Section 4.6 Flood

Flood

Floods caused by heavy or sustained rainfall and coastal high tides and surges cause more water to accumulate in an area than its natural or human-made drainage systems can support, which results in flood flow velocities that contain water filled debris and surge mudflow. Statistics below reflect event-based 1% annual chance flooding.

CHANGES SINCE 2018

+2
Declared Disasters

+19
Significant Events

COUNTIES MOST VULNERABLE

Kaua'i Honolulu Maui Hawai'i

SOCIALLY VULNERABLE POPULATION

1.11%
Of Total Population

15,800
Persons

HAZARD RANKING

Low Medium High

COMMUNITY LIFELINES

153
Total

Food, Water, Shelter
Greatest

CLIMATE PROJECTIONS

Coastal flooding from hurricanes and tropical storms will increase as sea levels rise

Heavy or extreme rain events will increase, causing more frequent or intense flooding

Event-based coastal flooding with sea level rise would alter the extent of the area impacted by flooding from storm events, increasing beach erosion

SQUARE MILES

489
State Buildings

147
Environmental Resources

4
Hawaiian Home Lands

48
Cultural Resources

85.5
Miles of State Road

CONTENTS

TABLES

FIGURES

[1] *Section Cover Photo: Flooding in the Hanalei River Valley, Kauaʻi. Photo by Anthony Quintano/Civil Beat*

SECTION 4. RISK ASSESSMENT

4.6 FLOOD

2023 SHMP Update Changes

- The flood hazard now combines event-based and chronic coastal flooding in the State of Hawai‘i.
- Flood events that occurred in the State of Hawai‘i from January 1, 2018, through December 31, 2022, were researched for this 2023 SHMP Update.
- New and updated figures from federal and state agencies are incorporated.
- This section now includes a discussion of how floods impact socially vulnerable populations and community lifelines.
- In Environmental Resources, reefs (both artificial and coral) are analyzed in their own category.
- Six types of cultural resources (archaeology, burial sensitivity area, historic building, historic district, historic object, and historic structure) are added to the vulnerability assessment.

4.6.1 HAZARD PROFILE

The State of Hawai‘i is a mountainous tropical archipelago, making floods a frequent occurrence (National Science Foundation n.d.). Flooding in the state is caused by numerous sources, including rainfall from storms, storm surge, tsunamis, dam failures, and tidal flooding. Coastal flooding will continue to worsen as the sea level continues to rise. Refer to Figure 4.6-1 for a schematic diagram of the sea level rise exposure area (SLR-XA).

This section includes the event-based coastal and inland flood hazard and the chronic coastal flood hazard, which includes passive flooding, annual high waves, coastal erosion, and tidal flooding, including king tides. Flooding caused by dam failure is discussed in Section 4.10 (Infrastructure Failure), and storm surge is discussed in Section 4.9 (Hurricane). The assessment of mid- to late-century sea level rise on chronic coastal flooding is discussed in Section 4.2 (Climate Change and Sea Level Rise).

HAZARD DESCRIPTION

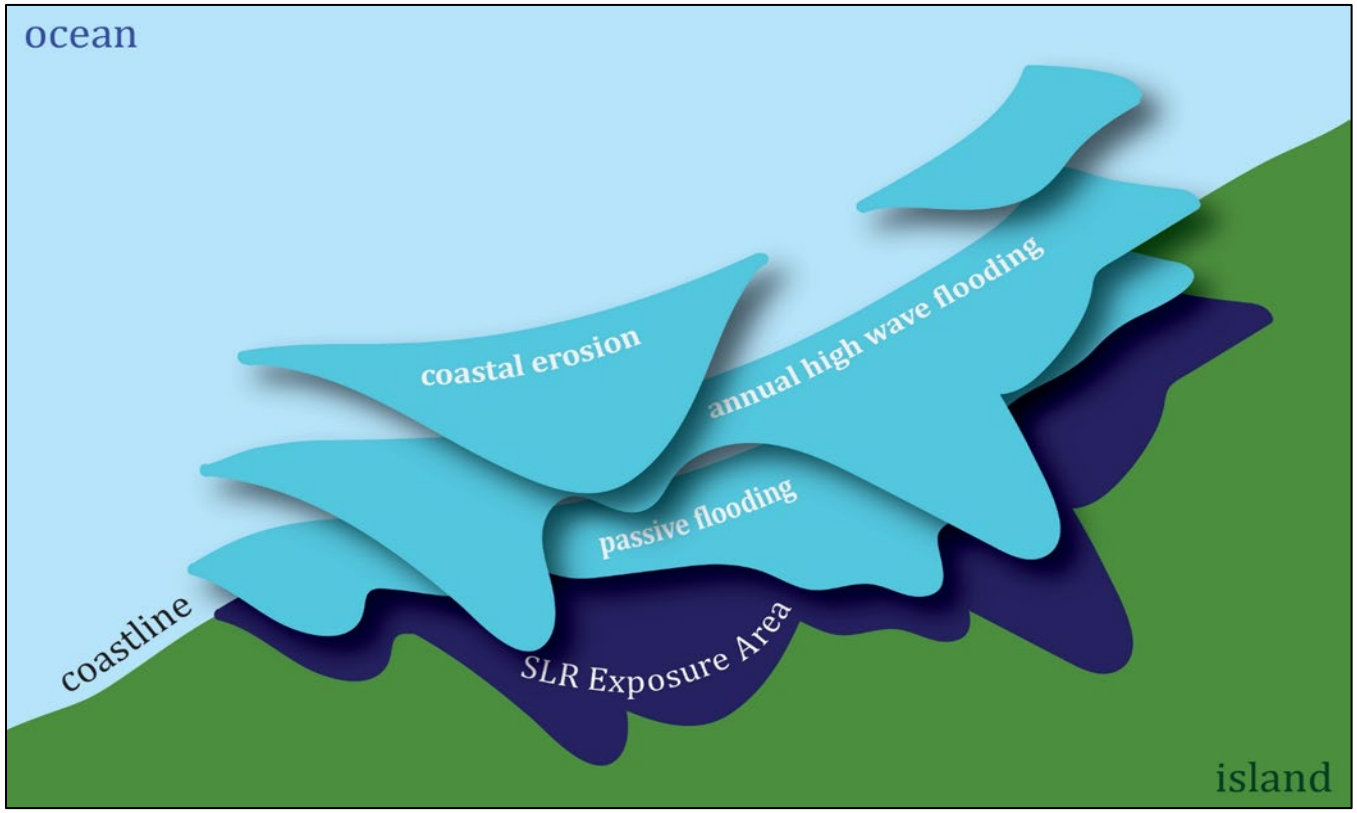
Event-Based Flooding

Event-based floods are the result of storms that cause temporary inundation of land from excessive rainfall or wave action. Flooding also occurs as a result of other event-types such as storm events which are discussed in other sections of the risk assessment. For the purposes of the 2023 SHMP Update, event-based flood include both coastal and inland flooding as depicted on Flood Insurance Rate Maps (FIRMs).

Key Terms

- **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).
- **V-Zones** – Areas subject to coastal flooding with velocity hazard (wave action of 3 feet or greater); includes V- and VE-zones.
- **A-Zones** – Special flood hazard areas that are not subject to wave heights of 3 feet or greater; includes A-, AE-, AO-, and AH-zones.
- **LiMWA** – The inland limit of the area expected to receive 1.5-foot or greater breaking waves during the 1% annual chance flood event.
- **Chronic Coastal Flood** – The combined effects of annual high wave flooding, passive flooding, and coastal erosion that are being exacerbated by sea level rise. The SLR-XA with 1.1 feet of sea level rise (SLR-XA-1.1), as defined in the 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report, approximates current or near-term exposure to chronic coastal flooding in the State of Hawai'i. Chronic coastal flooding represented by the SLR-XA-1.1 for the Islands of Moloka'i and Hawai'i is based on modeling passive flooding only due to limitations in data (Hawai'i Climate Change Mitigation and Adaptation Commission 2017).

Figure 4.6-1. Chronic Coastal Flooding as the Cumulative Impact of Passive Flooding, Annual High Wave Flooding, and Coastal Erosion

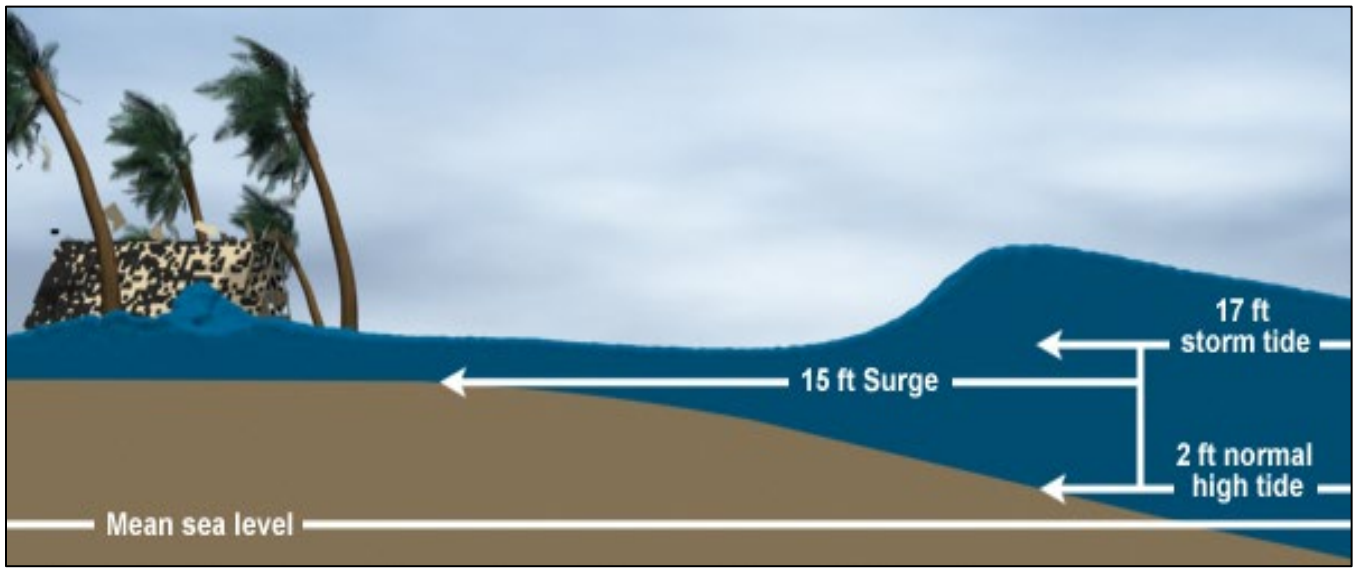


Source: (Hawai'i Climate Change Mitigation and Adaptation Commission 2017)

Event-Based Coastal Flooding

Coastal flooding in the State of Hawai'i generally occurs along the coasts of oceans, bays, and estuaries and is caused by seawater over and above normal tide action as a result of the storm surge (see Figure 4.6-2). Hurricanes and severe storms cause most coastal flooding (National Hurricane Center n.d.). During these events, high winds and surf can push water several feet and even hundreds of yards inland. Event-based coastal flooding is limited to discussion of such flooding from a 1% annual chance storm. Refer to Section 4.9 (Hurricane) for additional discussion on hurricanes and storm surge from less frequent and more severe events.

Figure 4.6-2. Storm Surge



Source: (National Hurricane Center n.d.)

Inland Flooding

Inland flooding is a general term used to describe non-coastal flooding. In the State of Hawai'i, inland flooding is caused by rainfall events, which cause three types of inland flooding:

- Riverine flooding—Riverine flooding is when streams and rivers exceed the capacity of their natural or constructed channels to accommodate water flow and water overflows the banks, spilling out into adjacent low-lying, dry land (FEMA n.d.).
- Overland sheet flow—Overland sheet flow occurs primarily in areas with undefined drainage ways and flood waters simply flow over land.
- Ponding of standing water in poorly drained low-lying areas—Poorly drained low-lying areas are a problem when flooding occurs even when rainfall is not heavy. Such drainage issues can be naturally occurring or human-caused. When human-caused, such flooding is sometimes referred to as urban flooding (see Figure 4.6-3).

Figure 4.6-3. Rainfall Flooding on Kaua'i

Source: (Dennis Fujimoto / The Garden Island 2021)

Chronic Coastal Flooding

The SLR-XA-1.1 represents the present-day or near-term exposure to chronic coastal flooding, defining the state's vulnerability to chronic coastal flooding (Hawai'i Climate Change Mitigation and Adaptation Commission 2017). The latest scientific literature suggests that 1.1 feet of sea level rise could be reached intermittently in the State of Hawai'i over the next couple of decades and sustained before midcentury. Long-term records from tide stations around the State of Hawai'i are already showing that the sea level is rising around the islands (refer to Figure 4.2-6 in the Climate Change and Sea Level Rise section). As seen in Figure 4.6-4, coastal areas are already experiencing an increase in frequency of chronic coastal flooding components (passive inundation, high wave flooding, coastal erosion, and tidal flooding, including king tides).

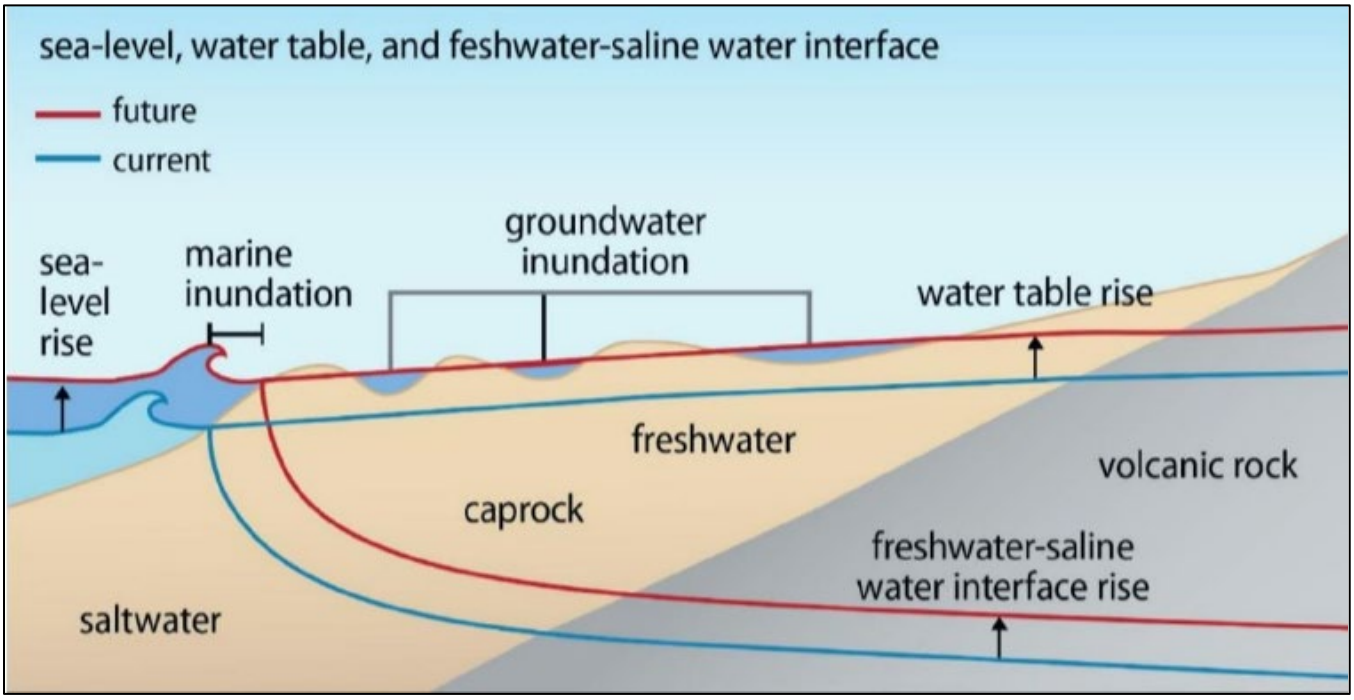
Passive Flooding

Passive flooding, also known as hydrostatic flooding, is depicted by bathtub modeling. Passive flooding includes marine flooding over the shoreline by stillwater flow into the lands that lie below the water level. The model also depicts low-lying areas indirectly flooded by sea level rise through water table rise and intrusion through storm drains. Passive flooding is exacerbated by rainfall as it prevents drainage, and as such, runoff and marine waters combine to produce larger impacts. Passive flooding provides an initial assessment of low-lying areas susceptible to flooding by sea level rise but does not include the effects of waves or coastal erosion. Passive flooding includes areas that are hydrologically connected to the ocean (marine flooding) and low-lying areas that are not hydrologically connected to the ocean (groundwater) (Figure 4.6-5) (Hawai'i Climate Change Mitigation and Adaptation Commission 2017).

