Section 4.1 Overview

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FIGURES

[1] *Section Cover Photo: Cloud lei around Mauna Kea, Hawaiʻi Island. Photo by Megan Brotherton*

SECTION 4. RISK ASSESSMENT

4.1 OVERVIEW

2023 SHMP Update Changes

- For the 2023 SHMP Update, all information on the risk assessment can be found in Section 4 as well as in the referenced supporting appendices. The hazards of concern have been reorganized and new hazards added to align with HI-EMA's February 2022 Hazards and Vulnerabilities Overview and THIRA. The Flood section combines chronic coastal flooding and event-based flooding. Dam failure is the primary hazard in the Infrastructure Failure section. The new hazards for 2023 are cyber threat and terrorism.
- An enhancement to the 2023 SHMP Update risk assessment is the analysis of community lifelines defined by FEMA along with additional critical facilities.
- Assessments performed for the County of Maui also include the County of Kalawao.
- The total areas for each county was calculated using 2020 Census County Boundary downloaded from State of Hawai'i GIS Program Geospatial Data Portal.
- The enhanced risk assessment not only evaluates the population as a whole but also analyzes the location of socially vulnerable populations in relation to mapped hazards.
- In addition to assessing Hawaiian Home Lands, the 2023 SHMP adds six types of cultural resources (archaeology, burial sensitivity area, historic building, historic district, historic object, and historic structure) to the vulnerability assessment.
- The environmental resources evaluated were expanded. Reefs (both artificial and coral) are analyzed in their own category for all the natural hazards.
- Mitigation success stories were added to various sections in the risk assessment to demonstrate the progress on implementing effective mitigation strategies.

44 CFR §201.4(c)(2): States are required to undertake a risk assessment that provides "…the factual basis for activities proposed in the strategy portion of the mitigation plan. Statewide risk assessments must characterize and analyze natural hazards and risks to provide a statewide overview."

The risk assessment is a process by which the state determines which hazards are of concern and addresses the potential impacts of those hazards statewide. The risk assessment helps communicate vulnerabilities, develop priorities, and inform decision-making for the hazard mitigation plan and other emergency management efforts.

Risk Defined

For the purposes of the 2023 HMP Update, risk is the potential for damage or loss created by the interaction of hazards with assets such as people, buildings, infrastructure, and/or natural and cultural resources.

The risk assessment for the State of Hawai'i 2023 SHMP Update provides the factual basis for developing a statewide mitigation strategy. It makes the connection between vulnerability and the proposed hazard mitigation actions.

The HI-EMA envisions the 2023 SHMP Update to serve as a technical reference for local HMP updates. With that in mind, the 2023 SHMP Update included a comprehensive update to the 2018 SHMP risk assessment. The enhanced risk assessment not only evaluates state assets but also evaluates each county's vulnerability to the identified hazards so that results may be integrated into upcoming local HMP updates. This will reduce the work required to update the local HMP risk assessments so that an enhanced focus may be placed on strengthening other areas of the local plans. In addition, HI-EMA envisioned that the risk assessment be more easily understood by a person without a technical background, while paralleling the structure of the requirements outlined in 44CFR 201.4 and FEMA's State Mitigation Planning Policy Guide (April 2022) and State Mitigation Planning Key Topics Bulletins: Risk Assessment (June 2016). Mitigation capabilities and mitigation strategy elements are found in Section 5 (Capability Assessment) and Section 6 (Mitigation Strategy).

To maintain consistency with the 2018 SHMP, the 2023 SHMP Update divides the risk assessment for each hazard into two parts: (1) hazard profile and (2) vulnerability assessment. The following is the consistent outline for each hazard's risk assessment section (Sections 4.2 through 4.16):

- Hazard Profile
    - Identify and describe hazards
    - Location of the hazards and areas vulnerable to damage
    - Extent (i.e., strength or magnitude) of hazard
    - Previous occurrences of hazard
    - Probability of future hazard events, including climate change impacts
- Vulnerability Assessment
    - Assessment of state vulnerability and potential losses, including community lifelines
    - Assessment of local vulnerability and potential losses, including socially vulnerable populations
    - Future changes that may impact vulnerability

The 2023 SHMP Update risk assessment characterizes the impacts of hazards on both state assets and counties, allowing the state to compare potential loss and determine priorities for mitigation measures. To summarize vulnerability, the state ranked the identified hazards based on factors related to the risks faced. These risk factors include the probability of occurrence, impacts, spatial extent, warning time, and duration as per the FEMA State Planning Key Topics Bulletin: Risk Assessment (June 2016). The state also integrated adaptive capacity and

changing future conditions into the hazard ranking to ensure these important factors are considered. Refer to Section 4.17 (Vulnerability Summary) for further details on the ranking methodology and results.

The results presented throughout the risk assessment are summarized geographically, from west to east, by county. County tabular results and maps presented throughout Sections 4.2 through 4.17 are in the following order: County of Kaua'i, City and County of Honolulu, County of Maui, and County of Hawai'i. Where results were given by island in other plans and studies integrated into the 2023 SHMP Update, the cumulative results are presented by county.

4.1.1 IDENTIFICATION OF HAZARDS

Element S3, FMAG1, and 44 CFR §201.4I(2)(i): The risk assessment shall include an overview of the type and location of all natural hazards that can affect the state, including a current overview of all natural hazards that can affect the state, location of hazards, and previous occurrences of hazards.

The HI-EMA considered a full range of hazards that could affect the state for the 2023 SHMP Update. The process included a review of the February 2022 Hazards and Vulnerabilities Overview. To maintain consistency across state planning documents, this 2023 SHMP Update aligns hazard categories with the Hazards and Vulnerabilities Overview. Extensive outreach was conducted to subject matter experts to ensure the appropriate elements of each hazard were included and best-available data was used for the risk assessment, described further below. The Forum was briefed on the updated list of hazards of concern for additional input.

Disaster History

The State of Hawaii's disaster history, in combination with an understanding of the location and type of state built and natural assets, provides direction on the identification of hazards and their significance to the state. Of the 61 federal disasters declared in the State of Hawai'i from 1955 to December 2022, Hawai'i received 36 major disaster declarations (DR); 5 emergency declarations (EM); and 20 fire management assistance declarations (FM). Table 4.1-1 outlines each federal declaration that the State of Hawai'i has received since 1955. Declarations prior to 1964 do not contain county data as it is not available (FEMA 2022). Additional details regarding declarations during the performance period of the plan are discussed further in Sections 4.2 through 4.16.

Table 4.1-1. Federal Major Disaster, Emergency, and Fire Declarations

Date Declared	Incident Type	Disaster Number	Counties Affected
April 1, 1955	Volcano	DR-32	Not Reported
March 16, 1957	Tidal Wave	DR-71	Not Reported
August 16, 1959	Hurricane Dot	DR-94	Not Reported
January 21, 1960	Earthquakes & Volcanic Disruptions	DR-96	Not Reported
May 25, 1960	Tidal Waves	DR-101	Not Reported
April 24, 1963	Heavy Rains & Flooding	DR-152	Not Reported
September 13, 1968	Heavy Rains & Flooding	DR-251	Maui
May 16, 1973	Earthquake	DR-383	Hawai'i
May 7, 1974	Heavy Rains & Flooding	DR-433	Honolulu, Kaua'i

Date Declared	Incident Type	Disaster Number	Counties Affected
December 7, 1975	Earthquake, Seismic Waves & Volcanic Eruption	DR-490	Hawai'i
March 7, 1979	Severe Storms & Flooding	DR-573	Hawai'i
February 6, 1980	Severe Storms, High Surf & Flooding	DR-613	Maui
April 22, 1982	Heavy Rains & Flooding	DR-656	Maui
November 27, 1982	Typhoon Iwa	DR-671	Honolulu, Kaua'i
March 3, 1983	Hawai'i Kīlauea	FM-2044	Not Reported
January 8, 1988	Severe Storms, Mudslides & Flooding	DR-808	Honolulu
May 18, 1990	Lava Flow, Kīlauea Volcano	DR-864	Hawai'i
September 12, 1992	Hurricane Iniki	DR-961	Hawai'i, Honolulu, Kalawao, Kaua'i, Maui, and Niihau (Census County Division)
November 18, 1996	Severe Storms and Flooding	EM-3122	Honolulu
November 26, 1996	Prolonged and Heavy Rains, High Surf, Flooding, Land/Mud Slide	DR-1147	Honolulu
February 18, 1998	Hawai'i Wildfire	FM-2195	Not Reported*
March 15, 1998	Puna District Wildfire	FM-2196	Not Reported*
August 24, 1998	Molokai Fire 98	FM-2236	Not Reported*
March 20, 2000	Puuaakapu Ranch Lot Fire	FM-2293	Hawai'i
November 9, 2000	Severe Storms and Flooding	DR-1348	Hawai'i, Maui
May 18, 2003	Hi - Waikoloa Village– Fire - 05/18/2003	FM-2468	Hawai'i
September 14, 2004	Kawaihae Road Fire Hawai'i	FM-2556	Hawai'i
February 1, 2005	Severe Storms and Flash Flooding	DR-1575	Honolulu
August 2, 2005	Lalamilo Fire	FM-2573	Hawai'i
August 4, 2005	Akoni Pule Highway Fire	FM-2574	Hawai'i
August 15, 2005	Nanakuli Brush Fire	FM-2576	Honolulu
August 19, 2005	Waikele Fire	FM-2577	Honolulu
May 2, 2006	Severe Storms, Flooding, Landslides, and Mudslides	DR-1640	Honolulu, Kaua'i
September 2, 2006	Ma'alaea Fire	FM-2673	Maui
October 17, 2006	Earthquake	DR-1664	Hawai'i, Honolulu, Kaua'i, and Maui
June 28, 2007	Olowalu Fire	FM-2701	Maui
August 14, 2007	Waialua Fire	FM-2720	Honolulu
August 17, 2007	Kohala Mountain Road Fire	FM-2722	Hawai'i
October 28, 2007	Puako Fire	FM-2740	Hawai'i
February 6, 2008	Severe Storms, High Surf, Flooding, and Mudslides	DR-1743	Hawai'i, Kaua'i, and Maui
January 5, 2009	Severe Storms and Flooding	DR-1814	Honolulu and Kaua'i
August 31, 2009	Kaunakakai Fire	FM-2834	Maui
June 9, 2010	Maalaea Fire	FM-2844	Maui
April 8, 2011	Tsunami Waves	DR-1967	Hawai'i, Honolulu, and Maui
April 18, 2012	Severe Storms, Flooding, and Landslides	DR-4062	Kaua'i and Maui
September 12, 2014	Tropical Storm Iselle	DR-4194	Hawai'i and Maui
November 3, 2014	Pu'u 'Ō'ō Volcanic Eruption and Lava Flow	DR-4201	Hawai'i
October 6, 2016	Severe Storms, Flooding, Landslides, and Mudslides	DR-4282	Maui
May 8, 2018	Severe Storms, Flooding, Landslides and Mudslides	DR-4365	Honolulu and Kaua'i
May 11, 2018	Volcanic Eruption and Earthquakes	DR-4366	Hawai'i
August 22, 2018	Hurricane Lane	EM-3399	Hawai'i, Honolulu, Kaua'i, and Maui

