feet of Sea Level Rise

FUTURE CHANGES THAT MAY IMPACT STATE VULNERABILITY

Understanding future changes that impact vulnerability in the State can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The State considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate.

Climate Change

Climate change, itself, is a factor of change that is already influencing vulnerability to many of the other hazards of concern. Impacts of climate change on both the probability of future events and their resulting impacts are discussed in the hazard profile and vulnerability assessment sections of each hazard of concern in the 2018 HMP Update. The extent to which climate change will be a factor of change in vulnerability for the State is yet to be determined. Two major factors will influence its impacts including whether or not global, human-caused greenhouse gas emissions will be reduced enough to avoid catastrophic impacts to the climate system and the extent to which feedback loops that are already occurring and little understood will exacerbate conditions.

Sea Level Rise

Sea level rise areas were overlain on areas that may experience significant changes in development or redevelopment in future years (see Table 4.2- below; refer to Section 3 for more information on projected development areas). The results of this assessment indicate that only small portions of these areas are likely to be lost to chronic flooding from 3.2 feet of sea level rise; however, substantial portions of these areas are located in areas that will be exposed to wave action during a 1% Annual Chance Flood event with 3.2 feet of sea level rise. In the City and County of Honolulu, 18.6% of the Hawaii Community Development Authority District Area and 8.1% of the Enterprise Zones would be exposed to these damaging waves. In the County of Kauai, 9.9% of the Enterprise Zone's total area is exposed. As development is considered in these areas, care should be taken to avoid further developing land that will be lost to sea level rise, to integrate appropriate flood mitigation into development in areas that are currently outside of flood zones or not currently exposed to wave action, and to allow enough room for the migration of coastal resources inland as the shoreline moves landward.

Table 4.2-19. HCDA Community Development Districts, Enterprise Zones, and Maui Development Projects Within Sea Level Rise Hazard Areas

County	Area (in square miles)								
	HCDA Community Development Districts (Total Area)	Total Area Exposed to Hazard	Hazard Area as % of Total Area	Maui Development Projects (Total Area)	Total Area Exposed to Hazard	Hazard Area as % of Total Area	Enterprise Zones (Total Area)	Total Area Exposed to Hazard	Hazard Area as % of Total Area
SLR-XA-3.2 Hazard Area									
County of Kaua‘i	-	-	-	-	-	-	252.3	6.4	2.5%
City and County of Honolulu	7.4	0.4	5.0%	-	-	-	288.3	6.0	2.1%
County of Maui	-	-	-	27.6	0.1	0.2%	1,016.7	8.2	0.8%
County of Hawai‘i	-	-	-	-	-	-	1,286.6	3.2	0.3%
Total	**7.4**	**4**	**5.0%**	**27.6**	**0.1**	**0.2%**	**2,844**	**24**	**0.8%**
1%CFZ-3.2 Hazard Area									
County of Kaua‘i	-	-	-	-	-	-	252.3	25.1	9.9%
City and County of Honolulu	7.4	1.4	18.6%	-	-	-	288.3	23.3	8.1%
County of Maui	-	-	-	27.6	0.1	0.3%	1,016.7	15.7	1.5%
County of Hawai‘i	-	-	-	-	-	-	1,286.6	13.6	1.1%
Total	**7.4**	**1.4**	**18.6%**	**27.6**	**0.1**	**0.3%**	**2,844**	**78**	**2.7%**

Total area calculated from: (1) HCDA Community Development District GIS layer from Hawai‘i Community Development Authority (2) Maui Development Projects GIS layer from Maui County Planning Department (3) Enterprise Zones from Community Economic Development Program, DBEDT

Hazard area clipped to coastline downloaded from State of Hawai‘i GIS Program Geospatial Data Portal

Notes: 1%CFZ-3.2 1% Annual Chance Coastal Flood Zone with 3.2 Feet of Sea Level Rise
GIS Geographic Information System
SLR Sea Level Rise
SLR-XA-3.2 Sea Level Rise Exposure Area with 3.2 Feet of Sea Level Rise