Figure 4.6-4. Wave Inundation at Honoapi'ilani Highway, Maui

Source: (Pacific Islands Ocean Observing System 2022)

Figure 4.6-5. Passive Marine and Groundwater Flooding

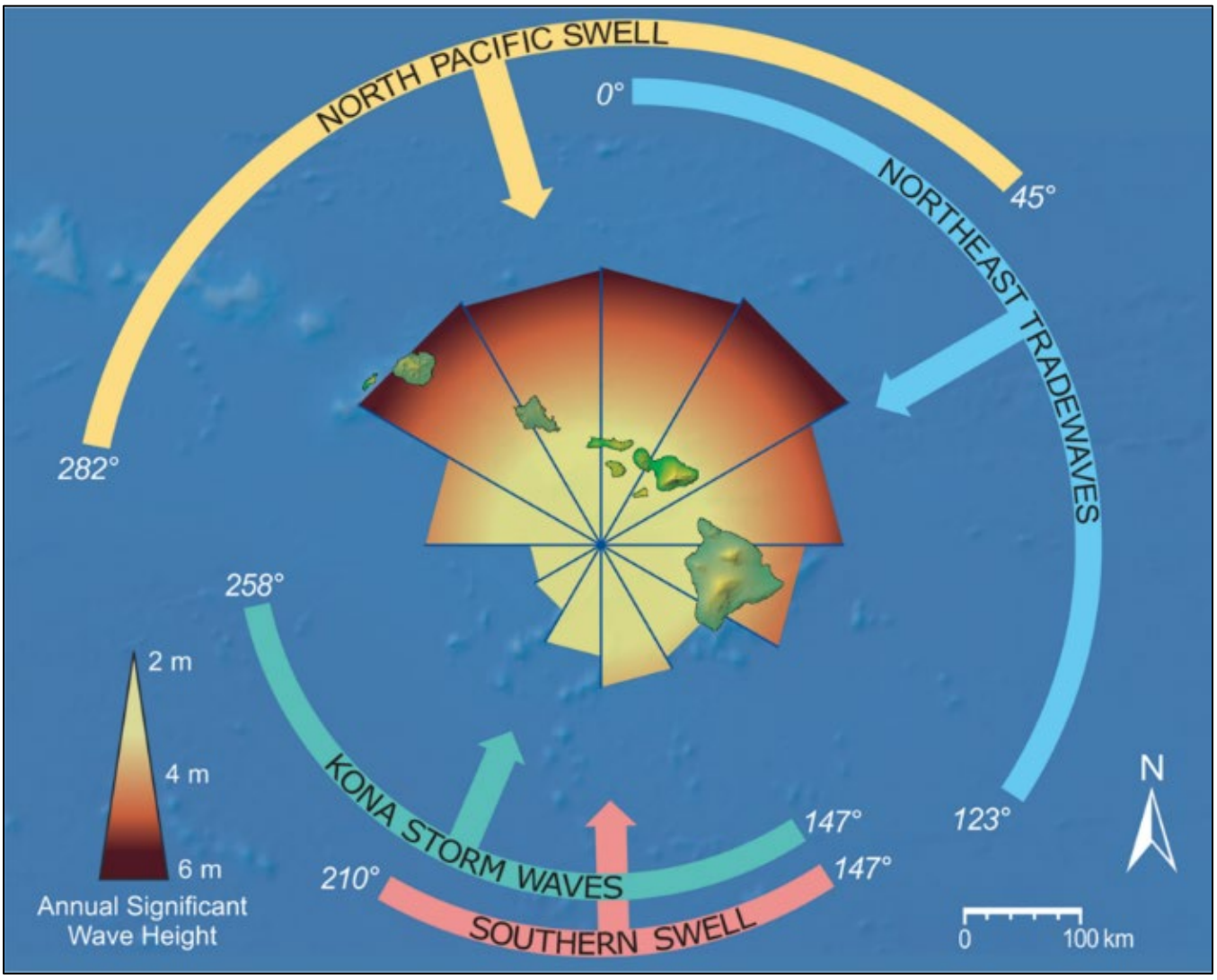


Source: (Hawai'i Climate Change Mitigation and Adaptation Commission 2017)

Annual High Wave Flooding

Storms or high winds over the open ocean can generate large waves that trigger high surf in coastal areas. Each year, waves that reach Hawaii's shorelines originate from four primary sources: North Pacific swell, northeast trade wind swell, South Pacific swell, and kona storm waves from a southerly direction. Figure 4.6-6 illustrates the primary wave sources and a wave rose depicting annual significant wave heights and direction. As shown in the wave rose, annual swell heights off north-exposed shores typically reach 6 meters (20 feet) or more in winter months. Breaking waves can be double that size or more on outer reefs.

Figure 4.6-6. Dominant Swell Regimes for the Hawaiian Islands



Source: (McDonald, et al. 2022)

Hazards associated with high waves include debris overwash, flooding, erosion, and turbulence and strong currents in the surf zone. Because the contact between deep water and the shallow margins around the Hawaiian Islands is abrupt, surface waves can grow very tall very quickly (University of Hawai'i 2022). High waves in Hawai'i are also generated by approaching storms, including tropical storms and hurricanes in the summer and fall, as

well as winter kona storms in winter months. These types of wave events are discussed in the Event-Based Flood portion of this section and Section 4.9 (Hurricane).

Coastal Erosion

Coastal erosion is the wearing away of material, typically sand, from the shoreline by waves and currents. The loss of sand causes the beach to become narrower and lower in elevation. Coastal erosion is typically measured as the horizontal movement or rate of change in the position of a shoreline over time. It is generally associated with high wave events, storms, and elevated water levels. Coastal erosion may be exacerbated by human activities such as shoreline hardening and sand mining. Natural recovery after erosive episodes can take months to years. A beach that is undergoing a long-term trend of chronic erosion will typically not recover fully after a storm or high waves, exposing shorefront development to further damage and land loss in subsequent events. Studies utilizing historical and recent aerial photographs find that 70% of beaches in the state are chronically eroding (Anderson, et al. 2018).

Seasonal coastal erosion (or episodic coastal erosion) occurs when beaches and other coastal areas are exposed to seasonally high waves. In the State of Hawai‘i, seasonal erosion occurs on all coasts but is most pronounced on north and west coasts, which are exposed to large winter swell and alternating wave directions between winter and summer. Unusually large wave events or high wave season can cause severe coastal erosion on any coast.

Sources of Erosion

The following are details regarding the sources of coastal erosion that may impact the State of Hawai‘i:

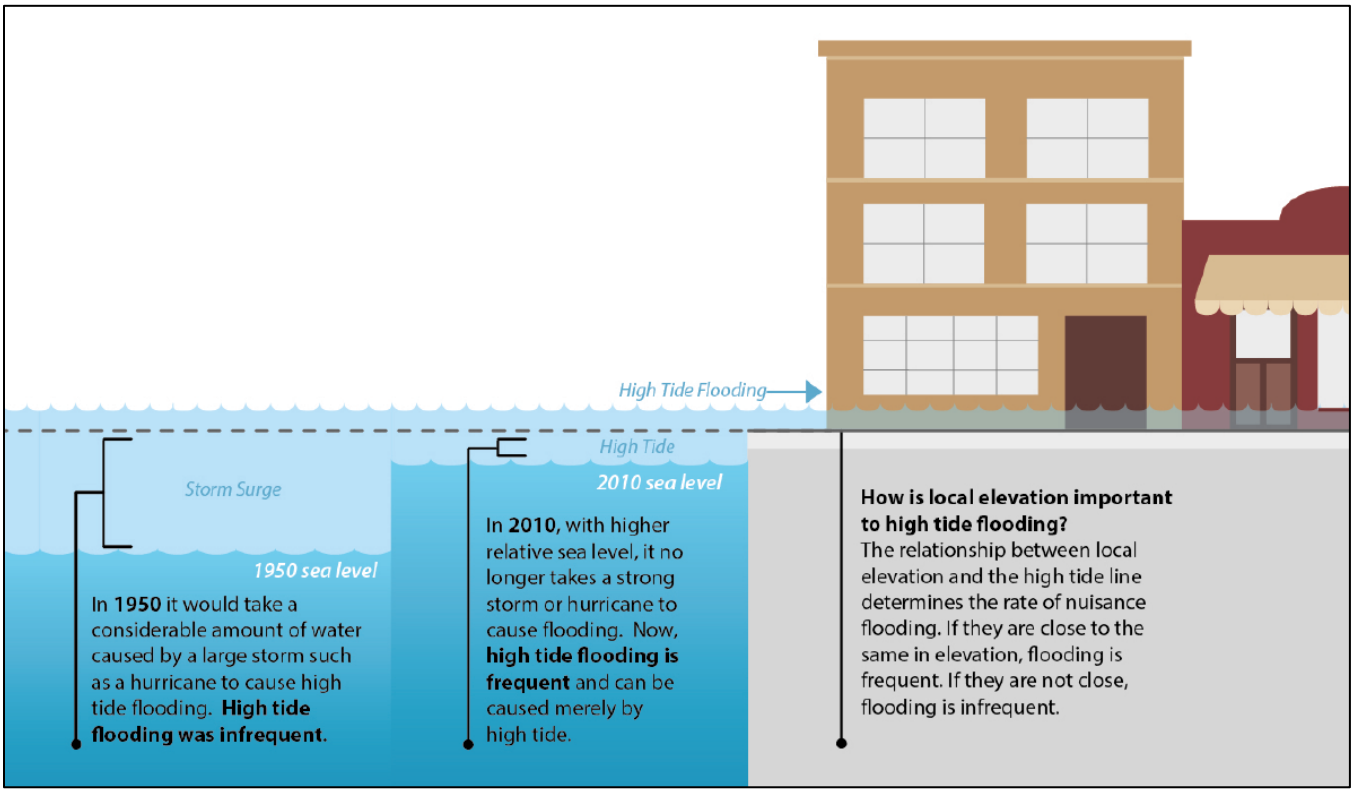
- High Waves and Strong Currents—High waves and strong currents will typically cause a beach to narrow and steepen as sand is carried offshore or down the coast and deposited in areas of lower energy. In Hawai‘i, fringing reefs play an important role in directing and modulating wave and current energy as waves then shoal and break further offshore. Erosion trends are highly variable along the shoreline and from one season to the next. For example, some sections of beach on the North Shore of O‘ahu, which are exposed to very large winter waves, widen during winter months and experience erosion during summer months when smaller trade wind waves dominate due to shifts in alongshore sand transport.
- Coastal Armoring—Coastal managers and property owners often attempt to stabilize coastal land and protect infrastructure along the coast by building shoreline armoring structures to stop land loss and protect shorefront development. These structures include seawalls and sloping rock revetments. Rock groins have also been used to stabilize beaches by slowing alongshore migration of sand.
- Coastal armoring can be an effective means of limiting property damage from coastal erosion and high waves. However, coastal armoring has had widespread negative impacts on beach environments in Hawai‘i. Seawalls and revetments trap sediment behind the structure that would otherwise be released by ongoing erosion to nourish the beach, leading to beach narrowing and loss on chronically eroding shores. These structures also tend to accelerate erosion on adjoining unprotected shorelines, increasing hazards for neighboring properties. Over 13 miles of beach has been completely lost to erosion fronting coastal armoring in Hawai‘i (Anderson, et al. 2018). Groins, breakwalls, and other coastal engineering structures are used in Hawai’i to stabilize beaches and protect infrastructure such as harbors but can also cause localized erosion, if not designed and sited properly, by changing wave and current patterns and trapping sediment on the updrift side of structures.

- Dune Leveling and Grading—Coastal dunes provide a critical reservoir of sand for beach during high waves and storms and can provide natural protection from flooding and damage by high waves, rising sea levels and strong storms. However, in the State of Hawai'i, many beachfront dunes have been graded down for development or degraded by the historical practice of sand mining. Deflated beaches and flattened dunes reduce the natural buffering capabilities of the beach system and are themselves a degraded environment with little to offer the normal coastal ecosystem and its host of organisms with beach-dependent life stages (including turtles, various marine larvae, and certain reef fishes) (DLNR Coastal Lands Program n.d.).
- Sand Mining—Sand mining from beachfront dunes is a presently outlawed, historic practice that refers to the process of collecting large amounts of coastal sands typical for use in construction or agriculture. The beaches in the State of Hawai'i, especially the beaches on the Islands of Maui and O'ahu, were subjected to sand mining for lime processing which was then baked to produce lime for use as a building material. Sand mining is in large part responsible for the historical retreat of both the vegetation line and the beach foreshore along some beaches. Besides loss of vegetation and beach foreshore, sand mining impacts beaches negatively by decreasing sand volumes, steepening the morphology of the shoreline, and reducing the ability of beach profiles to respond to seasonal wave stresses, increasing erosion and marine flooding hazards to shorefront development (Pilkey, et al. 2022).
- Canalization—Many streams that flow intermittently from Hawaiian mountain ranges to the coast are subject to flash flooding during heavy rainfall events. To prevent coastal zone flooding, many of the most hazardous of these streams have been canalized into concrete canals or gutters so that flooding is contained. Where canals and similar infrastructure open onto the coastal zone, the channel mouths tend to trap sand that is moving along the shoreline. The buildup of sand within the channel mouths increases the upstream flood hazard and creates a sand deficiency on the adjacent beach. Public works departments often clear these accumulations and dispose of the sand in various ways, including returning beach-quality sand to the beaches. Unless these sands are returned to the immediate beach area, the long-term dredging and clearing is nothing less than a sand mining effort, and it will have a similar detrimental impact on the adjacent beach. This process has the potential to reduce available sand volumes and create chronic erosion where none previously existed. By placing cleared sands onto adjacent beaches, it is important to be aware of prevailing sediment transport patterns so that returned sand can function in a manner that will provide nourishment. To ensure proper adjacent beach replenishment, it is necessary to conduct reviews of the ambient littoral processes and develop schedules of transport direction around each channel mouth, with guidelines on the placement of returned sand (DLNR Coastal Lands Program n.d.).

Tidal Flooding/King Tides

Tidal flooding, also known as sunny day flooding or high tide flooding, is the temporary inundation of low-lying areas during exceptionally high tides (Figure 4.6-7). King tides is a non-scientific term used to describe exceptionally high tides that occur in summer and winter when the moon is at its closest point to the Earth. Astronomical king tides are predictable but additional impacts on top of king tides, such as high waves and additional elevated water levels, can be hard to foresee more than a week in advance (University of Hawai'i Sea Grant College Program 2018). King tides combined with long-term global sea level rise, plus an additional high water level anomaly, resulted in the highest observed tide at Honolulu on August 21, 2017 (Yoon 2021). This type of flooding is predicted to occur more frequently and severely in coming decades with increasing sea level rise.

Figure 4.6-7. High Tide Flooding



Source: (National Oceanic and Atmospheric Administration n.d.)

LOCATION

Event-Based Flooding

FEMA conducts flood studies that use historical records to determine the probability of occurrence for different flood levels in a community. FIRMs show the location of these flood hazard areas. This mapping reflects risk from both coastal and major inland flooding but does not generally reflect risk from urban flooding as it has been defined in the 2023 SHMP Update. There is no statewide system for mapping risk from urban flooding. As a result, the location, extent, and vulnerability of the event-based flood hazard is analyzed using the special flood hazard areas (SFHA) depicted on each county's FIRM, which shows flood zones for rainfall flooding, coastal flooding, shallow flooding, and distinguishes areas where detailed studies have been conducted to determine flood elevations.

The special flood hazard area serves as the regulatory boundary in which each county's flood damage prevention ordinance is enforced. The flood damage prevention ordinance requires that development in the community's SFHAs meet certain standards to reduce damage from flooding, such as being elevated above the base flood elevation. The SFHA shows the horizontal extent of a flood that has a 1% chance of being equaled or exceeded in any given year (e.g., a 1% annual chance flood), while the base flood elevation shows the vertical height of flooding from a 1% annual chance flood at any given location within the SFHA.

The source of flooding used to determine base flood elevations within the SFHA for each county may include a combination of tsunami inundation, freshwater flooding from rain events, and storm surge as FIRMs differentiate flood zones based on flooding characteristics with a 1% annual chance of occurrence and do not differentiate based on flood source (e.g., tsunami, hurricane). Refer to the individual county's Flood Insurance Study (FIS) for details on the hydrologic analyses performed.

Table 4.6-1 displays the total area of each county that is located in the SFHA as calculated by using the National Flood Hazard Layer DFIRM data, effective February 26, 2021. Approximately 2.8% of the entire state is located within the mapped SFHA. The City and County of Honolulu has the largest SFHA area, with 6.9% of its land located in the SFHA. Figure 4.6-8 through Figure 4.6-11 illustrate the SFHAs throughout the State of Hawai'i.

Table 4.6-1. Area Located in the Special Flood Hazard Area by County

County	Area (square miles)		
	Total Area	SFHA	SFHA as Percent (%) of Total Area
County of Kaua'i	624.3	35.0	5.61%
City and County of Honolulu	598.6	41.1	6.86%
County of Maui	1,176.3	48.5	4.12%
County of Hawai'i	4,039.6	53.1	1.31%
Total	6,438.8	177.7	2.76%

Source: FEMA Map Service Center 2021[a]; U.S. Census Bureau 2021
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021

Chronic Coastal Flooding

Chronic coastal flooding is occurring throughout the Hawaiian Archipelago. Maps showing exposure to chronic coastal flooding in the main Hawaiian Islands, depicted as the SLR-XA-1.1, as well as the individual component hazards (passive flooding, erosion, wave overwash), can be found on the Hawai'i Sea Level Rise Viewer (http://www.pacioos.hawaii.edu/shoreline/slr-hawaii/).

Areas that are more susceptible to chronic coastal flooding include low-lying areas along the coast as well as inland areas which are susceptible to groundwater flooding or flooding through coastal storm drains. All exposed coasts around the islands are subject to high wave events at various times of the year. North and west-exposed shores of the islands are subject to extraordinary wave heights each winter, ranging between 20 and 40 feet from swells generated by storms moving across the North Pacific. The south shore, on average, sees waves of 4 to 8 feet each summer from swells generated by distant storms in the South Pacific. High waves in Hawai'i are also generated by approaching storms, including tropical storms and hurricanes in the summer and fall, as well as winter kona storms associated with passing storm fronts. Strong trade wind events also stir up high waves that influence the east-facing shorelines.

The extent of chronic coastal flooding varies by county. Table 4.6-2 shows the hazard area in square miles and the percent of the total area located in the chronic coastal flood hazard area based on the SLR-XA-1.1. The City and County of Honolulu have the largest percent (0.95%) of land in the chronic coastal flood hazard area.