Date Declared	Incident Type	Disaster Number	Counties Affected
September 12, 2018	Tropical Storm Olivia	EM-3404	Hawai'i, Honolulu, Kaua'i, and Maui
September 27, 2018	Hurricane Lane	DR-4395	Hawai'i, Kaua'i, and Maui
October 23, 2019	Kahana Ridge Fire	FM-5294	Maui
March 13, 2020	COVID-19	EM-3431	Hawai'i, Honolulu, Kaua'i, and Maui
April 1, 2020	COVID-19	DI-4510	Hawai'i, Honolulu, Kaua'i, and Maui
July 9, 2020	Severe Storms and Flooding	DR-4549	Kaua'i
July 25, 2020	Hurricane Douglas	EM-3529	Hawai'i, Honolulu, Kaua'i, and Maui
May 13, 2021	Severe Storms, Flooding, and Landslides	DR-4604	Maui
February 15, 2022	Severe Storms, Flooding, and Landslides	DR-4639	Honolulu and Maui
August 1, 2021	Mana Road Fire	FM-5404	Hawai'i

Source: FEMA 2023
** For this event, as per the FEMA website, no additional information was filed for this event*

Local HMP Risk Assessment Roll-Up

Element S6, HHPD2, and 44 CFR § 201.4(I2)(ii) and 201.4(c)(2)(iii): The risk assessment shall include an overview and analysis of jurisdictions' vulnerability to the identified hazards and the potential losses, including jurisdictions most threatened by the identified hazards and most vulnerable to damage and loss from hazard events with respect to populations, structures, infrastructure, and community lifelines. Additionally, potential losses to the identified vulnerable structures based on estimates in the local risk assessments as well as the state risk assessment should be included.

All local HMP risk assessments were reviewed, not only to consider data sources for the 2023 SHMP Update but to summarize losses across the state for each hazard. The local plan roll-up, however, proved challenging because all four local HMPs and specifically their risk assessments differ in structure, data used, and analysis methods. Therefore, the 2023 SHMP Update risk assessment not only included an evaluation of state asset vulnerability but also assessed the vulnerability to the population and built environment (buildings and land use), environmental resources, and cultural assets summarized by county. These results provide a technical resource for the next round of local HMP updates and will lend to a smoother local plan roll-up for the State of Hawai'i 2028 SHMP update. The evaluation of the local risk assessment data is included in each hazard profile.

The hazards identified in each local HMP were reviewed to determine the presence of each hazard on a county-by-county basis and to ensure that the 2023 SHMP Update incorporates information from local risk assessments. Table 4.1-2 lists the hazards identified during each county's local mitigation planning efforts, alongside the state's 2018 and 2023 SHMP Update hazards of concern.

Table 4.1-2. Summary of Hazards of Concern Captured in State and Local Hazard Mitigation Plans

Hazard	2023 SHMP	2018 SHMP	Local HMPs			
			County of Kaua'i (2021)	City and County of Honolulu (2020)	County of Maui (2020)	County of Hawai'i (2020)
Climate Change and Sea Level Rise	◆	◆	◆	◆	*	◆

Hazard	2023 SHMP	2018 SHMP	Local HMPs			
			County of Kaua'i (2021)	City and County of Honolulu (2020)	County of Maui (2020)	County of Hawai'i (2020)
Chronic Coastal Flood	◆ Flood	◆	◆ High Surf, Coastal Flood, Erosion	◆ Coastal Erosion, High Surf	◆ Coastal Erosion, High Surf	◆ High Surf, Storm Surge, Coastal
Cyber Threat	◆					◆ Other Hazards of Interest
Dam Failure	◆ Infrastructure Failure	◆	◆	◆	◆ Dam and Reservoir Failure	◆
Drought	◆	◆	◆ Heat, Drought	◆	◆ Drought, Extreme Heat	◆
Earthquake	◆	◆	◆	◆	◆	◆
Event-Based Flood	◆ Flood	◆	◆ Inland Flooding	◆ Coastal, Inland	◆	◆
Extreme Cold					◆	
Hazardous Materials	◆	◆	**	◆	◆	
Health Risks	◆	◆	**		◆	◆ Other Hazards of Interest
High Wind Storms	◆	◆	◆ Tropical Cyclones, high winds combined	◆	◆	◆
Hurricane	◆	◆	◆ Tropical Cyclones, high winds combined	◆ Tropical Cyclones, Hurricane Storm Surge, Scour	◆ Hurricane, Tropical Storm, Kona Storms	◆ Tropical Cyclone
Infrastructure Failure	◆					
Landslide and Rockfall	◆	◆	◆ Landslide	◆ Landslide, Debris Flows, Rockfall	◆ Landslide, Mudflows, Rockfall, Slurry	◆
Tsunami	◆	◆	◆	◆	◆	◆
Terrorism	◆					◆ Other Hazards of Interest
Volcanic Hazards	◆	◆		◆ Vog	◆ Lava Flow, Debris Flow, Ash, Vog	◆
Wildfire	◆	◆	◆	◆	◆	◆

Sources: County of Kaua'i, 2021; City and County of Honolulu 2020; County of Maui 2020; County of Hawai'i 2020

* *The County of Maui did not include climate change as a stand-alone hazard; however, climate change impacts are discussed throughout the plan.*

** *Hazardous materials and health and medical may have been included as critical facilities in the local HMPs and therefore estimated potential impacts discussed in all hazard sections.*

Table 4.1-3 compares the risk assessment terminology and ranking for each county HMP. The basis of the risk assessment and ranking for counties varied according the factors chosen by each jurisdiction. For example, the local plans assessed "asset" or "property" exposure and vulnerability. While community lifelines may have been part of the asset or property list, they were not specifically indicated as part of the analysis. The County of Maui

performed a ranking for socially vulnerable populations for each Community Planning Area which did not factor in with their overall priority risk index to rank the hazards. The City and County of Honolulu and the counties of Kaua‘i and Hawai‘i did not specifically include socially vulnerable populations in the hazard ranking criteria. The following list summarizes the basis for each county’s risk ranking methodology:

Kaua‘i County used a risk ranking methodology based on:

- Probability of occurrence
- Weighted impact to people based on the percentage of the total population exposed to the hazard event
- Weighted impact to property based on the percentage of the total property value exposed to the hazard event (includes tax assessor real property data)
- Weighted impact to the economy based on the percentage of the total property value vulnerable to the hazard event

City and County of Honolulu used a damage assessment ranking by average annual loss (AAL) estimates based on:

- Probability of occurrence
- Magnitude and severity
- Asset exposure and vulnerability
- Consequences

Maui County used a priority risk index (PRI) to rank hazards based on:

- Probability
- Impact
- Spatial Extent
- Warning Time
- Duration

For Maui County, a separate social vulnerability ranking was performed for each Community Planning Area based on:

- Household composition
- Socioeconomic status
- Information Access Vulnerability
- Housing Characteristics
- Access to Lifelines

Hawai‘i County used a risk ranking methodology based on:

- Probability of occurrence
- Weighted impact to people based on the percentage of the total population exposed to the hazard event
- Weighted impact to property based on the percentage of the total property value exposed to the hazard event (includes tax assessor real property data)
- Weighted impact to the economy based on the percentage of the total property value vulnerable to the hazard event