Figure 4.6-8. Special Flood Hazard Areas in the County of Kaua'i

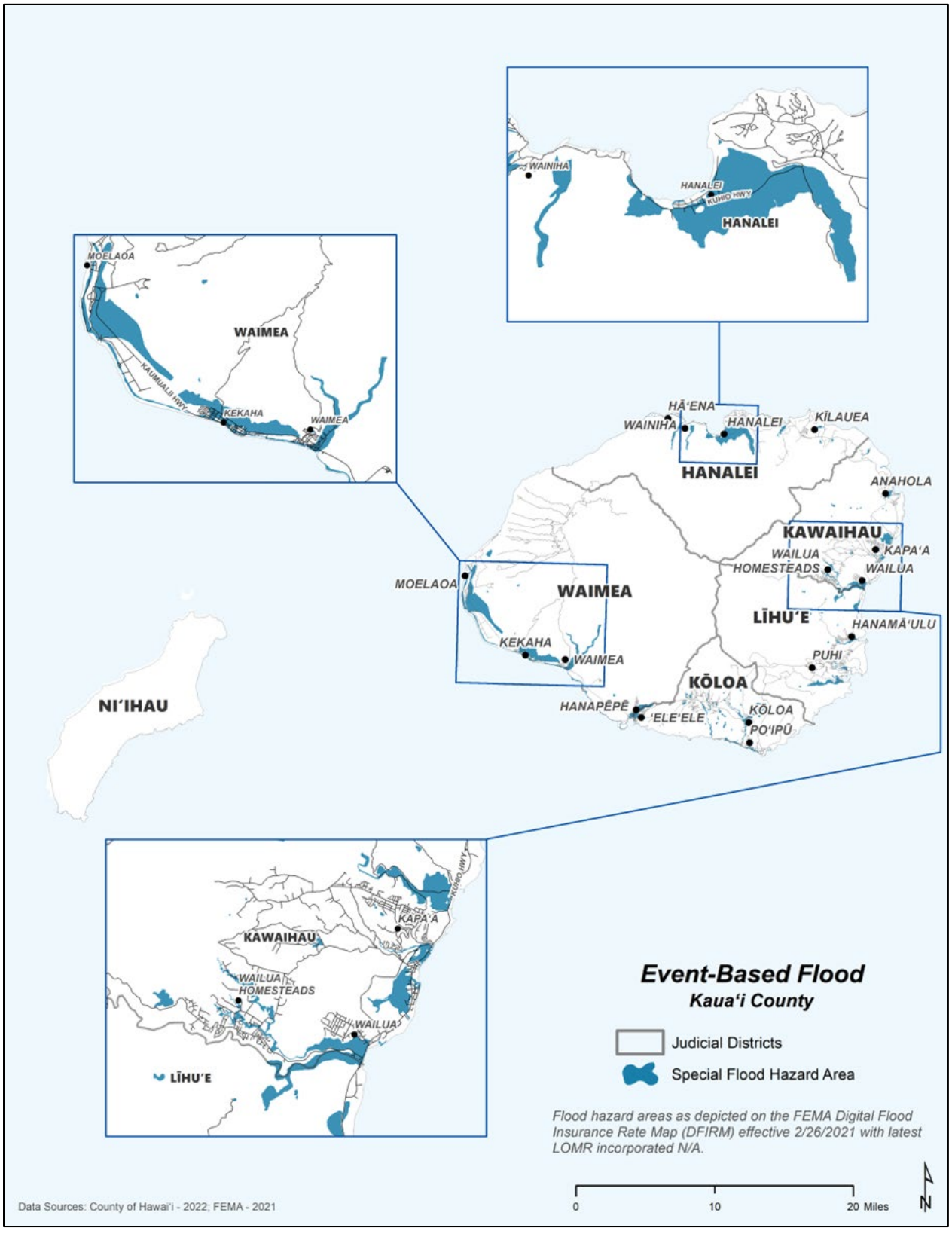


Figure 4.6-9. Special Flood Hazard Areas in the City and County of Honolulu

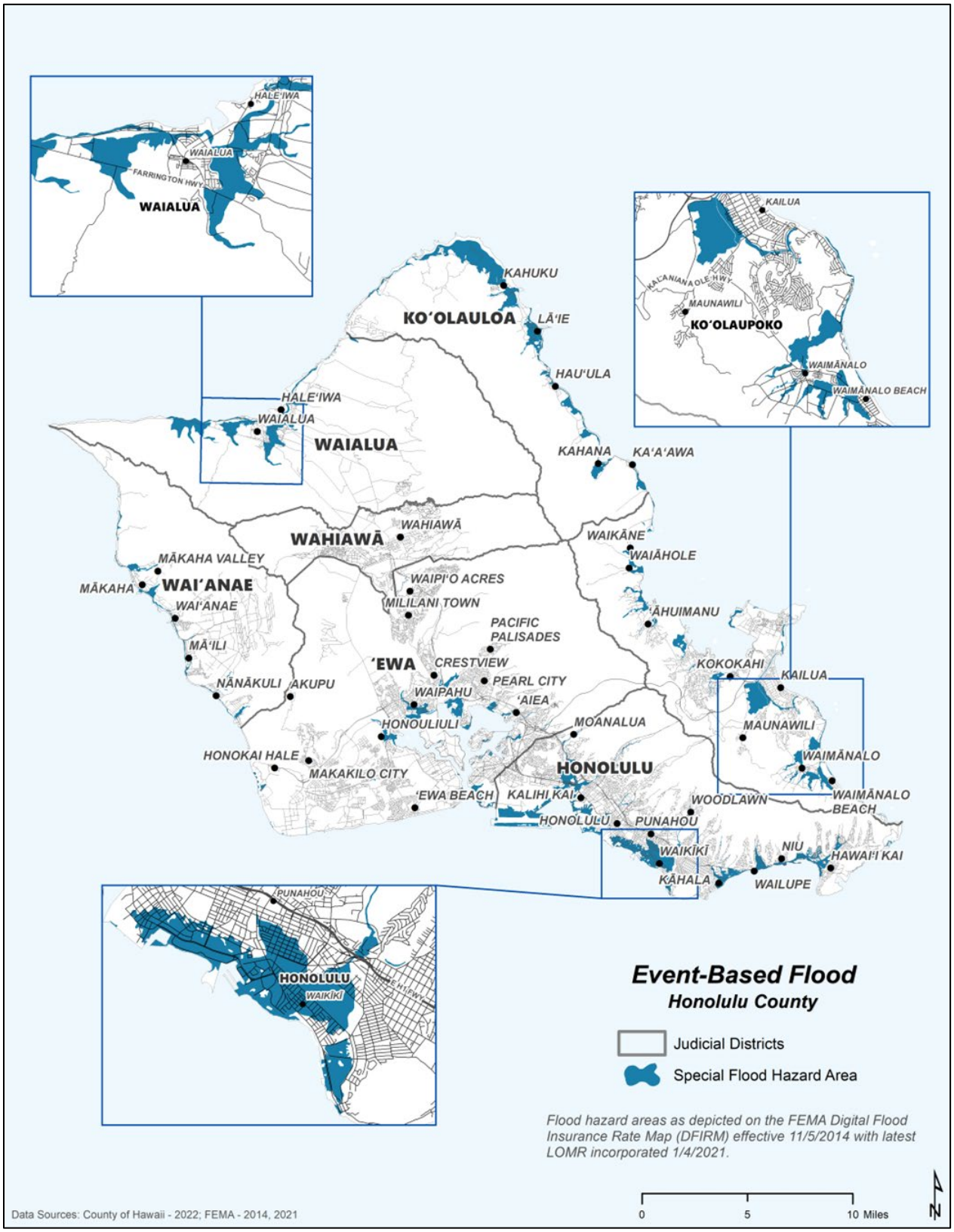


Figure 4.6-10. Special Flood Hazard Areas in the County of Maui

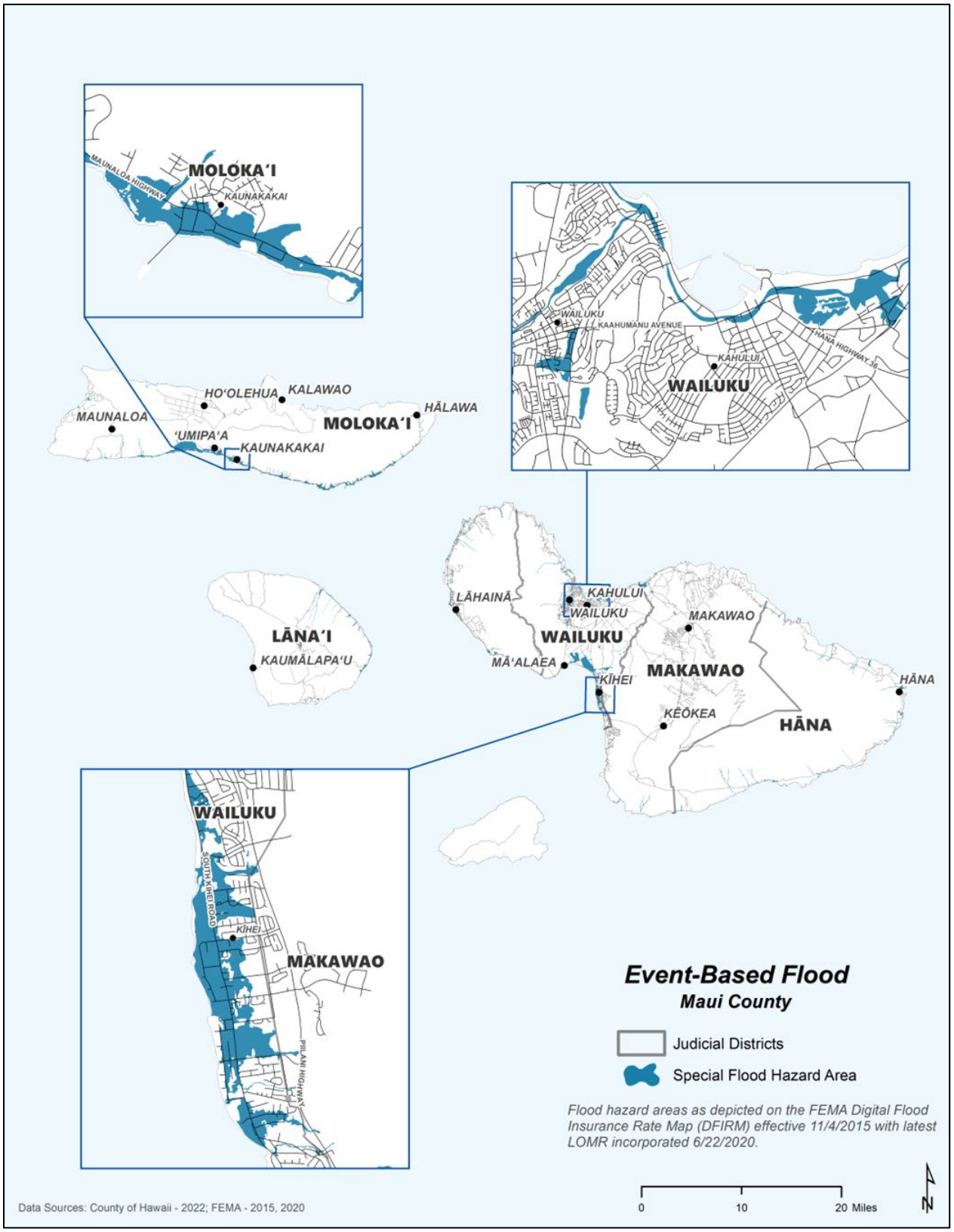


Figure 4.6-11. Special Flood Hazard Areas in the County of Hawai'i

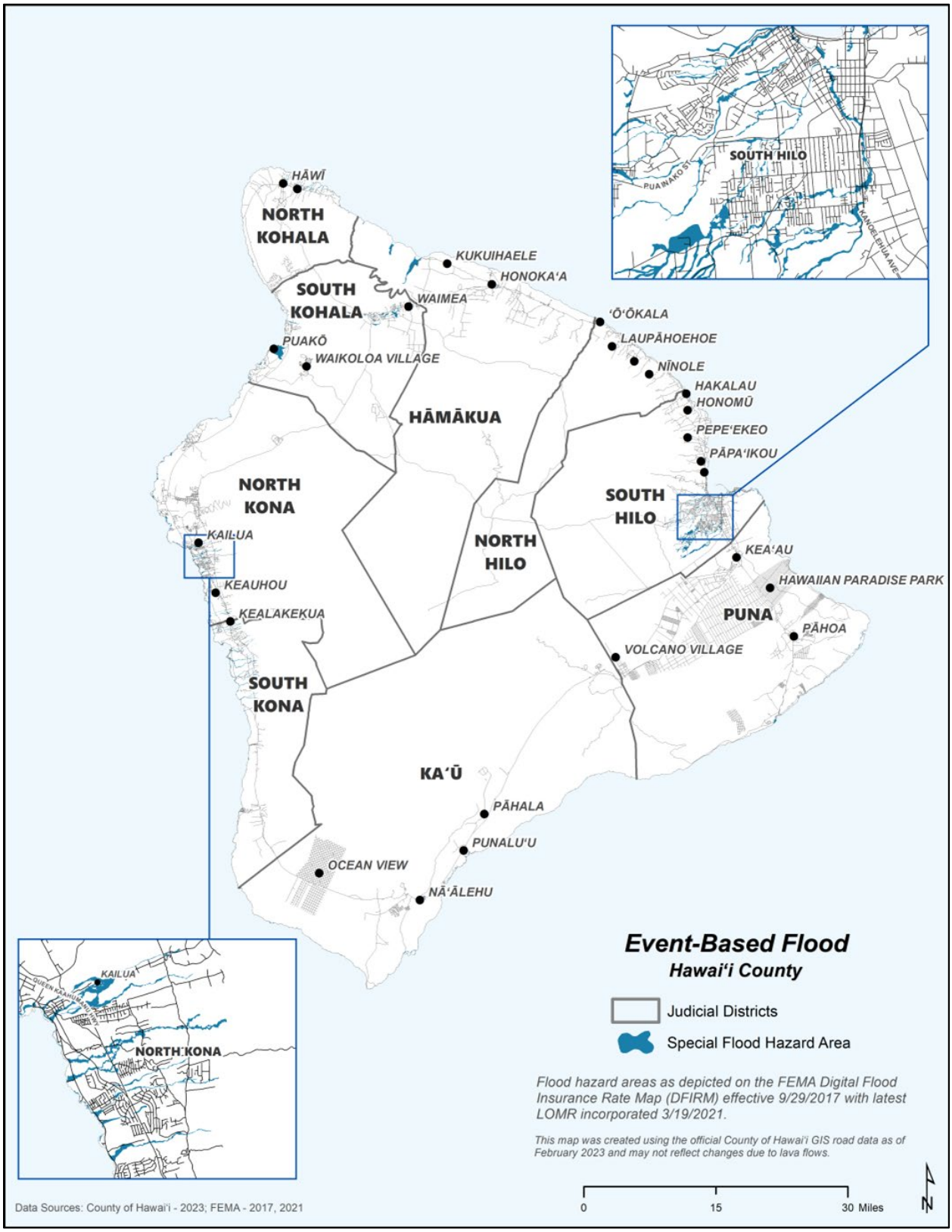


Table 4.6-2. Chronic Coastal Flood Hazard Area (SLR-XA-1.1) by County

County	Area		
	Total Area (square miles)	Chronic Coastal Flood Area (square miles)	Hazard Area as % of Total Area
County of Kaua'i	624.3	4.6	0.74%
City and County of Honolulu	598.6	5.7	0.95%
County of Maui	1,176.3	4.7	0.40%
County of Hawai'i	4,039.7	3.4	0.08%
Total	**6,438.8**	**18.4**	**0.29%**

Source: Hawai'i Climate Change Mitigation and Adaptation Commission 2017; Census Bureau 2021

EXTENT

Event-Based Flooding

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. The special flood hazard area on a community's FIRM is divided into different zones, generally referred to as A-zones and V-zones. These zones represent characteristics of flooding pertaining largely to depth and velocity.

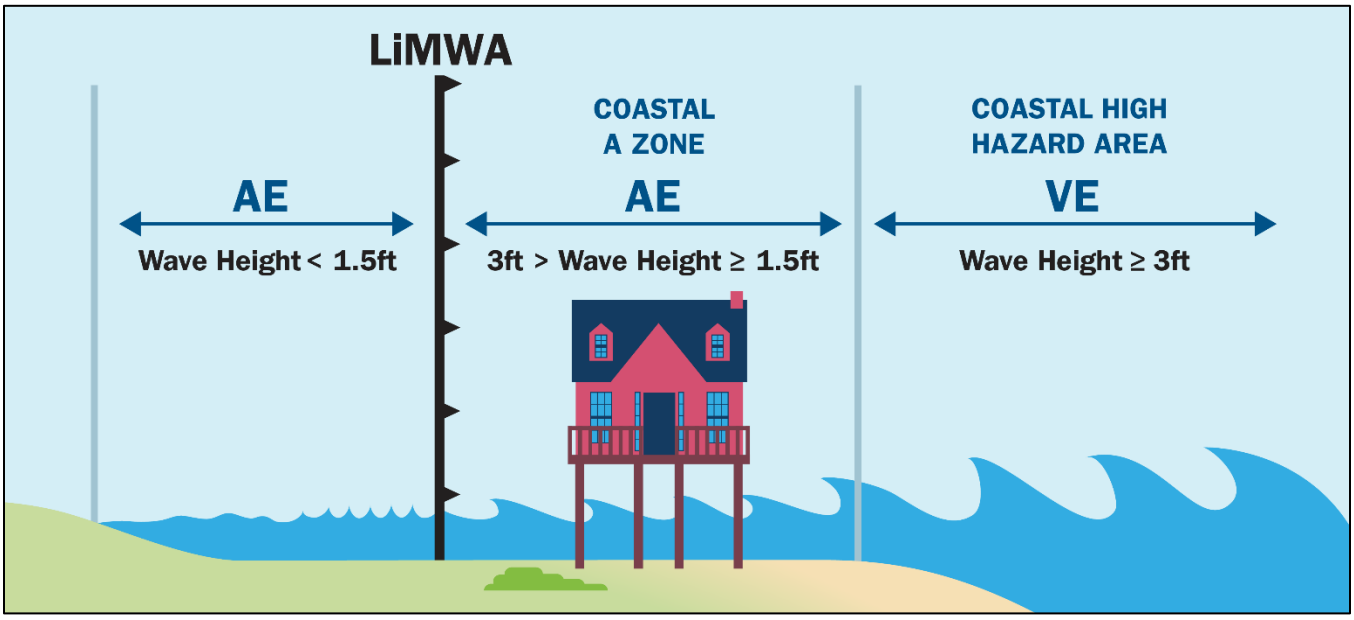
Event-Based Coastal Flooding

Flood severity from coastal flooding is generally determined by wave runup and setup. The degree of damage caused depends on the tidal cycle occurring at the time of the event. During high tides, water levels can be significantly higher than low tide and can inundate further inland causing more extensive damage. The area of impact of storm surge floods is confined to regions along the immediate coastlines and typically extends to a few hundred feet inland (National Hurricane Center n.d.).