Table 4.1-3. Risk Assessment and Ranking Used in County HMPs

Hazard	County of Kaua'i Risk Ranking	City and County of Honolulu Damage Assessment Ranking	County of Maui Hazard Ranking	County of Hawai'i Risk Ranking
Climate Change and Sea Level Rise	High	Not ranked	Not included as a stand-alone chapter	Medium
Chronic Coastal Flood	High	$3 Million / Year	High	Medium
Cyber Threat	Not included	Not included	Not included	Not ranked
Dam Failure	Low	Less than $1 Million / Year	Moderate	Low
Drought	Not ranked	Not ranked	Moderate	Low
Earthquake	Low	$21 Million / Year	Moderate	High
Event-Based Flood	High	$41 Million / Year	High	High
Extreme Cold	Not included	Not included	Low	Not included
Hazardous Materials	Included in the critical facilities of each hazard	Less than $0.10 Million / Year	Low	Not included
Health Risks	Included in the critical facilities of each hazard	Not ranked	Moderate	Not ranked
High Wind Storms	High	Not ranked	High	High
Hurricane	High	$410 Million / Year	High	High
Infrastructure Failure	Not included	Not included	Not included	Not included
Landslide and Rockfall	Medium	$1 to $5 Million / Year	High	High
Tsunami	Medium	$81 Million / Year	High	Low
Terrorism	Not Included	Not included	Not included	Not ranked
Volcanic Hazards	Not included	Not ranked	Moderate	High
Wildfire	High	$1 Million / Year	High	High

2023 SHMP Update Hazards of Concern

Based on this review, all hazards of concern in the 2018 SHMP are included in the 2023 SHMP Update. There are no commonly recognized natural hazards that have been omitted from the plan. However, changes have been made to the grouping and/or renaming of existing hazards; further, additional elements to existing hazards were included to capture a more current snapshot of risk. Two additional non-natural hazards were included to align the 2023 SHMP with the state's *2022 Hazards and Vulnerabilities Overview* and the *2022 Threat and Hazard Identification and Risk Assessment* (THIRA). The hazards of concern evaluated for the 2018 SHMP and 2023 SHMP Update are presented in Table 4.1-3 in alphabetical order for this update. The order of the listing does not indicate

the hazards' relative severity. Each hazard section contains a subsection that discusses the potential changes in future probability and impacts resulting from climate change and the impacts of the hazard to the socially vulnerable population.

4.1.2 ASSET INVENTORIES

National, state, and county resources were reviewed to identify best-available data to update the risk assessment. To protect individual privacy and the security of critical facilities, information on properties assessed is presented in aggregate, without details about specific individual properties.

STATE ASSETS

Element S5 44 CFR § 201.lc)(2)(ii) and 201.4(c)(2)(iii): The risk assessment shall address the vulnerability of state assets located in hazard areas and estimate the potential dollar losses to these assets, including state-owned and operated critical facilities, buildings, infrastructure, and community lifelines. The assessment should include a summary of the potential impacts to state assets from each of the identified hazards.

FEMA requires the state to identify its assets which may include state-owned or operated buildings, infrastructure and critical facilities. For the 2023 SHMP Update, the State of Hawai'i assessed the vulnerability of the following types of state assets: state-owned and leased buildings; state roads; and critical facilities identified by the state and others, which includes local and state-owned critical facilities and infrastructure.

State Buildings

The State Risk Management Office provided a list of 6,634 state buildings to utilize for the risk assessment. The data set did not have attribution to determine the number of owned versus leased buildings; this data will be referred to as state buildings in the 2023 SHMP Update. The list of facilities was geocoded to generate a spatial layer with the attributes needed for the analyses. Not all facilities had sufficient location data for geocoding. Of the total 6,634 facilities, 6,095 had sufficient data to be successfully geocoded and included in the spatial analyses reported in Sections 4.2 through 4.16. The data set included various structural attributes used for the analyses, including 2017 replacement cost values from the State of Hawai'i Risk Management Office, the agency that owns or leases the building, use description, year built, number of stories, and square footage. For buildings missing values for these attributes and for additional attributes required for the FEMA Hazus analyses, default values were used.

Table 4.1-4. Hazards Evaluated in 2018 and 2023

2018 SHMP Hazards	2023 SHMP Hazards
Climate Change and Sea Level Rise	Climate Change and Sea Level Rise ▪ Increased Surface Air Temperature ▪ Decline in Overall Precipitation ▪ Increase in Rain Intensity ▪ Sea Level Changes ▪ Increased Sea Surface Temperatures ▪ Ocean Acidification
(not included)	Cyber Threat (new hazard to align with the state's Hazards and Vulnerabilities Overview and THIRA)
Drought	Drought
Earthquake	Earthquake
Chronic Coastal Flood Event-Based Flood	Flood ▪ Event-Based Coastal Flooding ▪ Inland Flooding ▪ Passive Flooding ▪ Annual High Wave Flooding ▪ Coastal Erosion ▪ Tidal Flooding/King Tides (combines chronic coastal and event-based flooding to align with the state's Hazards and Vulnerabilities Overview and THIRA)
Hazardous Materials	Hazardous Materials ▪ Fixed-Site Hazardous Materials ▪ In-Transit Hazardous Materials
Health Risks	Health Risks ▪ COVID-19 ▪ Vector-Borne Disease ▪ Water-Borne Disease ▪ Pandemic Flu ▪ Bioterrorism
Hurricane	Hurricane
Dam Failure	Infrastructure Failure (includes dam failure to align with the state's Hazards and Vulnerabilities Overview and THIRA)
Landslide and Rockfall	Landslide and Rockfall
(not included)	Terrorism (new hazard to align with the state's Hazards and Vulnerabilities Overview and THIRA)
Tsunami	Tsunami
Volcanic Hazards	Volcanic Hazards ▪ Lava Flows ▪ Vog ▪ Bench Collapse ▪ Methane Explosions
Wildfire	Wildfire
High Wind Storm	Windstorm ▪ Trade Winds ▪ Kona Winds

Structures without replacement cost values were updated using RSMeans 2022 data. RSMeans is the industry-standard cost-estimate model for replacement cost. Therefore, replacement costs could vary significantly from actual values; however, this is a suitable methodology for planning. Replacement cost value does not include land value and may underestimate the total loss. Appendix F provides information on Hazus and the default values.

The analysis of state buildings is categorized according to the agency that uses the structure. Total building counts and replacement cost values for each agency are shown in Table 4.1-4. Individual hazard sections show the number and value of the buildings that may be impacted by the hazard.

Table 4.1-5. Summary of State Buildings by Agency

	State Building	
Agency	Count	Total Replacement Cost Value
Dept of Accounting & General Services	66	$953,963,738
Dept of Agriculture	70	$147,607,399
Dept of Attorney General	15	$108,425,480
Dept of Budget & Finance	16	$28,968,679
Dept of Business, Economic Development & Tourism	25	$645,480,379
Dept of Commerce & Consumer Affairs	2	$40,197,360
Dept of Defense	69	$267,352,836
Dept of Education	4,090	$10,598,205,739
Dept of Hawaiian Home Lands	12	$110,427,352
Dept of Health	44	$387,068,440
Dept of Human Resources Development	1	$5,973,872
Dept of Human Services	130	$480,212,294
Dept of Labor & Industrial Relations	22	$90,076,209
Dept of Land & Natural Resources	90	$101,441,821
Dept of Public Safety	154	$440,774,415
Dept of Taxation	1	$7,174,162
Dept of Transportation	68	$2,935,208,214
Hawai‘i State Ethics Commission	1	$984,533
Hawai‘i Health Systems Corporation	106	$1,230,852,871
Hawai‘i Housing Finance & Development Corporation	86	$360,851,671
Hawai‘i Public Housing Authority	273	$982,981,701
Hawai‘i State Legislature	2	$48,555,381
Hawai‘i State Public Library System	53	$525,584,082
Judiciary	41	$534,877,354
Legislative Reference Bureau	1	$2,996,162
Office of Hawaiian Affairs	11	$54,125,645
Office of the Auditor	2	$1,921,180
Office of the Governor	1	$2,996,162
Office of the Lieutenant Governor	2	$4,588,849
Office of the Ombudsman	1	$1,818,060
Research Corporation of the University of Hawai‘i	3	$4,189,026
University of Hawai‘i	637	$5,014,974,503
Total	**6,095**	**$26,120,855,568**

Source: State of Hawai‘i Risk Management Office 2017; RSMeans 2022

State Roads

The State of Hawai'i Department of Transportation's state route inventory, downloaded from the State of Hawai'i GIS Program Geospatial Data Portal, was used to determine the state road exposure to spatially delineated hazards. The spatial layer displays the state routes for the main Hawaiian Islands as of 2022. Economic impact of hazard events on road infrastructure has not been monetized, although exposure is identified and discussed. Appendix D (Map Atlas) includes maps of each island that depict the major transportation assets, highways, and airports located throughout the state.

Community Lifelines and Critical Facilities

Community lifelines are the most fundamental services of a community. FEMA developed the community lifelines construct to increase effectiveness in disaster operations, and during initial response, priority efforts should focus on stabilizing community lifelines.

Figure 4.1-1. Community Lifeline Categories

Source: (FEMA 2020)

For the risk assessment, HI-EMA provided a list of facilities deemed as critical. This list was compiled for the *Makani Pahili 2017 Emergency Power Prioritization Workshop Series Final Report*. This data set was used as the community lifeline inventory, which includes both local and state-owned buildings, critical facilities, and infrastructure. The facilities were assigned to community lifeline categories, as summarized in Table 4.1-5. The category "Additional Critical Facilities" are facilities that are also deemed critical by participants in the emergency power prioritization workshop series (i.e., community and civic centers, gyms, parks, warehouses, and home improvement stores); however, they did not fit seamlessly into a community lifeline category. Individual hazard sections show the category and number of lifelines and additional critical facilities may be impacted by the hazard.