On each county's FIRM, areas that have a 1% annual chance of experiencing wave heights of 3 feet or greater are shown as V-zones. These areas have been traditionally known as coastal high hazard areas, and there are stringent requirements in place to ensure that buildings constructed in these areas can withstand the velocities associated with this degree of wave action. Recent studies conducted after large-scale flood events, such as following Hurricane Katrina, have shown that wave heights as small as 1.5 feet can cause considerable damage to structures and other development. This means that V-zones depicted on FIRMs do not include all areas with a 1% annual chance of experiencing wave action velocities significant enough to cause serious structural damage. Some A-zones, commonly referred to as Coastal A-zones, may also be subject to these velocities. Requirements to withstand these wave impacts are not part of required building codes in the Coastal A-zones.

Because of this new information on structure vulnerability, FEMA now delineates an area known as the Limit of Moderate Wave Action (LiMWA) that can be shown on a FIRM when the FIS that provides the basis for the FIRM is updated. The LiMWA generally bisects an A-zone, which shows areas that have a 1% annual chance of flooding and less than 3 feet of expected wave heights. Areas seaward of the LiMWA may experience wave heights of 1.5 feet or greater. Areas landward of the LiMWA may still be flooded by ocean waves or other sources; however, the height of waves will be less than 1.5 feet in a 1% annual chance storm (see Figure 4.6-12). At the time of the 2023 SHMP Update, none of the county's FIRMs show the LiMWA (Department of Land and Natural Resources 2022).

Figure 4.6-12. Coastal Flooding on Flood Insurance Rate Maps



Source: (FEMA 2021)

Inland Flooding

Factors influencing inland flooding conditions include rainfall intensity and duration; rain shed area, topography and steepness, soil type, soil moisture before an event, and ground cover (National Weather Service n.d.). The frequency and severity of inland flooding that occurs along a stream or river is measured using a discharge probability, which is the probability that a certain discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels, which are then used to determine the extent of flooding. Inland flooding that has a 1% annual chance of exceedance is shown on FIRMs as A-zones. Because the county FIRMs do not show LiMWAs as described above, there is no simple way to differentiate between coastal and riverine A-zones besides making an educated guess based on location.

- **Minor Flooding**—minimal or no property damage, but possibly some public threat or inconvenience.
- **Moderate Flooding**—some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- **Major Flooding**—extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations (NOAA n.d.).

Prolonged rainfall may result in an accumulation of water, creating flooding conditions that last several days or even weeks. Alternatively, flooding can occur very quickly in instances of high rainfall intensity. When flooding emerges quickly over a matter of hours, it is known as flash flooding. Flash floods are characterized by rapid rise in water level, high velocity, large amounts of debris, and concentration in stream beds that are often normally small or even dry (National Weather Service n.d.).

Warning Time

It is unusual for a flood to occur without warning. Warning time for floods are typically between 24 and 48 hours. Flood warnings and watches are issued by the local National Weather Service (NWS) office. The NWS will update the watches and warnings and will notify the public when they are no longer in effect.

The NWS issues the following coastal flood advisories, warnings, and watches (National Weather Service n.d.):

- **Coastal Flood Advisory** is issued when minor or nuisance coastal flooding is occurring or imminent.
- **Coastal Flood Watch** is issued when moderate to major coastal flooding is possible. Such flooding could potentially pose a serious risk to life and property.
- **Coastal Flood Warning** is issued when moderate to major coastal flooding is occurring or imminent. This flooding will pose a serious risk to life and property.

The NWS issues the following inland flood advisories, watches, and warnings (National Weather Service n.d.):

- **Flood Watch**—A Flood Watch means heavy rain leading to flash flooding is possible. People in the area of a flash flood watch should be prepared for heavy rains and potential flooding. Flood Watches may be issued up to 48 hours before flash flooding is expected.
- **Flood Advisory**—A Flood Advisory means nuisance flooding is occurring or imminent. A Flood Advisory may be upgraded to a Flash Flood Warning if flooding worsens and poses a threat to life and property.
- **Flash Flood Watch**—A Flash Flood Watch means flash flooding is possible due to either 1) causes other than heavy rain (e.g., dam or levee failure), or 2) heavy rain on burn scars leading to the threat of flash flooding and debris flows.
- **Flash Flood Warning**—A Flash Flood Warning means that flooding is occurring or will develop quickly. If a Flash Flood Warning is issued for an area, the population needs to take shelter and/or move to high ground as necessary. Never drive or walk across a flooded roadway.

Duration of a flood event means the time between the start and end of the flood or the event that caused the flood. This can be difficult to define for floods, particularly inland floods, as they recede slowly and do not vanish completely; flood water moves from one area to another (M&E Studies n.d.). Additionally, the duration of a flood depends on the type of flood. Flash flooding occurs within six hours of a rain event, while other types of flooding are longer-term events and may last a week or more (National Weather Service n.d.).

Flood Control Structures

Flood control structures can significantly alter the extent of flooding in an area. Major flood control structures in the state include dams and levees. For details regarding dams, refer to Section 4.10 (Infrastructure Failure). The following provides information regarding levees located in the state.

Levees are usually earthen embankments or concrete floodwalls, which have been designed and constructed to contain, control, or divert the flow of water to reduce the risk of temporary flooding. Vertical concrete floodwalls may be erected in urban areas where there is insufficient land for an earthen levee. They are designed to provide a specific level of protection and can be overtopped in larger flood events. Levees require regular maintenance to retain their level of protection. Over time, levees decay and require maintenance. When levees fail or overtop, they can cause catastrophic impacts and lead to major flooding and impacts. Areas protected from flooding by levees certified to the 1% annual chance event are not located in SFHAs.

According to the U.S. Army Corps of Engineers (USACE), there are 28 levees in the state that are approximately 14 miles in total length (see Table 4.6-3). These 14 miles are located across the state with: 3.35 miles in the County of Hawai'i, 4.14 miles in the City and County of Honolulu, 2.7 miles in the County of Kaua'i, and 4.14 miles in the County of Maui. Of the 28 levees, 22 have a risk rating of low and 6 are unknown. For more detailed information on these levees, please refer to the Flood Insurance Studies for each county.

Table 4.6-3. Levees in the State of Hawai'i

County	System Name (and Acronym)	Length (in miles)	Construction Date	Date of Last Assessment	Risk
Kaua'i	Waimea River—RB, All Levees (WRR1)	1.44	January 1, 1950	March 15, 2017	Low
Kaua'i	Hanapēpē Stream—RB Levee (HRRB)	0.85	January 11, 1966	April 18, 2017	Low
Kaua'i	Hanapēpē Stream—LB Levee (HRLB)	0.41	January 11, 1966	April 18, 2017	Low
Honolulu	Fort Shafter Flats Flood Mitigation Project	0.31	2013	Not Screened	N/A
Honolulu	Waimalu Stream—NF Debris Basin and Channel (WSNB)	0.54	Unknown	Not Screened	N/A
Honolulu	Kalauao Stream—RB (NOKA)	0.2	April 12, 1966	Not Screened	N/A
Honolulu	Kuli'ou'ou Stream—RB & Channel (KIBR)	0.83	January 2, 1970	November 29, 2018	Low
Honolulu	Kuli'ou'ou Stream—LB & Channel (KIBL)	0.26	January 2, 1970	November 29, 2018	Low
Honolulu	Kawainui Marsh—6850 linear feet Levee, Floodwall and Oneawa Channel (KMFL)	1.5	January 8, 1966	October 27, 2016	Low
Honolulu	Kahawainui Stream—RB Levee (KSLR)	0.5	January 1, 1990	November 29, 2018	Low
Maui	'Īao Stream—Channel at Bottom and LB (ISAL)	0.28	January 10, 1981	May 3, 2018	Low
Maui	Kaunakakai Stream—RB Levee (KSRB)	0.21	January 1, 1950	November 21, 2017	Low
Maui	Kaunakakai Stream—LB Levee (KSUL)	0.72	January 1, 1950	November 21, 2017	Low
Maui	Kahoma Stream—RB, Channel and Levee (KORB)	0.09	January 4, 1990	June 20, 2017	Low
Maui	Kahoma Stream—LB, Channel and Levee (KOLB)	0.3	January 4, 1990	June 20, 2017	Low
Maui	'Īao Stream—Levee I, H, Channel at Bottom—LB (ISIL)	0.76	January 10, 1981	May 3, 2018	Low
Maui	'Īao Stream—Levee G, LB (ISLG)	0.27	January 10, 1981	November 9, 2017	Low
Maui	'Īao Stream—Levee F, LB (ISLF)	0.2	January 10, 1981	November 9, 2017	Low
Maui	'Īao Stream—Levee A, B, C, D, E, H, I, Channel and Revt X, RB (ISLE)	1.31	January 10, 1981	May 11, 2016	Low
Hawai'i	Keōpū Drainageway*	0.11	Unknown	Not Screened	N/A
Hawai'i	Wailoa Stream RB—Diversion Levee 1, 2, 3, 4 & Channel (WSRB)	0.99	January 8, 1965	June 20, 2017	Low
Hawai'i	Wailoa Stream LB (WALB)	0.23	January 8, 1965	February 28, 2018	Low
Hawai'i	Wailoa Stream—Diversion Levee LB 5 (WSL5)	0.07	January 8, 1965	July 31, 2018	Low
Hawai'i	Pā'au'au Stream—All (PALV)	0.4	January 10, 1984	December 18, 2017	Low
Hawai'i	Alenaio Stream LB—Levee, Floodwall C & Lined Channel (ASFC)	0.25	January 11, 1997	July 7, 2016	Low
Hawai'i	Alenaio Stream—Floodwall A, B—RB & Lined Channel (ASFA)	0.27	January 11, 1997	July 7, 2016	Low
Hawai'i	Kamuela Stream Levee	0.33	Unknown	Not Screened	N/A
Hawai'i	Lanimaumau	0.7	Unknown	Not Screened	N/A

Source: (U.S. Army Corps of Engineers n.d.)
Note:
The length, construction date, date of last assessment, and risk rating is for levee structure.
* *Inactive levee*
LB Left Bank
RB Right Bank

Chronic Coastal Flooding

The severity of any flood depends upon the type, cause, duration, and existing conditions (i.e., drainage design and pathways for water to exit). Flooding from severe rain events coupled with high tide flooding increases the severity of chronic coastal flooding.

Warning Time

As defined, chronic coastal flooding includes a range of daily, monthly, and annual occurrences. Warning times for high wave and tide events are available as high surf advisories and high tide advisories.

The NWS Honolulu Forecast Office uses the criteria for the issuance of high surf advisories and warnings in coordination with civil defense agencies and water safety organizations in the State of Hawai‘i (Table 4.6-4). Satellite observations, numerical forecasts, and offshore wave buoys help provide adequate warning to approaching high waves with damaging potential throughout the State of Hawai‘i. The NWS Honolulu Forecast Office issues surf forecasts for the State of Hawai‘i. Surf heights are forecast heights of the face, or front, of waves. It is based on the significant wave height, the average height of the one-third largest waves, at the locations of the largest breakers. Some waves may be more than twice as high as the significant wave height.

Table 4.6-4. High Surf Advisory/Warning Criteria

Location	Advisory	Warning
North-Facing Shores	15 feet	25 feet
West-Facing Shores - Island of Hawai‘i	8 Feet	12 Feet
West-Facing Shores - Remaining Islands	12 Feet	20 Feet
South-Facing Shores	10 Feet	15 Feet
East-Facing Shores	10 Feet	15 Feet

Source: (National Weather Service 2021)
Note:
All surf height observations and forecasts are for the full-face surf height, from the trough to the crest of the wave.

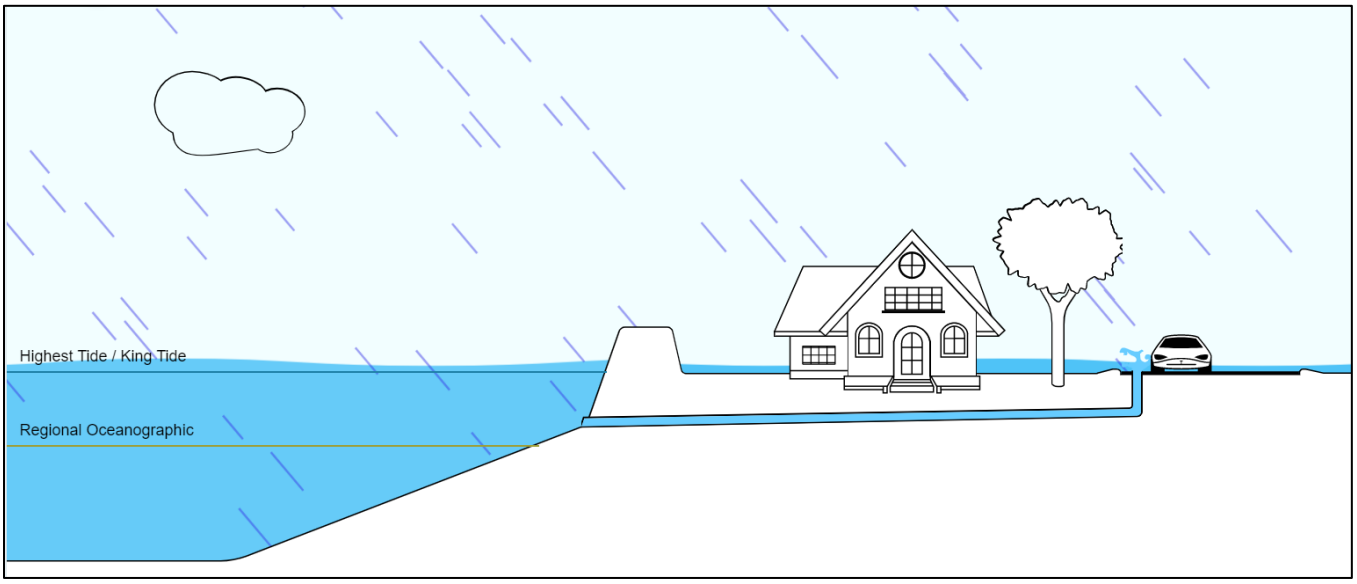
High tide flooding and king tides are fairly predictable due to their occurrence during new or full moons. The National Oceanic and Atmospheric Administration’s (NOAA) tide predictions for the State of Hawai‘i, are based on the astronomical tide calendar and takes into account the gravitational pull of the moon and sun on the Earth’s oceans. Using this information helps provide predictions as to when high tide flooding and king tides may occur and impact low-lying and coastal areas. However, as shown in Figure 4.6-13, impacts from king tides may be compounded by additional high water levels, high waves, storms, and rainfall flooding, which may be predicted only days to a week prior to arrival (NOAA Office for Coastal Mangement 2022).

Previous Occurrences and Losses

Event-Based Flooding

Many sources provided flooding information regarding previous occurrences and losses associated with flooding events throughout the State of Hawai‘i. The 2018 SHMP discussed specific flooding events that occurred in the State of Hawai‘i through 2017. For this 2023 SHMP Update, event-based flood events were summarized between January 1, 2018, and December 31, 2022.

Figure 4.6-13. King Tide Compounded by Rainfall Flooding



Source: (NOAA Office for Coastal Mangement 2022)

Table 4.6-5 includes details of significant flooding events that occurred in the state between 2018 and 2022. These events do not include tropical storms or hurricanes that may also cause flooding; refer to Section 4.9 (Hurricane) for a listing of these events. Major events include those that resulted in losses or fatalities, as reported by the NOAA National Centers for Environmental Information (NCEI), events that resulted in the activation of the state and/or county Emergency Operations Center (EOC), and/or events that led to a FEMA disaster declaration. For events prior to 2018, please refer to Appendix E (Hazard Profile Supplement).

According to the NOAA NCEI storm events database, the State of Hawai'i experienced 96 flash flooding events and 654 heavy rain events that led to flooding between 2018 and 2022. These events caused two deaths and three injuries. Total property damage of $107.3 million and crop damage of $1.8 million were reported.

Disaster and Emergency Declarations

The following disaster declarations or emergency proclamations related to the event-based flood hazard have been issued for Hawai'i:

- **Federal disaster (DR) or emergency (EM) declarations, 1955–2022**: 20 events, classified as flooding, heavy rains, high surf, mudslides, landslides, or severe storms
- **Hawai'i state emergency Proclamations, 2018–2022**: 6 proclamations classified as flood
- **USDA agricultural disaster declarations, 2012–2022**: 2 events classified as flood

Table 4.6-6 lists the event-based flood events that have affected the State of Hawai'i and were declared a FEMA disaster between 2018 and 2022. This list does not include tropical storm or hurricane disaster declarations that may have resulted in flooding; refer to Section 4.9 (Hurricane) for a listing of these events. For details regarding all declared disasters to date, refer to Section 4.1 (Overview). Refer to Appendix D (Map Atlas), which illustrates the number of flood-related federally declared disasters by county since 1955.

Table 4.6-5. Significant Event-Based Flood Events in the State of Hawai'i, 2018 to 2022

Date(s) of Event	Event Type and Federal Disaster Declaration (if applicable)	Counties Affected	Description
January 26, 2018	Heavy Rain	Hawai'i	Two hikers on the Wailuku River were swept away as waters rose from the precipitation. The man was able to make it to the riverbank, but the woman could not be located and was presumed drowned.
February 18, 2018	Flash Flood, High Winds	Hawai'i	Flooding rain damaged a store in Honoka'a, and a man was killed in Holualoa when the farm structure he was in blew off its foundation.
April 2018	DR-4365 Severe Storms, Flooding, Landslides, and Mudslides	Kaua'i and Honolulu	Heavy rains and flooding caused damages and losses to areas in the City and County of Honolulu and the County of Kaua'i. According to NOAA, a rain gauge on Kauai's North Shore recorded 49.69 inches of rain in 24 hours. In the County of Kaua'i, heavy rain caused extensive damage to the slopes adjacent to Kūhiō Highway and impacted the communities of Wainiha and Hā'ena. Multiple landslides led to the closure of the road. Numerous road closures were reported in the impacted areas. Many homes were damaged or destroyed. American Red Cross conducted damage assessments and distributed clean-up kits to residents in Aina Haina, Niu Valley, Kuli'ou'ou, Waimānalo, and Kailua. In the County of Kaua'i, the American Red Cross opened five shelters. Ten residents from Wainiha were airlifted to be taken to a shelter. Between April 13 and 19, the American Red Cross provided shelter to 110 individuals in the County of Kaua'i. $19.8 million in damages were reported. Governor Ige declared the District of Hanalei in the County of Kaua'i a disaster area. A federal disaster declaration was issued for Kaua'i and Honolulu Counties. Funding obligations included nearly $1.6 million in Individual Assistance, $15.5 million in Public Assistance, and nearly 2.8 million in Hazard Mitigation Assistance.
November 3, 2018	Heavy Rain, Flash Flood	Hawai'i	Thirteen hikers were stranded by flash flooding near Waimea. Two suffered minor injuries.
November 16, 2019	Flash Flood, Thunderstorm Wind	Kaua'i, Hawai'i	Flash flooding on Kaua'i and Hawai'i. Kūhiō Highway was closed at Hanalei Bridge and became impassable at the Twin Bridges in Wainiha due to water overflowing the rivers. A woman was rescued by the Kaua'i Fire Department after being swept away by the flood waters.
March 28, 2020	Heavy Rain, Flash Flood	Kaua'i	Kūhiō Highway was closed in two locations: near the Hanalei Bridge when the river overflowed its banks and in Wailua as debris piled up against the Wailua River Bridge. Homes and businesses sustained $30.6 million in reported damages.
February 18, 2021	Heavy Rain	Kaua'i, Honolulu, Maui, Hawai'i	Downpours over East Maui contributed to the death of a 26-year-old woman who was swept out to sea when Waioka Pond near Hāna became swollen by waters coming down the slope from near the Haleakala summit.
February 26, 2021	Heavy Rain	Honolulu, Maui, Hawai'i	Heavy rain cause ponding on roadways and small stream and drainage ditch flooding. Two hikers in East Maui were killed after being swept out to the ocean by a surging stream.
March 8-9, 2021	DR-4604 Severe Storms, Flooding, and Landslides	Kaua'i, Honolulu, Maui	Heavy showers and thunderstorms caused flash flooding that washed out bridges and roads; more than 100 homes were damaged or destroyed. The Hāna Highway in East Maui was closed, and water topped a dam in the same area, but no dam failure occurred. Kamehameha Highway and other roads in Honolulu County were flooded. Kūhiō Highway was closed near the Hanalei Bridge in Kaua'i, and the Keapana Bridge in Kapa'a became impassible. $47.1 million in structure damage and $1.8 in crop damage was reported. A federal disaster declaration was issued for Maui County, with nearly $6 in Public Assistance grants obligated.

Date(s) of Event	Event Type and Federal Disaster Declaration (if applicable)	Counties Affected	Description
May 1, 2022	Heavy Rain, Thunderstorms, Flash Flood	Maui, Hawai'i	A flash flood occurred on Maui between mile markers 31 and 39 along Pi'ilani Highway. A culvert was washed out. Additional stream and ditch flooding and ponding on roadways occurred in other parts of Maui and Hawai'i Counties. $1.2 million in damages were reported.

Source: (FEMA 2022, NOAA 2022)
Notes:
With flood documentation for the State of Hawai'i being so extensive, not all sources have been identified or researched. Additionally, loss and impact information for many events could vary depending on the source. Therefore, this table may not include all events that have occurred in the state and the accuracy of monetary figures discussed is based only on the available information identified during research for this 2023 SHMP Update.
The State of Hawai'i did experience flooding as a result of Hurricane Hector 2018, Hurricane Lane 2018 (DR-4194), Tropical Storm Olivia 2018, Tropical Storm Erick 2019, Hurricane Douglas 2020, and Hurricane Linda 2021. Flooding from hurricanes is discussed further in Section 4.9 (Hurricane).

Table 4.6-6. Flood-Related Federal Declarations (2018 to 2022)

Year	Event Type	Date Declared	Federal Designation	Counties Affected
2018	Severe Storms, Flooding, Landslides, and Mudslides	May 8, 2018	DR-4364	Honolulu and Kaua'i
2021	Severe Storms, Flooding, and Landslides	May 13, 2021	DR-4604	Maui

Source: (FEMA 2022)
Note:
Hurricane Lane 2018 (DR-4194), is in Section 4.9 (Hurricane).

Repetitive Loss Properties

Properties that are located within the SFHA and have federally backed mortgages or were constructed using federal or federally-related financial assistance are required to purchase flood insurance. When an insured property is damaged by flooding, they typically file a claim. If the insured property has had at least two paid flood losses of more than $1,000 each in any 10-year period since 1978, they are referred to as a Repetitive Loss (RL) property (FEMA 2020). An insured property is known as a Severe Repetitive Loss (SRL) property if: (1) the insured property has had four or more paid flood losses of $5,000 (amount of each claim) and a total amount of claims payments of $20,000; or (2) the insured property has had at least two separate claims that have been paid with the cumulative amount of claim payments exceeding the market value of the building (FEMA 2020).

Chronic Coastal Flooding

The 2018 SHMP discussed specific coastal erosion and high wave flooding events that occurred in the State of Hawai'i through 2017. For this 2023 SHMP Update, high wave flooding, coastal erosion, and tidal flooding/king tides were summarized between January 1, 2018, and December 31, 2022. For events prior to 2018, please refer to Appendix E (Hazard Profile Supplement). Table 4.6-7 includes details regarding significant chronic coastal flooding that occurred in the state between 2018 and 2022. Major events include those that resulted in losses or fatalities, as reported by NOAA NCEI, events that resulted in the activation of the state or county EOC, and events that led to a FEMA disaster declaration.

Table 4.6-7. Significant Chronic Coastal Flooding Events in Hawai'i, 2018 to 2022

Date(s) of Event	Event Type	Counties Affected	Description
March 21-22, 2018	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	Both lanes of Bayfront Highway in Hawai'i County were shut down because of water and debris washing ashore, and county parks were closed from Coconut Island eastward through Keaukaha as water was coming into the parking areas.
June 4-6, 2018	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	A swell from the Southern Hemisphere generated surf of 6 to 12 feet along the south-facing shores on all the islands. Two 21-year-old women on O'ahu required hospitalization for arm and leg injuries.
January 27-31, 2019	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	High surf of 8–15 feet was recorded along east-facing shores. Bayfront Highway on Hawai'i Island was closed because of debris and water on the roadway from the high surf.
December 7-8, 2019	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	The high surf caused an overwash along Bayfront Highway on Hawai'i Island, leaving debris on the roadway. A foot of standing water was observed on Coconut Island in Hilo.
December 1-3, 2020	High Surf, Erosion	Kaua'i, Honolulu, Maui	A large swell from the northwest generated surf of 20 to 30 feet, with sets to 40 feet. Ocean safety personnel performed many rescues and issued warnings to surfers and beachgoers because of the dangerous surf conditions. Significant erosion was reported at Sunset Beach on O'ahu's North Shore due to the elevated surf.
October 8-11, 2021	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	The combination of a trade wind swell and a swell from the Southern Hemisphere generated surf of 6–12 feet along the east- and south-facing shores of all the islands. A 24-year-old man was swept off a rocky ledge by large waves in East O'ahu. He was presumed drowned as the search ended after three days without success.
January 21-24, 2022	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	A large northwest swell generated surf of 15–25 feet, with occasional sets above 30 feet. Three individuals were injured, one critically, in the rough surf.
February 25-27, 2022	High Surf, Erosion	Kaua'i, Honolulu, Maui, Hawai'i	A large swell from the west-northwest generated surf of 20–30 feet, with occasional sets to 40 feet. Beach erosion caused by many episodes of high surf over the years undercut a home which collapsed on O'ahu's North Shore between Rocky Point and Sunset Beach. Damages of $115,000 were reported.
July 13-19, 2022	High Surf	Kaua'i, Honolulu, Maui, Hawai'i	A large, long-period swell from the Southern Hemisphere generated surf of 10–20 feet along the south-facing shores of all the Hawaiian Islands. Ho'one Road in Poipu on the island of Kauai was temporarily closed after sustained damage from the high surf. $7,000 in property damages were recorded.

Source: (NOAA 2022)

With flood documentation for the State of Hawai'i being extensive, not all sources have been identified or researched. Additionally, loss and impact information for many events could vary depending on the source. Therefore, Table 4.6-7 may not include all events that have occurred in the state and the accuracy of monetary figures discussed is based only on the available information identified during research for this 2023 SHMP Update.

According to the NOAA NCEI storm events database, the State of Hawai'i experienced 1,889 chronic coastal flooding events between 2018 and 2022. These events caused one death and five injuries. Total property damage of $122,000 was reported.

Disaster and Emergency Declarations

The following disaster declarations or emergency proclamations related to the chronic coastal flood hazard have been issued for Hawai'i:

- **Federal disaster (DR) or emergency (EM) declarations, 1955 – 2022**: 5 events, classified as severe storms, high wave flooding, flooding, heavy rains, and land/mudslides
- **Hawai'i state emergency Proclamations, 2018 – 2022**: none
- **USDA agricultural disaster declarations, 2012 – 2022**: none

During the 2018 SHMP Update performance period, the state has not had any declared disasters or emergencies related to the chronic coastal flood hazard. For details regarding all declared disasters, refer to Section 4.1 (Overview) and Appendix D (Map Atlas).

Probability of Future Hazard Events

Event-Based Flooding

Overall Probability

Flooding is common in the State of Hawai'i and can take place any time of the year; however, flooding is more frequent during the rainy season which runs from October through April. Based on the history of flood events and the evidence of climate change and sea level rise, flood events may become more frequent throughout the State of Hawai'i.

The recurrence interval of a flood, or flood frequency, is the average number of years between floods of a certain size. The actual number of years between floods of any given size varies because of the natural variations in climate and weather events (U.S. Geological Survey 2018). As discussed previously, FIRM maps identify a flood hazard area as the area that would be inundated by a flood with a 1% chance of occurring annually (FEMA 2021). These measurements reflect statistical averages only; it is possible for two or more floods with a 1% annual or greater chance to occur in a short time period. Table 4.6-8 describes the recurrence intervals and probabilities of occurrence for flood events.

Table 4.6-8. Recurrence Intervals and Probabilities of Occurrence

Recurrence Interval (in years)	Probability of Occurrence in Any Given Year	Percent Chance of Occurrence in Any Given Year
100	1 in 100	1%
50	1 in 50	2%
25	1 in 25	4%
10	1 in 10	10%
5	1 in 5	20%
2	1 in 2	50%

Source: (U.S. Geological Survey n.d.)

For the 2023 SHMP Update, the most up-to-date information was collected to calculate the probability of future occurrence of event-based flood events, of all magnitudes, in the State of Hawai'i. Information from FEMA and NOAA NCEI were used to identify the number of event-based flood events that occurred between 2018 and 2022. Using these resources ensures the most accurate probability estimates possible. Based on these historic statistics,

the State of Hawai‘i has a 100% chance of an event-based flood, of any magnitude, occurring any given year and can experience approximately 19 event-based flood events and 131 heavy rain events that lead to flooding each year. The state has a 40% chance (or two declarations every five years) of receiving a FEMA declaration for event-based floods in any given year. However, some areas in the state are more flood prone than others, and the frequency and size of flood events varies.

Climate Change Impacts

Climate projections for the State of Hawai‘i indicate an overall decline in rainfall; however, the state will experience an increase in heavy rain events, causing more frequent or intense flash flooding, infrastructure damage, runoff, and sedimentation. Sea level is also projected to rise, increasing the risk of coastal flooding from hurricanes and tropical storms. Event-based coastal flooding with sea level rise would increase the extent of the area subject to flooding from storm events where streams and rivers empty into the ocean. Beach and wetland systems may not be able to adapt to rising sea levels and could be lost if not able to migrate inland. Their loss reduces the coast’s ability to buffer impacts from storms and flooding (U.S. Environmental Protection Agency 2016). Overall, it is highly likely that changing future conditions will exacerbate current conditions and increase future event-based flood risk for inland and coastal areas statewide.

For additional information on impacts resulting from climate change and sea level, refer to Section 4.2 (Climate Change and Sea Level Rise) and Section 4.9 (Hurricane).

Chronic Coastal Flood

Overall Probability

Over time, recurring flooding at the highest tides in low-lying areas leads to chronic flooding and then to permanent flooding and permanent loss. Overall, the probability of future chronic coastal flooding will increase with increasing sea level rise and punctuated by severe flood events that will be clustered in time around high tides and/or periods of elevated water levels.

Chronic beach erosion leads to shoreline erosion and loss of shorefront property, resulting in loss of natural protection from coastal flooding and inundation. Coastal erosion will increase with increasing sea level rise in coming decades which will contribute to permanent loss and submergence of coastal lands. Shoreline recession and beach loss due to coastal erosion is already a severe problem along the State of Hawaii’s coastline, threatening shorefront development and infrastructure. Statewide, 70% of the State of Hawaii’s shorelines have retreated over years to decades (Anderson, et al. 2018). The frequency of episodic erosion events is related to the return period of a coastal storm, hurricane or tropical storm. However, the impacts of episodic erosion events will increase with climate change and sea level rise.

High wave flooding events occur frequently on exposed coasts of all islands in the State of Hawai‘i. Events that actually cause damage to property or loss of human life are far less common. During the time period from January 1, 2018, to December 31, 2022, high surf conditions and impacts occurred annually in the State of Hawai‘i. Based on the history of high wave flooding in the state, the State of Hawai‘i can expect high wave flooding events on an ongoing basis, with increasing impacts from climate change and sea level rise.

The probability of tidal flooding/king tides is predictable based on lunar cycles. However, impacts from king tide events depend on wave conditions, weather, and any additional water level anomalies. Low-lying areas in the State of Hawai'i have the highest probability of experiencing regular flooding from tides and king tides. As the sea level rises, these areas will become more vulnerable to regular flooding at high tides. The greatest potential for flooding from king tides alone is predictable and occurs in summer and winter months around new and full moons when the moon is at its closest point to the Earth (University of Hawai'i Sea Grant College Program 2018).

Climate Change Impacts

The frequency, extent and severity of chronic coastal flooding will increase with sea level rise. Sea level rise of 3 feet or more by the end of this century appears increasingly likely (National Oceanic and Atmospheric Administration 2022). For the 2023 SHMP Update, mid- to late-century sea level rise on chronic coastal flooding was assessed using the SLR-XA with 3.2 feet of sea level rise (SLR-XA-3.2). Statewide impacts are discussed further in Section 4.2 (Climate Change and Sea Level Rise). Overall, the loss of land and structures will take the form of incrementally eroding beaches, waterfront property inundated by increasingly high tides and by seasonal waves that reach farther inland, and low-lying areas becoming wetlands because of rising water tables and reduced drainage. However, these chronic processes will be punctuated by less frequent but more severe events such as storms, extreme high wave events, or high water level events. The estimated total amount of land loss is less than 1% of the state's total land area; however, much of this land is located in high-density urban, commercial, and industrial districts leading to great potential economic, societal, and environmental impacts for the state (Hawai'i Climate Change Mitigation and Adaptation Commission 2017).

4.6.2 VULNERABILITY ASSESSMENT

Event-Base Flooding

To assess the state's risk to the event-based flood hazard, a spatial analysis was conducted using the best available spatially-delineated flood hazard areas. To determine exposure, the hazard areas were overlaid with the assets to determine the total number and replacement cost value located in the hazard areas. If the asset is in the hazard area, it is deemed exposed to the hazard and potentially vulnerable to loss. FEMA's Hazus flood model was used to estimate potential losses to structures from event-based flooding by looking at the depth of flooding at each structure location.

EVENT-BASED FLOOD HAZARD AREA DEFINITION

Special Flood Hazard Area (SFHA)—The 1% annual chance flood as depicted on the FEMA Flood Insurance Rate Maps (inclusive of V- and A-zones).

Exposure represents assets located in the SFHA.

Estimated potential losses are calculated for the 1% annual chance flood event for assets located in the SFHA.

To evaluate vulnerability to event-based flooding, the SFHA was used. Estimated 1% annual chance flood depth grids were generated utilizing 3D Analyst tools in ArcGIS for A-zones and V-zones. The depth grids were integrated

into Hazus version 5.1, and the flood model was run to estimate potential losses to state buildings and critical facilities as user-defined facilities and the default general building stock in Hazus.

According to DLNR, the flood maps need to be updated due to new development. In addition, there are large sections in the City and County of Honolulu and the County of Hawai'i that have not been studied. Therefore, the estimated results below may be underestimating vulnerability.

As discussed previously, structures located in coastal high hazard areas (V-zones) are at considerable risk of structural damage due to wave action velocities. In order to highlight this added degree of risk, as well as the additional construction requirements in these areas, exposure and vulnerability estimates presented in the following sections show both V-zone risks and the combined risk (A-zone and V-zone) for the special flood hazard area.