Table 4.1-6. Summary of Community Lifelines and Critical Facilities by Category

Category	Count	Total Replacement Cost Value
Communications	188	$776,797,683
Energy	89	$3,093,949,530
Food, Water, Shelter	345	$11,847,189,588
Hazardous Material	12	$436,474,800
Health and Medical	193	$4,606,713,364
Safety and Security	486	$38,164,188,232
Transportation	56	$2,039,091,600
Additional Critical Facilities	106	$447,698,794
Total	**1,475**	**$61,412,103,591**

Source: HI-EMA 2017; FEMA 2020; RSMeans 2022

LOCAL ASSETS

Element S6, HHPD2, and 44IR § 201.4(c)(2)(ii) and 201.4(c)(2)(iii): The risk assessment shall include an overview and analysis of jurisdictions' vulnerability to the identified hazards and the potential losses, including jurisdictions most threatened by the identified hazards and most vulnerable to damage and loss from hazard events with respect to populations, structures, infrastructure, and community lifelines. Additionally, potential losses to the identified vulnerable structures based on estimates in the local risk assessments as well as the state risk assessment should be included.

In addition to assessing the vulnerability of state assets, a key component to the risk assessment is to evaluate potential losses to jurisdictions in the state. The State of Hawai'i 2023 SHMP Update risk assessment included a vulnerability assessment for the counties utilizing statewide population, building, environmental resource, and cultural asset spatial data sets. Estimated exposure and potential impacts to these assets are reported in each hazard section. In addition, economic impacts are discussed qualitatively for each hazard. Privately-owned agriculture and ranching structures were not included in the risk assessment; however, it should be acknowledged that if such structures are impacted by hazards, community lifelines and supply chains could be disrupted.

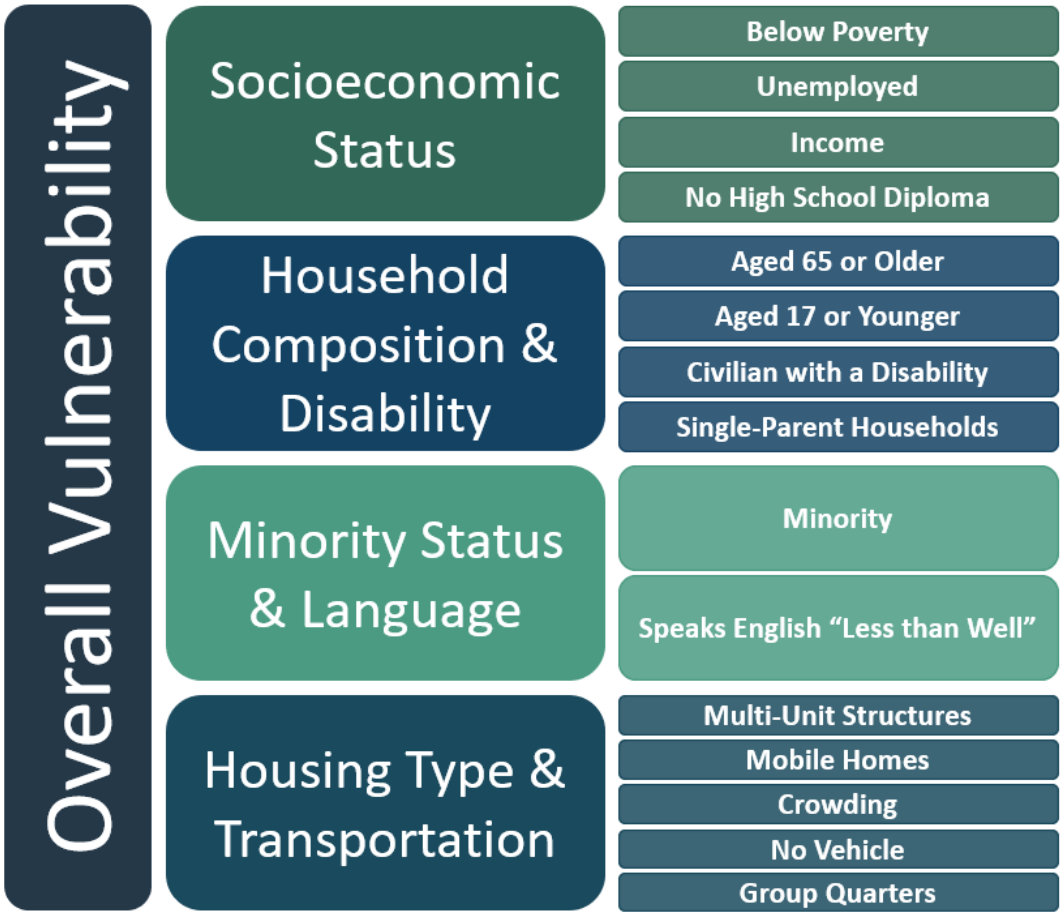
Each county is divided into judicial districts for election, taxation, education, city, county, and all other purposes (State of Hawai'i n.d.). Hazard mapping developed for the 2023 SHMP includes the judicial district boundaries to provide a higher resolution of vulnerability and to inform local decision-making.

Socially Vulnerable and Total Populations

Research has shown that some populations are at greater risk from hazard events because of decreased resources or physical abilities. Risk to the entire residential population is analyzed for each of the hazards. For the SHMP Update, the Social Vulnerability Focus Group identified the 2018 statewide Social Vulnerability Index (SVI) published by the Centers for Disease Control and Prevention (CDC) to be used to estimate risk to socially vulnerable populations. The SVI is a combination of 15 social factors that contribute to social vulnerability as shown in Figure 4.1-2. Index values are based on a percentile ranging from 0 to 1, with higher values indicating greater vulnerability. For this analysis, Census tracts with an overall SVI ranking of 0.8 or greater were categorized as highly vulnerable tracts with socially vulnerable populations. This aligns with FEMA's current annual Hazard Mitigation Assistance (HMA) evaluation scoring for high social vulnerability.

The SVI data is available by Census tract level and was clipped to areas of residential parcels only. Total population was adjusted for each census tract using the countywide percentage change calculated between the 2018 5-year American Community Survey (ACS) population shown in the SVI data and the 2020 5-year ACS countywide population totals compiled from the Census Bureau. Hazard risk to the population was estimated by overlaying the hazard areas to the processed census tracts. The percentage area of the tracts within each hazard boundary was used to estimate the number of persons at risk to each hazard. The socially vulnerable population makes up more than 20% of the state's total residents, which excludes visitors and tourists. Refer to Table 4.1-6 for a summary of these statistics. Figure 4.1-3 through Figure 4.1-6 depict low, medium, and high social vulnerability areas in each county.

Figure 4.1-2 CDC Social Vulnerability Indicators



Source: (U.S. Department of Health & Human Services 2022)

Table 4.1-7. Population Statistics by County

County	Total Population	Socially Vulnerable Population	Percent of Total Population
County of Kauaʻi	71,949	11,149	15.5%
City and County of Honolulu	979,682	224,567	22.9%
County of Maui	167,093	35,284	21.1%
County of Hawaiʻi	201,350	45,257	22.5%
Total	**1,420,074**	**316,257**	**22.3%**