When interpreting the information presented, it is important to remember that the entire state is unlikely to experience impacts from a 1% annual chance flood event in all SFHAs at the same time.

Chronic Coastal Flooding

CHRONIC COASTAL FLOOD HAZARD AREA DEFINITION

SLR-XA 1.1—To assess vulnerability to chronic coastal flooding the area generated by modeling of passive flooding, annual high wave flooding and coastal erosion (known as the SLR-XA) with 1.1 feet of sea level rise was used. The hazard area is called SLR-XA-1.1.

To assess the state's risk to the chronic coastal flood hazard, the SLR-XA-1. 1, developed for the *Hawai'i Sea Level Rise Vulnerability and Adaptation Report,* was used. Overall, vulnerability to chronic coastal flooding is assessed as chronic flooding with the potential permanent loss of assets and displacement of population located in the SLR-XA-1.1 hazard area.

ASSESSMENT OF STATE VULNERABILITY AND POTENTIAL LOSSES

Event-Based Flooding

This section discusses statewide vulnerability of areas susceptible to event-based flooding and potential losses to state assets (state buildings and state roads) and critical facilities.

State Assets

The exposure analysis for the event-based flooding hazard determined there are 489 state buildings (8.02%) located in the SFHA, of which 97 are located in the V-zone. As noted earlier, buildings located in the V-zone are at considerable risk of structural damage due to wave velocity. The City and County of Honolulu has the greatest total replacement cost value exposed to the SFHA ($635.8 million). The Department of Education has the greatest total replacement cost value exposed ($478.5 million). Table 4.6-9 summarizes the state buildings located in the SFHA by county. Table 4.6-10 summarizes state buildings' exposure and potential loss to event-based flooding by agency.

Table 4.6-9. State Buildings Located in the Special Flood Hazard Area by County

County	State Buildings in the SFHA (A- and V-Zones)		State Buildings in the V-Zone	
	Number	Total Replacement Cost Value	Number	Total Replacement Cost Value
County of Kaua'i	82	$126,300,316	2	$117,931
City and County of Honolulu	320	$635,827,829	69	$32,866,631
County of Maui	50	$160,108,533	18	$34,915,727
County of Hawai'i	37	$43,844,062	8	$3,931,360
Total	**489**	**$966,080,739**	**97**	**$71,831,649**

Source: FEMA Map Service Center 2021[a]; State of Hawaii Risk Management Office 2017
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021

Table 4.6-10. State Buildings Exposure and Potential Loss to the 1% Annual Chance Flood Event by Agency

Agency	Total Number of State Buildings	Total Replacement Cost Value	State Buildings Located in the SFHA				Potential Loss to the 1% Annual Chance Flood Event	
			Number	Percent (%) of Total Buildings	Replacement Cost Value	Percent (%) of Total Value	Estimated Potential Loss	Percent (%) of Total
Dept of Accounting & General Services	66	$953,963,738	6	9.09%	$50,683,417	5.31%	$1,292,066	0.1%
Dept of Agriculture	70	$147,607,399	5	7.14%	$5,736,536	3.89%	$11,771	0.0%
Dept of Attorney General	15	$108,425,480	1	6.67%	$2,254,706	2.08%	$0	0.0%
Dept of Budget & Finance	16	$28,968,679	1	6.25%	$138,422	0.48%	$0	0.0%
Dept of Business, Economic Development and Tourism	25	$645,480,379	2	8.00%	$26,786,125	4.15%	$8,787,528	1.4%
Dept of Commerce & Consumer Affairs	2	$40,197,360	0	0.00%	$0	0.00%	$0	0.0%
Dept of Defense	69	$267,352,836	17	24.64%	$70,600,137	26.41%	$24,722,355	9.2%
Dept of Education	4,090	$10,598,205,739	266	6.50%	$478,499,519	4.51%	$22,966,821	0.2%
Dept of Hawaiian Home Lands	12	$110,427,352	1	8.33%	$5,489,080	4.97%	$2,505,204	2.3%
Dept of Health	44	$387,068,440	1	2.27%	$429,251	0.11%	$60,274	0.0%
Dept of Human Resources Development	1	$5,973,872	0	0.00%	$0	0.00%	$0	0.0%
Dept of Human Services	130	$480,212,294	8	6.15%	$11,373,036	2.37%	$2,047,882	0.4%
Dept of Labor and Industrial Relations	22	$90,076,209	2	9.09%	$2,600,740	2.89%	$0	0.0%
Dept of Land and Natural Resources	90	$101,441,821	28	31.11%	$13,847,149	13.65%	$1,224,374	1.2%
Dept of Public Safety	154	$440,774,415	14	9.09%	$33,728,750	7.65%	$3,431,909	0.8%
Dept of Taxation	1	$7,174,162	0	0.00%	$0	0.00%	$0	0.0%
Dept of Transportation	68	$2,935,208,214	25	36.76%	$93,067,111	3.17%	$1,197,404	0.0%
Hawai'i State Ethics Commission	1	$984,533	0	0.00%	$0	0.00%	$0	0.0%

Agency	Total Number of State Buildings	Total Replacement Cost Value	State Buildings Located in the SFHA				Potential Loss to the 1% Annual Chance Flood Event	
			Number	Percent (%) of Total Buildings	Replacement Cost Value	Percent (%) of Total Value	Estimated Potential Loss	Percent (%) of Total
Hawai'i Health Systems Corporation	106	$1,230,852,871	1	0.94%	$936,734	0.08%	$0	0.0%
Hawai'i Housing Finance & Development Corporation	86	$360,851,671	1	1.16%	$39,460,800	10.94%	$6,031,270	1.7%
Hawai'i Public Housing Authority	273	$982,981,701	42	15.38%	$53,507,728	5.44%	$1,445,595	0.1%
Hawai'i State Legislature	2	$48,555,381	0	0.00%	$0	0.00%	$0	0.0%
Hawai'i State Public Library System	53	$525,584,082	8	15.09%	$15,206,807	2.89%	$1,637,290	0.3%
Judiciary	41	$534,877,354	1	2.44%	$2,284,530	0.43%	$0	0.0%
Legislative Reference Bureau	1	$2,996,162	0	0.00%	$0	0.00%	$0	0.0%
Office of Hawaiian Affairs	11	$54,125,645	5	45.45%	$17,170,287	31.72%	$3,120,281	5.8%
Office of the Auditor	2	$1,921,180	0	0.00%	$0	0.00%	$0	0.0%
Office of the Governor	1	$2,996,162	0	0.00%	$0	0.00%	$0	0.0%
Office of the Lieutenant Governor	2	$4,588,849	0	0.00%	$0	0.00%	$0	0.0%
Office of the Ombudsman	1	$1,818,060	0	0.00%	$0	0.00%	$0	0.0%
Research Corporation of the University of Hawai'i	3	$4,189,026	1	33.33%	$463,328	11.06%	$171,583	4.1%
University of Hawai'i	637	$5,014,974,503	53	8.32%	$41,816,547	0.83%	$7,242,144	0.1%
Total	**6,095**	**$26,120,855,568**	**489**	**8.02%**	**$966,080,739**	**3.70%**	**$87,895,751**	**0.3%**

Source: FEMA Map Service Center 2021[a]; State of Hawaii Risk Management Office 2017; FEMA Hazus v5.1
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021

Hazus estimates $87.9 million in damages to state buildings as a result of the 1% annual chance flood. This does not include the cost of damage to roads or utilities, which could be considerable. The City and County of Honolulu is estimated to experience the greatest loss ($78 million, or 0.5% of the county's total building replacement cost value), with more than $8 million of the total loss located in the V-zone. Table 4.6-11. The Department of Education and the Department of Defense occupy buildings with the greatest potential loss, nearly $23 billion and $24.7 billion in damages, respectively which equate to more than half of the state building estimated loss.

Statewide, there are 85.5 miles of state roads exposed to event-based flooding. There is a major public safety hazard when residents attempt to drive on flooded roadways. Many state roads serve as evacuation routes to higher ground. Not only will these roads be closed during a flood event and potentially isolate communities, the flood waters may accelerate the degradation of these roads, leading to increased repair and replacement costs. Bridges exposed to flood events can be extremely vulnerable due to the forces transmitted by the velocity and by the impact of debris carried by the water.

Table 4.6-11. State Building Estimated Potential Loss to the 1% Annual Chance Flood Event by County

County	Total Replacement Cost Value	Estimated Potential Loss to the 1% Annual Chance Flood Event (A- and V-Zones)		Estimated Potential Loss in the V-Zone Only	
		Replacement Cost Value	Percent (%) of Total	Replacement Cost Value	Percent (%) of Total
County of Kaua'i	$990,850,824	$8,512,936	0.9%	$17,290	0.0%
City and County of Honolulu	$17,393,945,915	$78,383,895	0.5%	$8,214,065	0.0%
County of Maui	$3,097,491,689	$0	0.0%	$0	0.0%
County of Hawai'i	$4,638,567,141	$998,920	0.0%	$221	0.0%
Total	**$26,120,855,568**	**$87,895,751**	**0.3%**	**$8,231,575**	**0.0%**

Source: FEMA Map Service Center 2021[a]; State of Hawaii Risk Management Office 2017; FEMA Hazus v5.1
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021

Table 4.6-12 shows the length of state roads in the SFHA by county. The City and County of Honolulu has the greatest number of miles (44.9 miles) exposed, followed by the County of Maui (20.7 miles). A complete list of state roads, located in the A- and V-zones, and by individual road name, is included in Appendix F (State Profile and Risk Assessment Supplement).

Table 4.6-12. State Road Exposure to the 1% Annual Chance Flood Event by County

County	Length (in miles)		
	Total Length	Length in the SFHA	Percent (%) of Total Length
County of Kaua'i	103.7	15.5	14.95%
City and County of Honolulu	374.9	44.9	11.98%
County of Maui	245.9	20.7	8.42%
County of Hawai'i	379.2	4.4	1.16%
Total	**1,103.70**	**85.5**	**7.75%**

Source: State of Hawaii Department of Transportation 2022; FEMA Map Service Center 2021[a]
Note:
a. *National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021*

Community Lifelines and Critical Facilities

Critical transportation hubs and critical infrastructure located are exposed to the event-based flood hazard. Utility lines commonly follow roads, and those located underground may be impacted, resulting in disruption of services. Table 4.6-13 summarizes the total number of community lifelines and additional critical facilities by category located in the SFHA by county. The City and County of Honolulu has the greatest number of community lifelines (68) exposed, followed by the County of Maui (42). Table 4.6-14 summarizes the community lifeline and critical facility exposure and potential losses by category. Safety and security has the greatest estimated potential loss at $3.87 billion, followed by food, water, and shelter with greater than $1.87 billion.

Table 4.6-13. Community Lifelines and Critical Facilities Located in the 1% Annual Chance Flood Event, by County

County	Community Lifeline Categories								Additional Critical Facilities
	Communications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medial	Safety & Security	Transportation	Total in the 1% Annual Chance Flood Event	
County of Kaua'i	2	1	7	0	0	8	0	18	2
City and County of Honolulu	12	14	20	0	2	15	2	65	3
County of Maui	2	1	17	0	4	8	8	40	2
County of Hawai'i	0	2	13	1	0	1	5	22	1
Total	**16**	**18**	**57**	**1**	**6**	**32**	**15**	**145**	**8**

Source: Hawai'i Emergency Management Agency 2017; Federal Emergency Management Agency Lifeline Data 2020; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

Table 4.6-14. Community Lifeline and Critical Facility Exposure and Potential Losses to the 1% Annual Chance Flood Event, by Category

Category	Total Number of Facilities by Category	Total Replacement Cost Value of Facilities by Category	Community Lifelines and Critical Facilities Located in the SFHA				Estimated Potential Loss to the 1% Annual Chance Flood Event (A- and V-Zones)	
			Number of Facilities	Percent (%) of Total Facilities	Replacement Cost Value	Percent (%) of Total Value	Replacement Cost Value	Percent (%) of Total
Communications	188	$776,797,683	16	8.51%	$51,867,477	6.68%	$9,174,631	1.2%
Energy	89	$3,093,949,530	18	20.22%	$633,568,650	20.48%	$63,540,298	2.1%
Food, Water, Shelter	345	$11,847,189,588	57	16.52%	$1,874,147,290	15.82%	$269,439,273	2.3%
Hazardous Material	12	$436,474,800	1	8.33%	$36,294,000	8.32%	$187,845	0.0%
Health and Medical	193	$4,606,713,364	6	3.11%	$148,607,658	3.23%	$3,296,056	0.1%
Safety and Security	486	$38,164,188,232	32	6.58%	$3,872,254,354	10.15%	$44,666,514	0.1%
Transportation	56	$2,039,091,600	15	26.79%	$546,303,600	26.79%	$47,815,784	2.3%
Additional Critical Facilities	106	$447,698,794	8	7.55%	$27,907,140	6.23%	$3,359,748	0.8%
Total	**1,475**	**$61,412,103,591**	**153**	**10.37%**	**$7,190,950,168**	**11.71%**	**$441,480,149**	**0.7%**

Source: Hawai'i Emergency Management Agency 2017; Federal Emergency Management Agency Lifeline Data 2020; FEMA Map Service Center 2021; FEMA Hazus v5.1[a]

Note:

a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021

Chronic Coastal Flooding

This section discusses statewide vulnerability of exposed state assets (state buildings and state roads) and critical facilities to the chronic coastal flooding hazard.

State Assets

The exposure analysis determined there are eight state buildings located in the chronic coastal hazard area, of which the greatest number are in the City and County of Honolulu (6 buildings with a replacement cost value of $31.5 million). Over time, recurring flooding at these locations may lead to the permanent loss of these structures. Only replacement cost value was available for state buildings; this was the best available data and therefore, this value is reported as the estimated total loss. However, a more accurate reflection of loss to the chronic coastal flood hazard would be the combined value of the land and structure. Table 4.6-15 summarizes the state buildings located in the chronic coastal flood area by county. Table 4.6-16 summarizes the state buildings by state agency.

Table 4.6-15. State Buildings Loss to the SLR-XA-1.1 by County

County	Total Number of State Buildings	Total Value	Located in the SLR-XA-1.1			
			Number	% of Total	Total Value	% of Total
County of Kaua'i	531	$990,850,824	0	0%	$0	0.000%
City and County of Honolulu	3,472	$17,393,945,915	6	<0.1%	$31,502,653	0.121%
County of Maui	831	$3,097,491,689	2	<0.1%	$370,372	0.001%
County of Hawai'i	1,261	$4,638,567,141	0	0%	$0	0.000%
Total	**6,095**	**$26,120,855,568**	**8**	**0.13%**	**$31,873,025**	**0.122%**

Source: State of Hawai'i Risk Management Office 2017; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

Table 4.6-16. State Building Loss to the SLR-XA-1.1 by Agency

Agency	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-1.1	Percent (%) of Total Buildings	Value in the SLR-XA-1.1	Percent (%) of Total Value
Dept of Accounting & General Services	66	$953,963,738	0	0.00%	$0	0.00%
Dept of Agriculture	70	$147,607,399	1	1.43%	$2,350,211	1.59%
Dept of Attorney General	15	$108,425,480	0	0.00%	$0	0.00%
Dept of Budget & Finance	16	$28,968,679	0	0.00%	$0	0.00%
Dept of Business, Economic Development and Tourism	25	$645,480,379	0	0.00%	$0	0.00%
Dept of Commerce & Consumer Affairs	2	$40,197,360	0	0.00%	$0	0.00%
Dept of Defense	69	$267,352,836	0	0.00%	$0	0.00%
Dept of Education	4,090	$10,598,205,739	0	0.00%	$0	0.00%
Dept of Hawaiian Home Lands	12	$110,427,352	0	0.00%	$0	0.00%
Dept of Health	44	$387,068,440	0	0.00%	$0	0.00%

Agency	Total Number of State Buildings	Total Value	Number of State Buildings in SLR-XA-1.1	Percent (%) of Total Buildings	Value in the SLR-XA-1.1	Percent (%) of Total Value
Dept of Human Resources Development	1	$5,973,872	0	0.00%	$0	0.00%
Dept of Human Services	130	$480,212,294	2	1.54%	$3,234,562	0.67%
Dept of Labor and Industrial Relations	22	$90,076,209	0	0.00%	$0	0.00%
Dept of Land and Natural Resources	90	$101,441,821	2	2.22%	$370,372	0.37%
Dept of Public Safety	154	$440,774,415	0	0.00%	$0	0.00%
Dept of Taxation	1	$7,174,162	0	0.00%	$0	0.00%
Dept of Transportation	68	$2,935,208,214	1	1.47%	$3,754,467	0.13%
Hawai'i State Ethics Commission	1	$984,533	0	0.00%	$0	0.00%
Hawai'i Health Systems Corporation	106	$1,230,852,871	0	0.00%	$0	0.00%
Hawai'i Housing Finance & Development Corporation	86	$360,851,671	0	0.00%	$0	0.00%
Hawai'i Public Housing Authority	273	$982,981,701	1	0.37%	$5,340,000	0.54%
Hawai'i State Legislature	2	$48,555,381	0	0.00%	$0	0.00%
Hawai'i State Public Library System	53	$525,584,082	0	0.00%	$0	0.00%
Judiciary	41	$534,877,354	0	0.00%	$0	0.00%
Legislative Reference Bureau	1	$2,996,162	0	0.00%	$0	0.00%
Office of Hawaiian Affairs	11	$54,125,645	0	0.00%	$0	0.00%
Office of the Auditor	2	$1,921,180	0	0.00%	$0	0.00%
Office of the Governor	1	$2,996,162	0	0.00%	$0	0.00%
Office of the Lieutenant Governor	2	$4,588,849	0	0.00%	$0	0.00%
Office of the Ombudsman	1	$1,818,060	0	0.00%	$0	0.00%
Research Corporation of the University of Hawai'i	3	$4,189,026	0	0.00%	$0	0.00%
University of Hawai'i	637	$5,014,974,503	1	0.16%	$16,823,413	0.34%
Total	**6,095**	**$26,120,855,568**	**8**	**0.13%**	**$31,873,025**	**0.12%**

Source: State of Hawai'i Risk Management Office 2017; Hawai'i Climate Change Mitigation and Adaptation Commission 2017
Total Value = Replacement Cost of facility; does not include land value which may be underestimating the loss due to the SLR-XA-1.1

Roads provide a vital transportation link between populated areas on the Hawaiian Islands. Approximately 15 miles of state roads are located within the SLR-XA-1.1 hazard area. These state roads will become potentially impassable, jeopardize critical access and isolate communities. Loss of road use may result in regional issues such as loss of commerce and increased traffic on other roads and highways. Utility lines commonly follow roads, and those located underground may be impacted, resulting in disruption of services.