Source: CDC 2018; ACS 5-year 2020 Population Estimates

Figure 4.1-3. County of Kaua'i Social Vulnerability Ranking

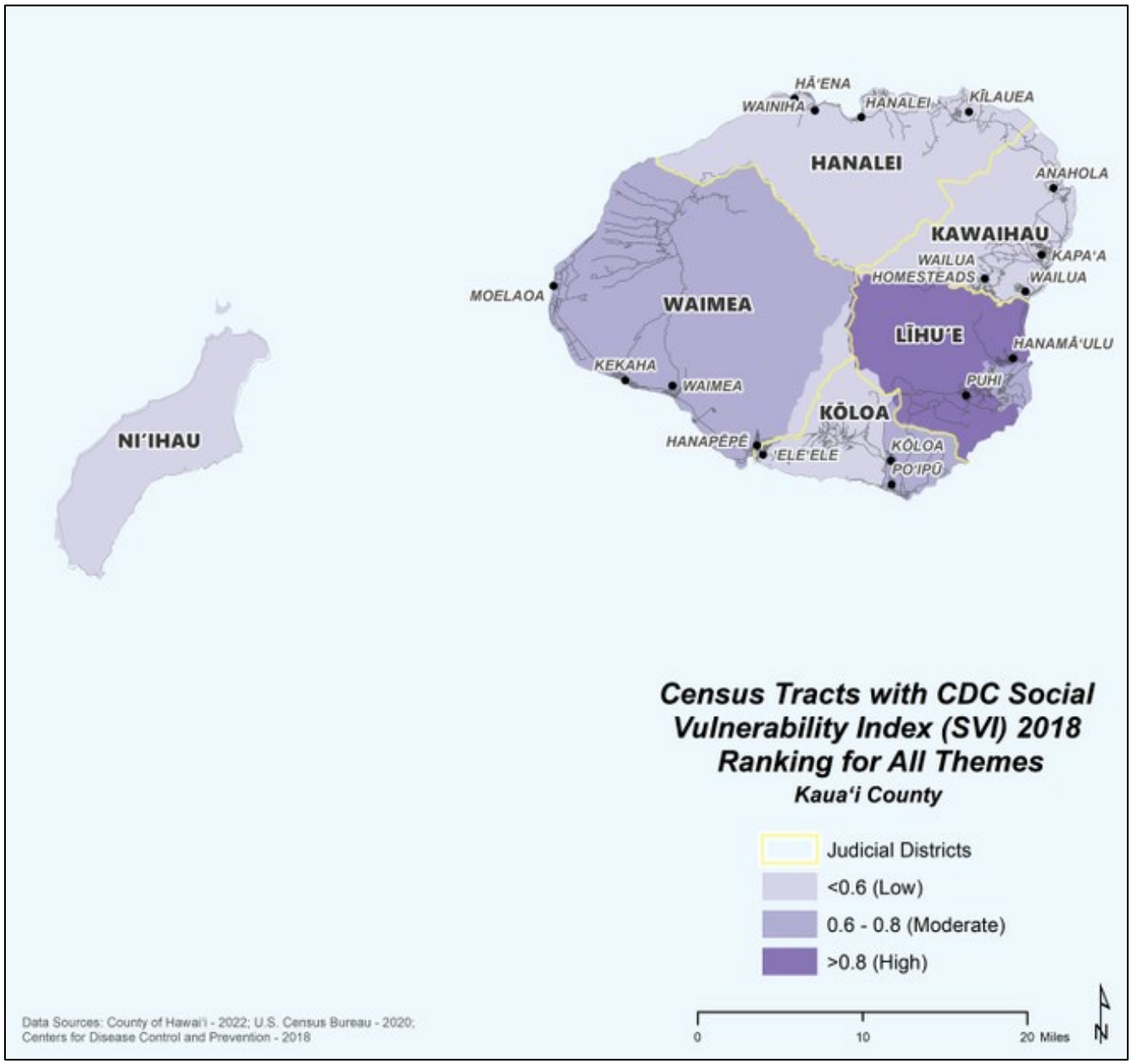


Figure 4.1-4. City and County of Honolulu Social Vulnerability Ranking

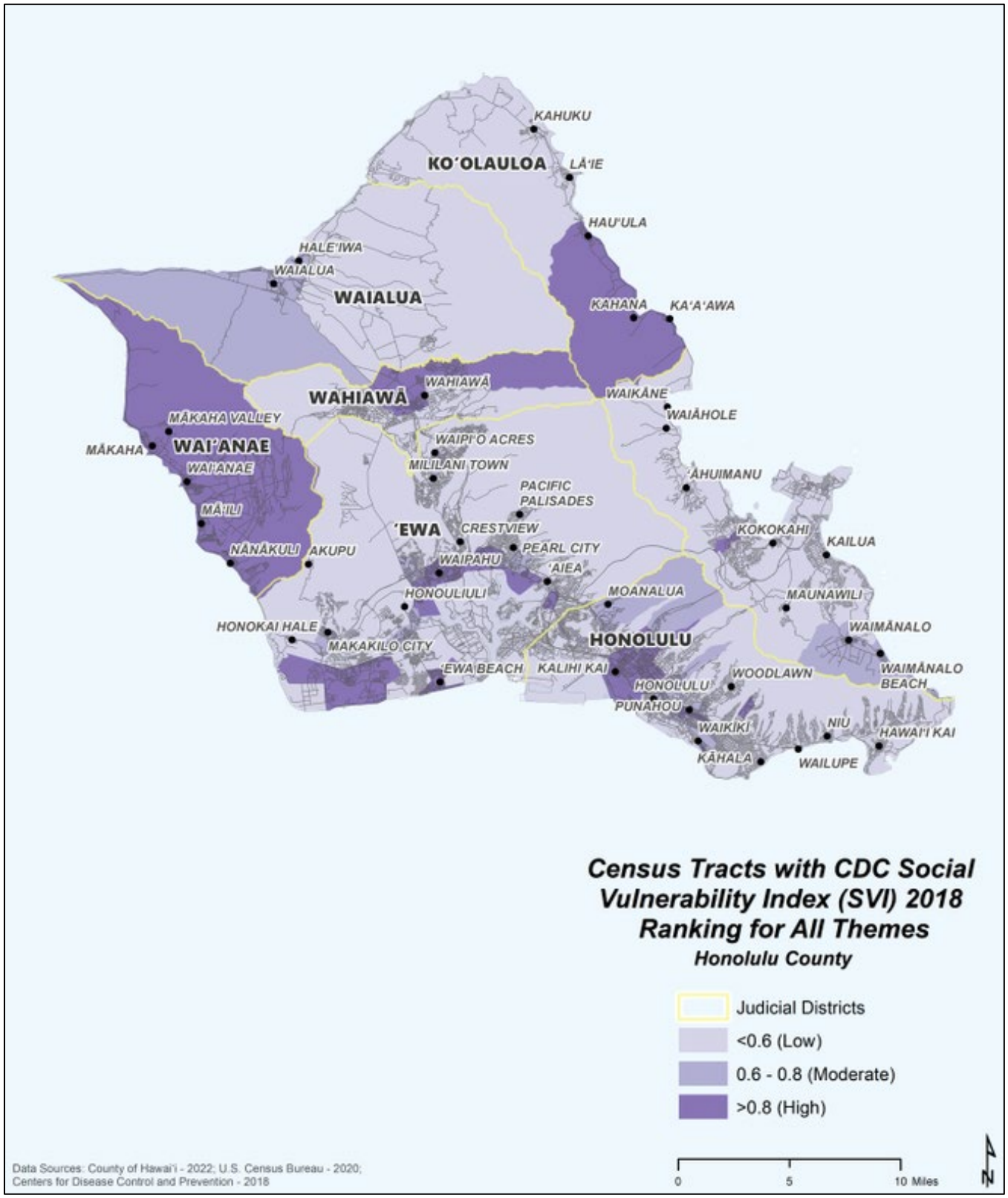


Figure 4.1-5. County of Maui Social Vulnerability Ranking

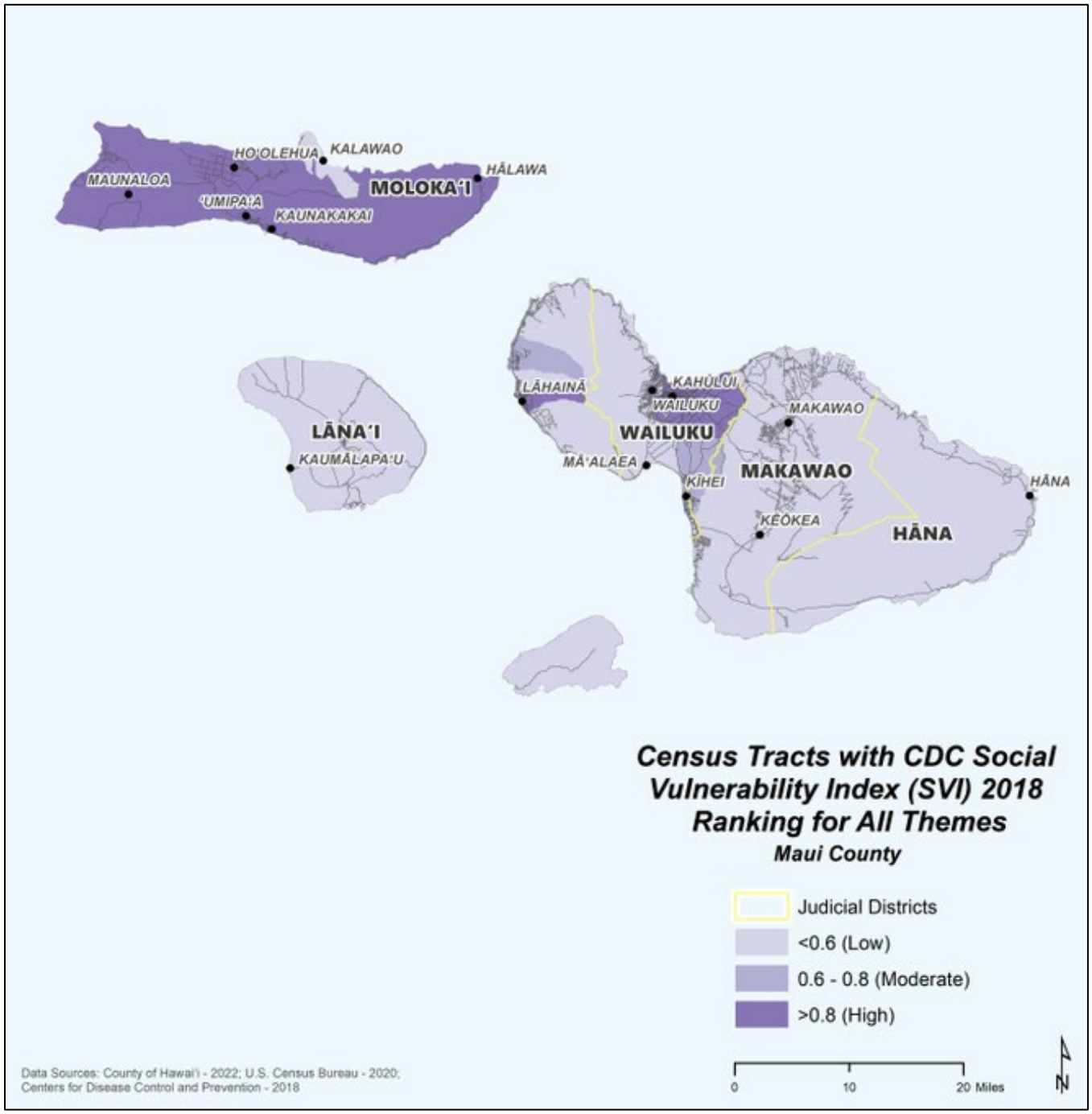
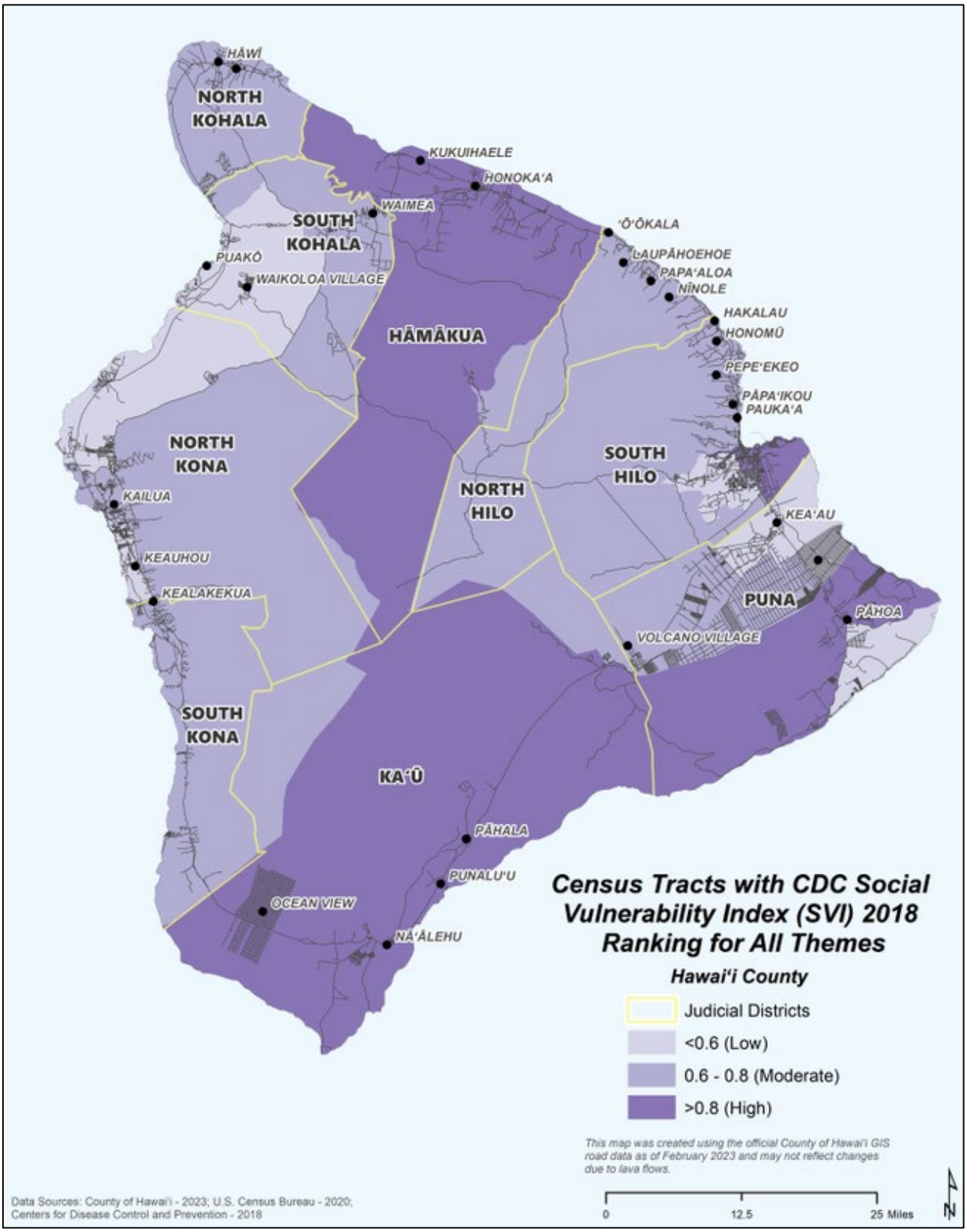


Figure 4.1-6. County of Hawai'i Social Vulnerability Ranking



General Building Stock

To assess the built environment, a 2022 structure level general building stock inventory data set created by Niyam IT for HI-EMA was used for the risk assessment. This building data used the U.S. Army Corp of Engineers 2021 National Structure Inventory and was modified for the state to remove structures impacted by the 2018 Kīlauea Eruption. The structures contained attributes compatible for Hazus modeling and were updated with RSMeans 2022 values for the replacement cost valuation. The spatial hazard layers were overlaid with the building inventory in GIS to determine the replacement cost value located in the impact area of the hazard. When Hazus was utilized to evaluate the earthquake, flood, hurricane, and tsunami events, the potential loss to the building stock was estimated.

Environmental Resources

The state contains an abundant array of onshore and offshore environmental assets, including many species that are endemic only to the Hawaiian Islands. The HI-EMA identified the following assets to include in the risk assessment based on the availability of spatial data: critical habitats (or habitats that are known to be essential for an endangered or threatened species), wetlands, parks and reserves, reefs, and watersheds. The spatial hazard layers were overlaid with the environmental resources in GIS to determine which environmental resources are located in the impact area of the hazard. Refer to Section 3 (State Profile) for a more detailed description of these assets in the state.

Cultural Assets

Cultural asset information in the State of Hawai‘i is managed by the Hawai‘i State Historic Preservation Division in the Hawai‘i Department of Land and Natural Resources (DLNR). The location of cultural resources was provided by DLNR and include archaeology sites, burial sensitivity areas, historic buildings, historic districts, historic objects, and historic structures. Additionally, the 2021 Hawaiian Homelands spatial data was used to assess cultural assets at risk to impacts from the natural hazards evaluated. The spatial hazard layers were overlaid with the cultural asset data in GIS to determine the area of land located in the impact area of the hazard.

4.1.3 CHANGES THAT IMPACT VULNERABILITY

Element S7 and 44 CFR § 201.4(d): The risk assessment shall reflect changes in development, including a summary of recent development and potential or projected development in hazard-prone areas on state and local government risk assessments. Changes in development include changes in land use and the built environment, population demographics, vulnerability of state assets, and development that could impact jurisdictions most threatened by identified hazards.

In addition to summarizing the current vulnerability, the State of Hawai‘i has identified three factors of change that can affect the State’s vulnerability to hazards: (1) changes in population; (2) changes in development, and (3) other identified conditions as relevant and appropriate, including the impacts of climate change. Identifying these changes and integrating them into the risk assessment ensures they are considered when developing the mitigation strategy to reduce these vulnerabilities in the future.