Table 4.6-17 shows the length of state roads in the hazard area by county. The City and County of Honolulu has the greatest length of roads (6.4 miles) exposed, followed by the County of Maui (4.7 miles) and the County of Kauai (3.7 miles). A complete list of state roads exposed to the chronic coastal flood hazard is included in Appendix F.

Table 4.6-17. State Road Exposure to the SLR-XA-1.1 by County

County	Length (in miles)		
	Total Length	Length of Road in the SLR-XA-1.1	Percentage (%) of Total Length
County of Kaua'i	103.7	3.7	3.57%
City and County of Honolulu	374.9	6.4	1.71%
County of Maui	245.9	4.7	1.91%
County of Hawai'i	379.2	0.2	0.05%
Total	**1,103.70**	**15**	**1.36%**

Source: State of Hawai'i DOT 2017; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

Community Lifelines and Critical Facilities

Table 4.6-18 summarizes the total number of community lifelines and critical facilities, by county, located in the chronic coastal flooding by county. The County of Maui has five community lifelines located in the chronic coastal flood hazard area. Table 4.6-19 summarizes the community lifeline and critical facility exposure by category.

Table 4.6-18. Community Lifelines and Critical Facilities Located in the SLR-XA-1.1, by County

County	Community Lifeline Categories								Additional Critical Facilities
	Communications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medial	Safety & Security	Transportation	Total in the SLR-XA	
County of Kaua'i	0	0	0	0	0	0	0	0	0
City and County of Honolulu	0	0	1	0	0	2	0	3	0
County of Maui	1	0	3	0	0	1	0	5	0
County of Hawai'i	0	0	0	0	0	0	0	0	0
Total	**1**	**0**	**4**	**0**	**0**	**3**	**0**	**8**	**0**

Source: Hawai'i Emergency Management Agency 2017; Federal Emergency Management Agency Lifeline Data 2020; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

Table 4.6-19. Community Lifeline Exposure and Potential Losses to Chronic Coastal Flooding, by Category

Category	Total Number of Facilities by Category	Total Value	Number of Facilities in SLR-XA-1.1	Percent (%) of Total Lifelines	Value in the SLR-XA-1.1	Percent (%) of Total Value
Communications	188	$776,797,683	1	0.53%	$9,296,169	1.20%
Energy	89	$3,093,949,530	0	0.00%	$0	0.00%
Food, Water, Shelter	345	$11,847,189,588	4	1.16%	$145,176,000	1.23%
Hazardous Material	12	$436,474,800	0	0.00%	$0	0.00%
Health and Medical	193	$4,606,713,364	0	0.00%	$0	0.00%
Safety and Security	486	$38,164,188,232	3	0.62%	$2,748,370,036	7.20%
Transportation	56	$2,039,091,600	0	0.00%	$0	0.00%
Total	**1,369**	**$60,964,404,797**	**8**	**0.58%**	**$2,902,842,204**	**4.76%**

Source: Hawai'i Emergency Management Agency 2017; Federal Emergency Management Agency Lifeline Data 2020; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

Overall, the food, water and shelter category has the greatest exposure to the chronic coastal flood hazard. Similar to state buildings, only replacement cost value of the facility was available for community lifelines and does not include the value of the land; therefore, this value is reported as the total loss. However, a more accurate reflection of loss to the chronic coastal flood hazard would be the combined value of the land and structure using tax-assessed data. Further, the loss of service of that community lifeline or critical facility would increase the total loss from the hazard.

Critical transportation hubs and critical infrastructure located on the coast are exposed to chronic coastal flooding. As summarized in Section 4.2 (Climate Change and Sea Level Rise), the primary transportation arteries for the entry of people and goods to the state are the Daniel K. Inouye International Airport and Honolulu Harbor. In addition, each island has critical points of entry for people and goods which are considered vulnerable to chronic coastal flooding 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 Change Mitigation and Adaptation Commission 2017).

Assessment of Local Vulnerability and Potential Losses

Event-Based Flooding

This section provides a summary of vulnerability and potential losses to population, general building stock, and environmental resources and cultural assets by county. A spatial exposure analysis was conducted using the SFHA and potential losses were estimated using Hazus. These results are summarized below.

Additionally, the local HMPs were reviewed to integrate risk assessment results into the 2023 SHMP Update; a summary of information available is below.

- **County of Kaua'i** –The County HMP includes Inland Flood as a standalone hazard. The HMP identifies five types of inland flood hazard, including riverine floods, flash floods, rain bombs, overland sheet flow, and dam failure floods. Kaua'i County participates in the National Flood Insurance Program and has 45 FEMA-identified repetitive loss properties. There are 61 critical facilities within the Special Flood Hazard Area (SFHA); there are 6,796 residents living within the SFHA. The HMP also identifies socially vulnerable populations particularly impacted by flood events, including economically disadvantaged populations, residents over the age of 65, and residents under 1 (County of Kaua'i 2020).
- **City and County of Honolulu** – The county provided a qualitative overview of flood risk, including descriptions of flood sources and types of coastal and inland floods. The HMP includes NOAA rainfall intensity maps. The city and county both participate in the NFIP; there are 114 Repetitive Loss properties in the county (City and County of Honolulu 2020).
- **County of Maui** – The county provided a qualitative overview of flood risk, including types of coastal and inland floods and principal sources of flood risk. Maui County is a Class 7 CRS community. Around 3.3% of the county lies within the SFHA, including 38 critical facilities; there are 34 Repetitive Loss properties within the county. The HMP also provides maps of transportation routes that could be impacted by flooding and a list of residents who are most vulnerable to flood risk, including single parent and dependent households, residents living below the poverty line, residents without adequate

communication infrastructure and/or limited English proficiency, residents living in properties built prior to the 1950s, and residents with limited mobility (County of Maui 2020).

- **County of Hawai'i** – The county provided a qualitative overview of flood risk, including National Flood Insurance Program statistics for the county. Hawai'i County is a CRS Class 7 community. Major floods happen in the rainy winter, accounting for approximately 84% of floods in the county. The HMP lists principal flooding sources, identified from FEMA's Flood Insurance Study for the area, as well as areas prone to flash flooding. Only 0.3 percent of the entire County (7,358 acres) is located within the mapped 1 percent annual chance floodplain, exposing 4,754 residents. There are 45 Repetitive Loss properties in the county, and 19 critical facilities are exposed to a 1 percent annual flood event. The HMP also identifies socially vulnerable populations particularly impacted by flood events, including economically disadvantaged populations, residents over the age of 65, and residents under 16 (County of Hawai'i 2020).

Socially Vulnerable and Total Populations

Socially vulnerable populations are most susceptible based on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate.

The aftermath of flooding events present numerous threats to public health and safety, including unsafe food, contaminated drinking and washing water and poor sanitation, mosquitoes and animals, mold and mildew, carbon monoxide poisoning, and mental stress and fatigue. Current loss estimation models such as Hazus are not equipped to measure public health impacts. The best preparation for these effects includes awareness that they can occur, education of the public on prevention, and planning to deal with them during responses to flooding events.

Over 91,400 residents statewide reside in the SFHA; nearly 16,000 of those residents are considered socially vulnerable populations (Table 4.6-20). These residents may be displaced by the flooding of their homes, requiring them to seek temporary shelter with friends and family or in emergency shelters. The City and County of Honolulu has the greatest number of people (73,711) located in the SFHA. This analysis does not include the number of tourists and visitors in the state; therefore, this estimate may be underestimating exposure and vulnerability.

The City and County of Honolulu has the largest socially vulnerable population exposed to the SFHA (13,226). Appendix F summarizes the population exposure to the A-Zone and V-Zone areas.

Table 4.6-20. 2020 U.S. Census Population Located in the SFHA by County

County	Population				
	Total Population	Population in the SFHA	Population Exposed as % of Total Population	Socially Vulnerable Population in the SFHA	Socially Vulnerable Population Exposed as % of Total Population
County of Kaua'i	71,949	3,526	4.90%	211	0.29%
City and County of Honolulu	979,682	73,711	7.52%	13,226	1.35%
County of Maui	167,093	9,206	5.51%	1,225	0.73%
County of Hawai'i	201,350	5,019	2.49%	1,138	0.57%

County	Population				
	Total Population	Population in the SFHA	Population Exposed as % of Total Population	Socially Vulnerable Population in the SFHA	Socially Vulnerable Population Exposed as % of Total Population
Total	1,420,074	91,462	6.44%	15,800	1.11%

Source: U.S. Census Bureau 2020; Centers for Disease Control and Prevention 2018; FEMA Map Service Center 2021[a]
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021

Floods and their aftermath present numerous threats to public health and safety:

- **Vehicles in flood waters**—Flood waters can carry large amounts of debris, potentially increasing the damage they do.
- **Unsafe food**—Floodwaters can contain disease-causing bacteria, dirt, oil, human and animal waste, and farm and industrial chemicals. Their contact with food items, including food crops in agricultural lands, can make that food unsafe to eat.
- **Contaminated drinking and washing water and poor sanitation**—Flooding impairs clean water sources with pollutants; pollutants also infiltrate into the groundwater contaminating potable water. Flooded wastewater treatment plants and private sewage disposal systems can be overloaded, resulting in backflows of raw sewage becoming a cause of disease.
- **Mosquitoes and animals**—Floods provide new breeding grounds for mosquitoes in wet areas and stagnant pools; deceased animals can carry viruses and diseases if not disposed of timely and properly.
- **Mold and mildew**—Excessive exposure to mold and mildew can cause flood victims, especially those with allergies and asthma, to contract upper respiratory diseases, triggering cold-like symptoms. Infants, children, elderly people, and pregnant women are considered most vulnerable to mold-induced health problems.
- **Carbon monoxide poisoning**—In the event of power outages, the use alternative fuels in enclosed or partially enclosed spaces can lead to carbon monoxide poisoning.
- **Hazards when reentering and cleaning flooded homes and buildings**—Flooded buildings can pose significant health and physical hazards to people entering them, including live electrical wires, gas leaks, flood debris, and hazardous materials.
- **Mental stress and fatigue**—People who live through a devastating flood can experience long-term psychological impact.

General Building Stock

Economic losses to the State of Hawai‘i from event-based flooding include but are not limited to general building stock damage, agricultural losses, and business interruption. These losses will negatively affect the tax base. Damage to general building stock can be quantified using Hazus. Other economic components, such as loss of facility use, functional downtime, and social economic factors, are less quantifiable. For the purposes of this analysis, the general building stock damage is discussed further.

Low-lying urban areas have the greatest vulnerability to a flood event. To estimate the potential losses by county, the Hazus flood model and default general building stock provided by the model were used. Table 4.6-21 summarizes the estimated potential losses to the general building stock by county.

Table 4.6-21. General Building Stock Exposure and Potential Losses to the 1% Annual Chance Flood Event

County	Total Replacement Cost Value	Replacement Cost Value in the SFHA	% of Total in the SFHA	Estimated Potential Loss to the 1% Annual Chance Flood Event (A-and V-Zones)		Estimated Potential Loss to Buildings in the V-Zones	
				Replacement Cost Value	Percent (%) of Total	Replacement Cost Value	Percent (%) of Total
County of Kaua'i	$24,246,497,228	$3,406,707,898	14.05%	$575,360,000	2.37%	$107,754,000	0.44%
City and County of Honolulu	$239,152,051,766	$24,917,056,964	10.42%	$1,339,204,000	0.56%	$73,291,000	0.03%
County of Maui	$50,796,693,140	$4,307,043,691	8.48%	$240,731,000	0.47%	$134,247,000	0.26%
County of Hawai'i	$58,395,349,136	$2,321,499,927	3.98%	$92,079,000	0.16%	$43,949,000	0.08%
Total	**$372,590,591,270**	**$34,952,308,481**	**9.38%**	**$2,247,374,000**	**0.60%**	**$359,241,000**	**0.10%**

Source: NIYAM IT 2022; United States Army Corps of Engineers 2022; FEMA Map Service Center 2021[a]; FEMA Hazus v5.1
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021

Hazus estimates $2.2 billion in statewide potential damages to the general building stock inventory associated with the 1% annual chance flood event. Although this loss represents less than 1% of the state's total building replacement cost value, the flooded areas include some of the most valued buildings in the state. The City and County of Honolulu is estimated to experience the greatest loss: $1.3 billion in building damages (repair or replacement costs), of which $73 million of the damages are in the V-zone. The cost to repair or replace buildings is estimated at $240 million in the County of Kaua'i and $575 million in the County of Maui. Hazus estimates $92 million in building loss for the County of Hawai'i. Appendix F (State Profile and Risk Assessment Supplement) summarizes the exposure and potential losses to the 1% Annual Chance Flood A-Zone and V-Zone areas.

The National Flood Insurance Program (NFIP) data are also a useful tool to determine areas vulnerable to flood.

Table 4.6-22 summarizes the NFIP policies, claims, and RL and SRL buildings in each county. Currently, the City and County of Honolulu has the highest number of repetitive loss properties (132), followed by the Counties of Hawai'i and Kaua'i (46 each). The County of Honolulu has the greatest total losses paid (nearly $56 million). Over the performance period of the 2018 SHMP, the number of repetitive loss properties has increased from 227 to 262 (an approximate 13% increase).

Table 4.6-22. NFIP Statistics for the State of Hawai'i

County	Number of Policies	Insurance In Force	Number of Paid Losses	Total Losses Paid	Repetitive Loss		Severe Repetitive Loss	
					2018	2022	2018	2022
					Total	Total	Total	Total
County of Kaua'i	3,580	$922,928,100	1,406	$43,934,328	31	46	0	2
City and County of Honolulu	34,822	$8,637,960,700	2,732	$55,797,231	117	132	1	13

County	Number of Policies	Insurance In Force	Number of Paid Losses	Total Losses Paid	Repetitive Loss		Severe Repetitive Loss	
					2018	2022	2018	2022
					Total	Total	Total	Total
County of Maui	11,614	$2,795,483,600	589	$9,333,535	34	38	2	6
County of Hawai'i	3,980	$1,029,437,700	728	$19,654,298	45	46	6	32
Total	**53,996**	**$13,385,810,100**	**5,455**	**$128,719,392**	**227**	**262** [a]	**9**	**53**

Source: FEMA PIVOT Database 2022
Notes:
Policies, insurance in force, and losses are as of September 30, 2022.
Repetitive and severe repetitive loss property statistics are as of August 31, 2022.
a. Includes severe repetitive loss properties

An analysis was conducted to summarize the current repetitive loss statistics across the state.

- 20.2% of the 262 Repetitive Loss properties have been identified as "Severe Repetitive Loss" by FEMA.
- The County with the greatest number of Severe Repetitive Loss properties is Hawai'i County with 32 (69.5 % of its total Repetitive Loss Properties).
- 25.7% of the Severe Repetitive Loss properties are located outside of the SFHA.
- 33.2% of the 262 Repetitive Loss properties in the state are located outside of the SFHA.
- The County with the most Repetitive Loss properties located outside the SFHA is Honolulu (40.9% of its total Repetitive Loss properties).
- 30.9% of the 262 Repetitive Loss properties are currently insured under the NFIP.
- 1.5% of the 262 Repetitive Loss properties have been identified as "mitigated".
- The County with the most "mitigated" Repetitive Loss properties is Maui (3), 7.9% of the total Repetitive Loss properties.
- The 262 identified Repetitive Loss properties have accounted for 703 total Losses totaling $24,835,397 claims paid by the NFIP.
- This amounts to an average claim paid of $24,241. This is below the National average flood insurance claim under the NFIP of just over $31,000 per claim.
- All 4 Counties within the state have identified RL properties.
- The County with the highest Average Loss per Repetitive Loss property is Kaua'i at $71,945 per claim.

Land Use Districts

Table 4.6-23 shows the square miles of SFHAs in each state land use district statewide; refer to Appendix F for results by county. Agricultural District lands and Urban District lands have the greatest area exposed to A-zone flooding in the state, 36.9 and 28.8 square miles, respectively. This is not surprising for two reasons: 1) productive agricultural lands tend to be located along steams as rivers as sediment build up and accumulation from prior flood events results in fertile soil, and 2) floodplain mapping is generally conducted in areas that are developed or are likely to be developed in the future.

Table 4.6-23. State Land Use Districts Located in the Special Flood Hazard Area

Land Use District	Total (square miles)	Square Miles in the SFHA	Percent (%) of Total Area
Agricultural	2,973.6	36.90	1.2%
Conservation	3,202.9	25.50	0.8%

Land Use District	Total (square miles)	Square Miles in the SFHA	Percent (%) of Total Area
Rural	16.3	2.10	12.9%
Urban	319.1	28.80	9.0%
Total	**6,511.95**	**93.30**	**1.4%**

Source: State Land Use Commission, Hawaii Statewide GIS Program 2021; Honolulu County GIS 2022; FEMA Map Service Center 2021[a]
Notes:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021
Total area was calculated from the State of Hawai'i State Land Use District GIS layer.
Original FEMA effective DFIRM boundary is maintained. This hazard area is not clipped to the coastline.
Total area may differ slightly between this and other calculations due to slight differences in the shoreline geography.