As summarized in Section 3 (State Profile), the State of Hawai'i has experienced changes in development over the performance period of the 2018 SHMP; and new development, population demographic changes, and increases in visitors/tourists are anticipated in the future. There is no statewide system that tracks where this development has occurred or is anticipated to occur. Therefore, it proves challenging to conduct a statewide assessment to determine whether development has occurred in hazard areas.

For example, more than 600 residences were inundated with lava during the 2018 Kīlauea eruption on Hawai'i Island. Many of the displaced residents built homes in other areas within the County of Hawai'i, but that shift in development was not tracked. Additionally, over 32 miles of public and private roads were inundated. While many of the roads have not been rebuilt yet, State Routes 132 and 137 have been reopened.

While there were no changes in the number of state-owned and/or leased buildings and critical facilities assessed in the 2023 SHMP Update compared to the 2018 SHMP, the replacement cost value of these structures did increase; therefore, the risk and vulnerability of these structures increased. In addition, different general building inventories were used in the 2018 SHMP than the 2023 SHMP Update making it impossible to conduct a side-by-side comparison analysis to determine changes in vulnerability. However, using a structure-level general building stock data set in the 2023 SHMP Update did indicate that the replacement cost value of structures at risk to hazards in the state are greater than what was analyzed in the 2018 SHMP.

Development continues to occur in the state. Any new development that has occurred since 2021 is not reflected in the reported general building stock risk assessment results. Generally speaking, damages and losses as a result of hazard events are generally associated with older existing infrastructure and buildings rather than new development. This is because building codes and land use regulations, described in Section 5 (Capability Assessment), limit development in hazard areas or require construction to meet higher standards within hazard areas. This provides a reduction of risk in areas where new development or redevelopment is occurring.

In an attempt to understand if projected new development may be impacted by hazards, an exposure analysis was conducted using three data sets that were available in spatial formats to generally assess and discuss where development may occur; 1) Hawai'i Community Development Authority's Community Development Districts; 2) Enterprise Zones and 3) Maui Development Projects; refer to Section 3 (State Profile). The spatial hazard layers were overlaid with the projected development areas to determine the area of land located in the impact area of the hazard. These results are reported at the end of each hazard section (Sections 4.2 through 4.15). A qualitative discussion regarding other factors of change is also included, as appropriate.

Because the state is currently experiencing the impacts of the changing climate today, climate change continues to be a stand-alone hazard of concern included in the SHMP. Climate change and associated impacts are discussed in Section 4.2 (Climate Change and Sea Level Rise).