Environmental Resources

Environmental resources are valuable assets to the environment and overall economy in the state. Coral reefs and wetlands provide a coastal buffer and protect from wave and flood impacts. However, flooding may adversely impact the natural environment, including: beach erosion; loss or submergence of wetlands and other coastal ecosystems; saltwater intrusion; high water tables; loss of coastal recreation areas, beaches, protective sand dunes, parks, and open space; and loss of coastal structures (sea walls, piers, bulkheads, bridges, or buildings) (FEMA n.d.). Flash floods often result in increased sediment deposited in the nearshore environment negatively impacting coral reefs from sedimentation and stormwater runoff (U.S. Environmental Protection Agency 2022).

Environmental resource areas, including critical habitat (or habitats that are known to be essential for an endangered or threatened species), wetlands, and parks and reserves are vulnerable to event-based flooding. The area of each environmental resource located in the SFHA was calculated and is summarized in Table 4.6-24.

Table 4.6-24. Environmental Resources Located in the SFHA

Environmental Resource	Total Square Miles of Resource	Resource Area in the SFHA (square miles)	Percent (%) of the Total Resource Area
Critical Habitat[a]	951	3	0.3%
Wetlands	3,637	109	3.0%
Parks and Reserves	2,778	16	0.6%
Reefs[b]	55	19	34.3%
Total[c]	**7,420**	**147**	**2.0%**

Source: U.S. Fish and Wildlife Service, Pacific Islands Office, 2022, U.S. Fish and Wildlife Service 2021; Hawaii State Department of Land and Natural Resources, Division of Forestry and Wildlife 2022, NOAA raster nautical charts 2020, State of Hawaii Department of Land and Natural Resources, Division of State Parks 2021; FEMA Map Service Center 2021[d]
Notes:
Original FEMA effective DFIRM boundary is maintained. This hazard area is not clipped to the coastline.
a. *Critical area mileage includes the combined area of coverage of individual critical habitat areas.*
b. *Reefs include artificial and coral reefs.*
c. *Total square miles include environmental assets within 3 nautical miles of each county and may be over-reported as some environmental asset areas may overlap.*
d. *National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021*

Cultural Assets

Many Native Hawaiian cultural resources are located near the shoreline and may be impacted by event-based flooding. Structures that experience damage would result in displaced residents in need of shelter or new homes.

More than 4 acres of the Hawaiian Home Lands are in the 1% Annual Chance Flood areas (this includes the A-Zone, V-zone, and SFHA) in all four counties (see Table 4.6-25). Table 4.6-26 Summarizes cultural resources by square miles statewide that are located in the SFHA.

Table 4.6-25. Hawaiian Home Lands Located in the SFHA

County	Area (in square miles)		
	Total Area	Land in the SFHA	Percent (%) of Total Area
County of Kaua'i	32.1	0.4	1.1%
City and County of Honolulu	10.6	0.2	2.3%
County of Maui	102.6	2.6	2.6%
County of Hawai'i	191.5	1.1	0.6%
Total	**336.7**	**4.3**	**1.3%**

Source: Hawaii State Department of Hawaiian Home Lands 2021; FEMA Map Service Center 2021[a]
Note:
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021

Table 4.6-26. Cultural Resources Located in the SFHA

Cultural Resource Site Type	Area (in square miles)		
	Total Square Miles of Asset	Total Square Miles in SFHA Area	Percent (%) of Total Asset Area
Archaeology	90.9	9.3	10.3%
Burial Sensitivity Area	2.1	1.1	51.1%
Historic Building	2.7	0.3	10.7%
Historic District	849.4	36.2	4.3%
Historic Object	9.6	0.0	0.0%
Historic Structure	20.7	0.8	3.8%
Total	**975.4**	**47.7**	**4.9%**

Source: Department of Land and Natural Resources, Hawai'i State Historic Preservation Division 2022; FEMA Map Service Center 2021[a]
Notes:
Original FEMA effective DFIRM boundary is maintained. This hazard area is not clipped to the coastline.
a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021, with latest Letter of Map Amendment January 4, 2021

Chronic Coastal Flooding

This section provides a summary of vulnerability and potential losses to population, general building stock, and 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 chronic coastal flooding is assessed as chronic flooding with the potential permanent loss of assets and displacement of population located in the SLR-XA-1.1 hazard area.

Socially Vulnerable and Total Populations

Socially vulnerable populations are most susceptible based on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate.

The aftermath of flooding events presents numerous threats to public health and safety, including unsafe food, contaminated drinking and washing water and poor sanitation, mosquitoes and animals, mold and mildew, carbon monoxide poisoning, and mental stress and fatigue. Current loss estimation models such as Hazus are not equipped to measure public health impacts. The best preparation for these effects includes awareness that they can occur, education of the public on prevention, and planning to deal with them during responses to flooding events.

People living and working in the chronic coastal flood 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, an estimated 4,160 people may be displaced as a result of the potential permanent loss to structures and land in the SLR-XA-1.1 hazard area (Table 4.6-27). The analysis indicates that the City and County of Honolulu has the greatest number of people that may be displaced, and the County of Kaua'i has the greatest percent population that may be displaced (1.5%).

Table 4.6-27. Estimated Population Displaced by the Chronic Coastal Flood Hazard

County	Total Population	Displaced Population	Percent (%) of Total Population
County of Kaua'i	71,949	1,000	1.50%
City and County of Honolulu	979,682	2,000	<1%
County of Maui	167,093	710	<1%
County of Hawai'i	201,350	450	<1%
Total	**1,420,074**	**4,160**	**<1%**

Source: Hawai'i Climate Mitigation and Adaptation Commission 2017

According to the 2018 SHMP, the greatest number of deaths, injuries and rescues in the Hawaiian Islands due to natural hazard events are from high waves breaking at the shoreline. High surf is typically described as waves ranging in height from 10 feet to 20 feet or more. These waves typically come from storms passing across the higher latitudes of the Northern and Southern Hemispheres in addition to tropical storms passing across the Central Pacific in proximity to the Hawaiian Islands.

Land Use Districts

Table 4.6-28 shows the number of square miles in each state land use district statewide exposed to the chronic coastal flood hazard areas; refer to Appendix F for results by county. Conservation District lands will experience the greatest total loss of area from chronic coastal flooding in the near-term. Conservation District lands contain valuable environmental resources. Additional discussion of exposure and vulnerability of these resource areas can be found in the subsection below. Urban District areas, where populations and development are concentrated, will lose the greatest percentage of total land area to chronic coastal flooding in the near-term.

Table 4.6-28. State Land Use Districts Located in the SLR-XA-1.1

Land Use District	Total (square miles)	Square Miles in the SLR-XA-1.1	% of Total Area
Agricultural	2,973.6	2.99	0.10%
Conservation	3,202.9	10.28	0.32%
Rural	16.3	0.24	1.47%
Urban	319.1	5.27	1.65%
Total	**6,511.9**	**18.78**	**0.29%**

Source: Hawai'i Climate Mitigation and Adaptation Commission 2017; State Land Use Commission, Hawaii Statewide GIS Program 2021; Honolulu County GIS 2022
Note:
Total area calculated from the State of Hawai'i State Land Use District GIS layer.
Hazard area clipped to coastline using 2020 Census County Boundary from State of Hawai'i GIS Program Geospatial Data Portal.
Total area may differ slightly between this and other calculations due to slight differences in the shoreline geography.

General Building Stock

The 2017 *Hawai'i Sea Level Rise Vulnerability and Adaptation Report* calculated the estimated potential loss to both structure and land by island; as both the structures and land may become permanently inundated due to the chronic coastal flood hazard over time. These calculations were totaled by county with an estimated economic loss of $1.96 billion statewide (Table 4.6-29).

Table 4.6-29. Estimated Structure and Property Value (Structure and Land) Loss from SLR-XA-1.1 by County

County	Number of Structures in the SLR-XA-1.1	Estimated Structure and Land Value Located in the SLR-XA-1.1
County of Kaua'i	170	$136,514,291
City and County of Honolulu	563	$936,636,782
County of Maui	331	$884,955,696
County of Hawai'i	3	$3,945,797
Total	**1,067**	**$1,962,052,566**

Source: NIYAM IT 2022; U.S. Army Corps of Engineers 2022; Hawai'i Climate Mitigation and Adaptation Commission 2017

Environmental Resources

The loss of natural resources statewide is difficult to quantify; however, their loss would deeply cost the state. Parks and beaches play a critical role in recreation, employment and the local economy. In addition, wetland areas and coastal habitats are important ecosystems for many species and provide other environmental benefits such as flood mitigation and may be altered through chronic coastal flood conditions. As discussed in Section 4.2 (Climate Change and Sea Level Rise), chronic coastal flooding 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.

Environmental resource areas, including critical habitat (or habitats that are known to be essential for an endangered or threatened species), wetlands, and parks and reserves are vulnerable to chronic coastal flooding. The area of each environmental asset located in the SLR-XA-1.1 hazard area was calculated and summarized by asset (Table 4.6-30).

Table 4.6-30. Environmental Resources Located in the SLR-XA-1.1

Environmental Asset	Total Square Miles of Asset	Asset Area in the SLR-XA-1.1	Percent (%) of the Total Asset Area
Critical Habitat[a]	950.6	1.3	0.1%
Wetlands	3636.7	15.8	0.4%
Parks and Reserves	2777.7	4.7	0.2%
Reefs[b]	54.8	0.5	0.9%
Total[c]	**7419.8**	**22.3**	**0.3%**

Source: U.S. Fish and Wildlife Service, Pacific Islands Office, 2022; U.S. Fish and Wildlife Service 2021, 2017; Hawai'i State Department of Land and Natural Resources, Division of Forestry and Wildlife 2022; NOAA raster nautical charts 2020; State of Hawai'i Department of Land and Natural Resources, Division of State Parks 2021; Hawai'i Climate Mitigation and Adaptation Commission 2017

Note:

a. Critical area mileage includes the combined area of coverage of individual critical habitat areas.

b. Reefs include artificial and coral reefs.

c. Total square miles includes environmental assets within 3 nautical miles of each county and may be over-reported as some environmental asset areas may overlap.

Cultural Assets

Coastal portions of the Hawaiian Home Lands are vulnerable to chronic coastal flooding which may displace Native Hawaiian families that live in this area. Table 4.6-31 summarizes the area of the Hawaiian Home Lands located in the chronic coastal flood hazard area. In addition, many Native Hawaiian cultural and historical resources are located near the shoreline and threatened by flooding and beach erosion (Table 4.6-32). The 2017 *Hawai'i Sea Level Rise Vulnerability and Adaptation Report* summarizes cultural sites located in the SLR-XA-1.1 hazard area.

Table 4.6-31. Hawaiian Home Lands Located in the SLR-XA-1.1

County	Area (in square miles)		
	Total Area	Asset Area in the SLR-XA-1.1	Percent (%) of Total Area
County of Kaua'i	32.09	0.07	0.22%
City and County of Honolulu	10.61	0.04	0.38%
County of Maui	102.59	0.2	0.19%
County of Hawai'i	191.46	0.06	0.03%
Total	**336.75**	**0.37**	**0.11%**

Source: Hawai'i State Department of Hawaiian Homelands 2021; Hawai'i Climate Mitigation and Adaptation Commission 2017

Table 4.6-32. Cultural Resources Located in the SLR-XA

Cultural Resource Site Type	Area (in square miles)		
	Total Square Miles of Asset	Total Square Miles in SLR-XA-1.1 Area	Percent (%) of Total Asset Area
Archaeology	90.9	2.2	2.5%
Burial Sensitivity Area	2.1	0.3	13.9%
Historic Building	2.7	0.0	1.6%
Historic District	849.4	6.7	0.8%
Historic Object	9.6	0.0	0.0%
Historic Structure	20.7	0.2	0.7%
Total	975.4	9.4	1.0%

Source: Department of Land and Natural Resources, Hawai'i State Historic Preservation Division 2022; Hawai'i Climate Change Mitigation and Adaptation Commission 2017

FUTURE CHANGES THAT MAY IMPACT STATE VULNERABILITY

Event-Based Flooding

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, including the impacts of climate change

Potential or Projected Development

The SFHAs were overlain on areas that may experience significant changes in development or redevelopment in future years (see Table 4.6-33; refer to Section 3 for more information on projected development areas). The results of this assessment indicate none of the Hawai'i Community Development Authority (HCDA) Community Development Districts and only a very small amount of the Maui Development Projects are located in SFHAs. Approximately 68.7 square miles of the Enterprise Zones statewide are located in SFHAs. Most of the exposed area, 49.6 square miles, is located in A-zone SFHAs. Each county participates in the NFIP and has flood damage prevention regulations in place that regulate how development can occur in mapped SFHAs. Future development in these areas will require adherence to flood damage prevention standards. If new development occurs in areas that currently support natural and beneficial floodplain functions, such as in upland conservation areas, impacts to event-based flooding may be seen throughout the associated watershed.

Table 4.6-33. HCDA Community Development Districts, Maui Development Projects, and Enterprise Zones Located in SFHAs

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
A-Zone									
County of Kaua'i	0	0	0.00%	0	0	0.00%	251	14.5	5.78%
City and County of Honolulu	7.4	0.6	8.11%	0	0	0.00%	297.3	13.3	4.47%
County of Maui	0	0	0.00%	27.6	0.2	0.72%	1,059.80	13.8	1.30%
County of Hawai'i	0	0	0.00%	0	0	0.00%	1,274.90	8.04	0.63%
Total	7.4	0.6	8.11%	27.6	0.2	0.72%	2,883.00	49.64	1.72%
V-Zone									
County of Kaua'i	0	0	0.00%	0	0	0.00%	251	1.42	0.57%
City and County of Honolulu	7.4	0.08	1.08%	0	0	0.00%	297.3	3.4	1.14%
County of Maui	0	0	0.00%	27.6	0.02	0.07%	1,059.80	6.8	0.64%
County of Hawai'i	0	0	0.00%	0	0	0.00%	1,274.90	7.6	0.60%
Total	7.4	0.08	1.08%	27.6	0.02	0.07%	2,883.00	19.22	0.67%

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
Special Flood Hazard Area									
County of Kaua'i	0	0	0.00%	0	0	0.00%	251	15.97	6.36%
City and County of Honolulu	7.4	0.7	9.46%	0	0	0.00%	297.3	16.6	5.58%
County of Maui	0	0	0.00%	27.6	0.24	0.87%	1,059.80	20.5	1.93%
County of Hawai'i	0	0	0.00%	0	0	0.00%	1,274.90	15.6	1.22%
Total	7.4	0.7	9.46%	27.6	0.24	0.87%	2,883.00	68.67	2.38%

Source: Maui County Planning Department 2016; Hawaii Community Development Authority 2021; Community Economic Development Program, Department of Business, Economic Development & Tourism, County Planning Departments 2021; FEMA Map Service Center 2021[a]

Note:

a. National Flood Hazard Layer DFIRM data obtained from the FEMA Map Service Center, effective February 26, 2021 with latest Letter of Map Amendment January 4, 2021

Other Factors of Change

Climate change is certain to alter flood dynamics in the state. Changes in the timing and intensity of rainfall may impact inland and stormwater flooding, changes in wind and storm patterns may impact coastal flooding, and sea level rise will increase the areas exposed to coastal and some inland flooding as well as flood heights in some areas. For more information on how climate change will impact event-based flooding, please refer to Section 4.2 (Climate Change and Sea Level Rise).

Chronic Coastal Flooding

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, including the impacts of climate change.

Chronic coastal flood areas were overlain on areas that may experience significant changes in development or redevelopment in future years (see Table 4.6-34); refer to Section 3 for more information on projected development areas). Only very small amounts of the HCDA Community District Areas and Maui Development Projects intersect with these areas. Larger portions of the Enterprise Zone areas in each county are exposed; however, exposure is still less than 1% of the total area of these zones. Care should be taken to not increase development in these Chronic Coastal Flood Areas as the incidence of flooding and/or erosion will increase over time. It is likely, however, that existing rules and regulations in the state, such as shoreline setback regulations (see Section 5 for more information) already prohibit or strictly regulate most new development in these areas. It is possible that chronic flooding conditions may exist outside of existing regulated areas if chronic flooding is a result of stormwater system failure due to higher than design level tidal flooding or in very flat areas where chronic

flooding may extend further inland. Potential or projected development exposed to risk from long-term coastal flooding as it will be further exacerbated by climate change is discussed in Section 4.2 (Climate Change and Sea Level Rise).

Table 4.6-34. HCDA Community Development Districts, Maui Development Projects, and Enterprise Zones Located the SLR-XA-1.1

County	Area (in square miles)								
	HCDA Community Development Districts	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
County of Kaua'i	0	0	0	0	0	0	251.0	2.7	1.08%
City and County of Honolulu	7.4	0.13	1.76%	0	0	0	297.3	2.3	0.77%
County of Maui	0	0	0	27.62	0.02	0.06%	1,059.8	4.0	0.38%
County of Hawai'i	0	0	0	0	0	0	1,274.9	2.5	0.20%
Total	**7.4**	**0.13**	**1.76%**	**27.62**	**0.02**	**0.06%**	**2,883**	**11.5**	**0.40%**

Source: Maui County Planning Department 2016; Hawaii Community Development Authority 2021; Community Economic Development Program, Department of Business, Economic Development & Tourism, County Planning Departments 2021; Hawai'i Climate Change Mitigation and Adaptation Commission 2017; U.S. Census Bureau 2021

Flood Hazard Mitigation Success Story

Credit: County of Kaua'i

Weke Road in the Hanalei River Basin of Kaua'i was washed out after the severe rainstorm in February 2018. The damage impeded access to residences and beaches in the area. DR-4365 Federal funding was used for the reconstruction project and included two mitigation measures:

- The road through the washed-out area was reconstructed with mechanically stabilized earth (MSE) walls
- Cement concrete was used for pavement instead of asphalt

This area of Kaua'i is prone to severe flooding events. These mitigation measures strengthened the roadway to be more resilient to floods and erosion in the future.