4.1.4 HAZARD-SPECIFIC DATA AND METHODOLOGIES

Element S3, FMAG1, and 44 CFR § 201.4(c)(2)(i) and 204.51(d)(2): The risk assessment shall include an overview of the type and location of all natural hazards that can affect the state, including information on previous occurrences of hazard events, probability of future events, range of observed and anticipated intensities of hazards, using maps where appropriate.

To assess vulnerability, three different levels of analysis were used depending upon the data available for each hazard as described below. In addition, location and potential loss estimates documented in the four local HMPs were also integrated into each hazard section, when available. Table 4.1-7 summarizes the types of analyses performed for each hazard followed by a discussion of each approach.

- **Historic Occurrences and Qualitative Analysis** – This analysis includes an examination of historic impacts to understand potential impacts of future events of similar size. In addition, potential impacts and losses are discussed qualitatively using best-available data and professional judgment.
- **Exposure Assessment** – This analysis involves overlaying available spatial hazard layers, or hazards with defined extent and locations, with assets in GIS to determine which assets are located in the impact area of the hazard. The analysis highlights which assets may be affected by the hazard. If the center of each asset is located in the hazard area, it is deemed exposed and potentially vulnerable to the hazard.
- **Loss estimation** — The Hazus modeling software was used to estimate potential losses for the event-based flood, earthquake, hurricane, and tsunami hazards. In addition, an examination of historic impacts and an exposure assessment was conducted for these spatially-delineated hazards. Refer to Appendix F (State Profile and Risk Assessment Supplement) for more information on FEMA's Hazus model.

Table 4.1-8. Summary of Risk Assessment Analyses

Hazard	Data Analyzed						
	State Buildings	State Roads	Community Lifelines and Critical Facilities	Population	General Building Stock	Environmental Resources	Cultural Assets
Climate Change and Sea Level Rise	E	E	E	E, H	E, H	E	E
Cyber Threat	Q	Q	Q	Q	Q	Q	Q
Drought	Q	Q	Q	Q	Q	Q	Q
Earthquake	E, H	E	E, H	E, H	E, H	E	E
Flood	E, H	E	E, H	E, H	E, H	E	E
Hazardous Materials	Q	Q	Q	Q	Q	Q	Q
Health Risks	Q	Q	Q	Q	Q	Q	Q
Hurricane	E, H	E	E, H	E, H	E, H	E	E
Infrastructure Failure	E	E	E	E	E	E	E
Landslide and Rockfall	E	E	E	E	E	E	E
Terrorism	Q	Q	Q	Q	Q	Q	Q
Tsunami	E, H	E	E, H	E, H	E, H	E	E
Volcanic Hazards	E	E	E	E	E	E	E
Wildfire	E	E	E	E	E	E	E
Windstorm	Q	Q	Q	Q	Q	Q	Q

E – Exposure analysis; H – Hazus analysis; Q – Qualitative analysis

Note: The four local HMPs were also consulted and potential losses summarized in hazard location and vulnerability assessment subsections when available.

Extensive outreach was conducted at the early stages of the 2023 SHMP Update process to collaborate with hazard SMEs to obtain the best-available data and methodologies to assess risk (refer to Section 2 and Appendix A – Planning Process Documentation). The following summarizes the data and analysis conducted to evaluate each

hazard of concern. Sections 4.2 through 4.15 summarize the vulnerability assessment results. Appendix F (State Profile and Risk Assessment Supplement) includes all data generated as a result of the risk assessment in further detail (e.g., by state agency). Appendix D (Map Atlas) includes additional maps gathered or generated to support the risk assessment.

Climate Change and Sea Level Rise

Element S4 and 44 CFR § 201.4(c)(2)(i): The risk assessment shall include an overview of the probabilities of future hazard events, including considerations of changing future conditions such as climate change (e.g., long-term weather patterns, average temperature, and sea levels) on the type, location, and range of anticipated intensities of identified hazards.

The climate change and sea level rise hazard is limited to the discussion and analysis of key indicators of the changing climate and sea level rise. A qualitative assessment was conducted for the climate change indicators presented: rising air temperatures; decreased rainfall and stream flow; increased rain intensity; increased sea level and sea surface temperatures; and acidification of the ocean.

Sea level rise data compiled for the *2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report* was used to assess exposure. Three modeled hazards (passive flooding, annual high wave flooding, and coastal erosion) were combined to define the projected extent of chronic flooding called the Sea Level Rise Exposure Area (SLR-XA). The SLR-XA for the islands of Hawai'i, Moloka'i, and Lāna'i is based on modeling passive flooding only.

To assess the chronic coastal flood hazard (defined as SLR-XA with 1.1 feet of sea level rise discussed in Section 4.2) with sea level rise, the SLR-XA with 3.2 feet of sea level rise was utilized (SLR-XA-3.2).

Key Terms in the 2023 HMP Update to Assess Flood and Sea Level Rise Vulnerability

- **SLR-XA** – Depicts the area exposed to potential chronic coastal flooding and land loss based on modeling passive flooding, annual high wave flooding, and coastal erosion.
- **Chronic Coastal Flood** – Three chronic flooding hazards were modeled: passive 'bathtub' flooding, annual high wave flooding and coastal erosion (a.k.a. SLR-XA). The SLR-XA with 1.1 feet of sea level rise, or chronic coastal flooding, is currently happening in the State and was assessed in Section 4.6 (Flood).
- **SLR-XA-3.2** – The SLR-XA with 3.2 feet of sea level rise, representing chronic coastal flooding and sea level rise, was assessed in Section 4.2 (Climate Change and Sea Level Rise).
- **Event-Based Flood** – The 1% annual chance flood event as depicted on the FEMA Flood Insurance Rate Maps, also known as the Special Flood Hazard Area (inclusive of V- and A-zones) was assessed in Section 4.6 (Flood).
- **1% CFZ-3.2** – The 1% annual coastal flood zone with 3.2 feet of sea level rise, was assessed to examine potential impacts to event-based flooding with SLR (Section 4.2 - Climate Change and Sea Level Rise).

To assess event-based coastal flooding with sea level rise, the 1% coastal flood zone with 3.2 feet of sea level rise (1%CFZ-3.2) was utilized (Tetra Tech Inc. and Sobis Inc. 2017). Refer to Appendix F for more details on the generation of the 1%CFZ-3.2.

When assessing impacts from the SLR-XA-3.2, permanent loss of the structure and land is assumed. The most accurate way to estimate this loss is to utilize the combined value of the structure and the land using tax assessor data. However, the asset data used in this analysis did not contain structure or land values from the tax assessor. Therefore, to estimate impacts and potential losses for the state, assets located within the hazard area are considered at risk and vulnerable to the hazard area.

Cyber Threat

To assess the vulnerability of the state to cyber threat and its associated impacts, a qualitative assessment was conducted. Refer to Section 4.3 for more information about this hazard of concern.

Drought

To assess the vulnerability of the state to drought and its associated impacts, a qualitative assessment was conducted. Refer to Section 4.4 for more information about this hazard of concern.

Earthquake

ShakeMap data prepared by the U.S. Geological Survey (USGS) and probabilistic earthquake data in Hazus version 5.1 were used to assess the earthquake hazard. The evaluation of the following historic events utilizing the current environment provides an understanding of potential loss if the event were to happen today.

- The Kalapana 1975 M7.7 scenario with an epicenter approximately 26 miles south-southeast of Hilo. This scenario represents the Kalapana M7.2 earthquake on November 29, 1975.
- The Kaʻū M8.0 scenario with an epicenter approximately 4 miles northwest of Pāhala. This scenario represents the Kaʻū District M7.9 earthquake on April 3, 1868.
- The Lānaʻi M7.0 scenario with an epicenter approximately 13 miles north-northwest of Lānaʻi City. This scenario represents the Lānaʻi M6.8 earthquake on February 20, 1871.
- The NE Maui M7.0 scenario with an epicenter approximately 31 miles northeast of Kahului. This scenario represents the Maui M6.5 earthquake on January 23, 1938.
- The standard Hazus 100-year probabilistic event.

A Level 2 analysis was performed in Hazus version 5.1 to estimate potential losses as a result of each scenario using the Advanced Engineering Building Module (AEBM) Hazus model (Section 4.5); refer to Appendix F (State Profile and Risk Assessment Supplement) for further details on Hazus and Level 2 analyses. The statewide general building stock data was used to update the aggregate building stock data within Hazus. The state-owned and/or leased facilities and critical facilities were uploaded in the Hazus AEBM model to update structure-level data.

The National Earthquake Hazard Reduction Program (NEHRP) soils and landslide susceptibility data were also integrated into the Hazus model. NEHRP soils D and E were identified as areas potentially more vulnerable to damage; these areas were used as the hazard extent for the exposure analysis.

- NEHRP soils data for the County of Hawai'i was provided by AECOM.
- NEHRP soils data for the County of Maui was originally compiled by Tetra Tech for the 2015 Maui County Hazard Mitigation Plan. The NEHRP soils data were generated using the USGS Geologic Map of the State of Hawai'i data and the County of Maui Probable Site Classes map in the 2013 Hawai'i State Mitigation Plan. Data was recreated from static sources, as GIS data files were unavailable. This methodology has resulted in a rather coarse resolution that is limited in applicability to planning purposes.
- The area of NEHRP soil classifications for the Counties of Kaua'i and City and County of Honolulu are unknown at this time.
- Landslide susceptibility data for the County of Hawai'i was provided by the Pacific Disaster Center. Landslide susceptibility data categorized for use in Hazus was not available for the other counties.

FLOOD

Event-Based Flood

The National Flood Hazard Layer Digital Flood Insurance Rate Map (DFIRM) data, effective February 26, 2021, with the latest Letter of Map Amendment January 4, 2021, was used to assess exposure from the 1 percent annual chance flood event. Table 4.1-8 summarizes the effective dates of each county's DFIRM. Additionally, depth grids for each county were updated with the following data:

- **County of Kaua'i:** The effective countywide DFIRM from February 26, 2021, and National Oceanic and Atmospheric Administration's (NOAA) 2013 3-meter coastal Digital Elevation Model (DEM).
- **City and County of Honolulu:** The effective statewide DFIRM from September 29, 2017, with the latest Letter of Map Amendment January 4, 2017, NOAA's 2013 3-meter coastal DEM, and USGS' 2016 1-meter and 10-meter DEM.
- **County of Maui:** The effective statewide DFIRM from September 29, 2017, with the latest Letter of Map Amendment January 4, 2017, NOAA's 2013 3-meter coastal DEM, and USGS' 2016 1-meter and 10-meter DEM.
- **County of Hawai'i:** The effective countywide Digital Flood Insurance Rate Map (DFRIM) from September 29, 2017, with the latest Letter of Map Amendment June 28, 2019, NOAA's 2013 3-meter coastal DEM, and USGS 2016 10-meter DEM.

Table 4.1-9. FEMA Digital Flood Insurance Rate Maps Effective Dates

County	DFIRM Effective Date	Letter of Map Ammendment (LOMA) Effective Date
County of Kaua'i	2/26/2021	-
City and County of Honolulu	11/5/2014	1/4/2021
County of Maui	11/4/2015	6/22/2020
County of Hawai'i	9/29/2017	3/19/2021

Source: FEMA Map Service Center

In Hazus, the default general building stock inventory was updated with the structure level general building stock to estimate potential loss to buildings. A Level 2 user-defined analysis was performed for state buildings and critical facilities. To estimate damage that would result from a flood, Hazus uses pre-defined relationships

between flood depth at a structure and resulting damage, with damage given as a percent of total replacement value. Curves defining these relationships have been developed for damage to structures and for damage to typical contents within a structure. By inputting flood depth data and known property replacement cost values, dollar-value estimates of damage were generated. New development has not been factored into the inventory assessed in the 2023 SHMP Update, so the limitations of the flood analysis are recognized.

Chronic Coastal Flood

To assess the state's risk to the chronic coastal flood hazard, the SLR-XA with 1.1 feet of sea level rise inundation developed for the *Hawai'i Sea Level Rise Vulnerability and Adaptation Report* was used for the state asset exposure analyses (refer to Section 4.6). The SLR-XA with 1.1 feet of sea level rise depicts the area exposed to potential chronic coastal flooding and land loss based on modeling passive flooding, annual high wave flooding, and coastal erosion with sea level rise for the Islands of Maui, O'ahu, and Kaua'i. The SLR-XA for the Islands of Hawai'i, Moloka'i, and Lāna'i is based on modeling passive flooding only. In addition, the *Sea Level Rise Vulnerability and Adaptation Report* quantitative results were integrated into the chronic coastal flood vulnerability assessment for estimated potential loss to population and the general building stock.

When assessing impacts from the SLR-XA-1.1, permanent loss of the structure and land is assumed. The most accurate way to estimate this loss is to utilize the combined value of the structure and the land using tax assessor data. To estimate loss to the general building stock, the assessed value of both the structure and the land was utilized and reported in Section 4.6 (Flood) as per the *Hawai'i Sea Level Rise Vulnerability and Adaptation Report*. However, this tax data (structure and land value) was not available to report permanent loss to state assets (state buildings and critical facilities). Therefore, to report the required potential impact to state assets, the replacement cost value of state buildings and critical facilities is listed, and the limitations of this are acknowledged.

Hazardous Materials

The hazardous materials hazard is limited to the discussion and analysis of fixed site and in-transit hazard material releases. A qualitative assessment was conducted for the hazardous materials hazard. Refer to Section 4.7 for more information about this hazard of concern.

Health Risks

The health risks hazard is limited to the discussion and analysis of the following: COVID-19, infectious diseases (dengue fever, chikungunya, zika, rat lungworm, Legionnaires' disease, leptospirosis), waterborne disease, pandemic flu (including H5N1 or avian flu and H1N1 or swine flu) and bioterrorism. A qualitative assessment was conducted for the health risks hazard (Section 4.8). Risks to human health that occur as a result of natural hazard events are discussed throughout Sections 4.2 through 4.15.

Hurricane

A Level 2 analysis was performed in Hazus version 5.1 to assess hurricane exposure and vulnerability for one statewide scenario (500-year mean return period hurricane wind event). An aggregate general building stock

analysis was performed using the updated general building stock data. The default critical facilities were replaced in the Hazus model with the updated critical facilities.

Hurricane storm surge (SLOSH) data provided by the NOAA was used for the exposure analysis. The data is the maximum of maximums (MOM) for each hurricane category 1 through 4; the MOM provides a worst-case snapshot for a particular storm category. This data was created by running multiple analysis runs for hurricanes approaching from different directions and retaining the highest value at a given location. The storm surge inundation is from wave action and does not include freshwater inundation. An exposure assessment was conducted, and results were generated for all category hurricanes. For the purposes of the 2023 SHMP Update risk assessment, assets located in the Category 4 storm surge inundation area are reported in Section 4.9 to align with the *2015 Hawai'i Catastrophic Hurricane Plan* and Hazus analysis performed. Exposure assessment results for Category 1 through 3 are reported in Appendix F (State Profile and Risk Assessment Supplement).

The two data sets referenced above (Hazus and SLOSH data) are not directly connected. The wind data was used to determine general building stock losses, displaced households, and shelter needs. The storm surge data was used to determine the estimated risk of state buildings, critical facilities, population, general building stock, environmental resources, and culture assets to the hazard.

Infrastructure Failure

Statewide dam failure inundation area data was provided by the DLNR. For the 2023 SHMP Update, the total number of state assets located in all spatially-delineated high hazard dam failure inundation areas was examined. Assets located in the high hazard dam failure inundation areas are considered at risk to impacts from dam failure. However, it is highly unlikely that all dams would fail at the same time.

Landslide and Rockfall

The landslide and rockfall hazard section is limited to discussion and analysis of landslides (inclusive of all types of soil/rock movement and debris flow) and rockfalls. Landslide susceptibility data for the County of Hawai'i was provided by the Pacific Disaster Center. A categorical slope risk map was prepared using an adaptation of the slope hazard methodology given in the FEMA 2007 HAZUS-MH MR3 Technical Manual. The approach involved the interactions of three primary slope hazard input criteria simplified to low, medium and high hazard susceptibility (State of Hawai'i HMP 2013).

Hazus version MR4 provides susceptibility categories combining slope angle, soil type, and soil moisture with an assigned yield acceleration to each category. The combined susceptibility categories when mapped represent zones of potential landslide triggering under different levels of ground shaking. The following summarizes the criteria used to spatially categorize landslide susceptibility into high, moderate, or low areas in the County of Hawai'i (State of Hawai'i HMP 2013).

- Slope
    - Low Susceptibility – Slope less than 20 degrees
    - Moderate Susceptibility – Slope of 20 to 40 degrees
    - High Susceptibility – Slope greater than 40 degrees

- Geology
    - Low Susceptibility - Fresh volcanic rock at shallow depths
    - Moderate Susceptibility – Clay-rich surficial soils, weathered rock
    - High Susceptibility – Weak soft soils, ash deposits, mapped historic talus (rockfall deposits)
- **Soil Moisture** – Soil moisture assignments are derived from NOAA rainfall mapping of the island since regional groundwater and soil moisture data are unavailable island wide. Areas receiving more than 2,000 mm annual precipitation are considered to have wet soil; these areas are located primarily on the windward side of the island. In addition, coastal areas below elevation 200 feet are considered wet due to potential groundwater seepage gradients from higher elevations, except in the arid Kona coast areas.

For the landslide exposure analysis, the Hazus values provided in the Pacific Disaster Center (PDC) source data were categorized into three landslide susceptibility areas described below.

- **Low** – Hazus susceptibility type values 1 through 3
- **Moderate** – Hazus susceptibility type values 4 through 6
- **High** – Hazus susceptibility type values 7 through 10

This landslide susceptibility data has not been generated for the County of Kaua‘i, City and County of Honolulu, and County of Maui. To determine the areas at greatest risk to landslide for these three counties, slope was calculated using a USGS 10-meter DEM. Areas of slope were assigned low, moderate, and high landslide susceptibility categories to align with the slope categories for the County of Hawai‘i. This data is considered suitable for planning purposes only.

A statewide spatial analysis was conducted using the high landslide susceptibility areas available to determine exposure and vulnerability to the landslide hazard. A qualitative assessment was conducted for the rockfall hazard. Refer to Section 4.11 for more information about this hazard of concern.

TERRORISM

To assess the vulnerability of the state to terrorism and its associated impacts, a qualitative assessment was conducted. Refer to Section 4.12 for more information about this hazard of concern.

TSUNAMI

The Standard Evacuation Zone (SOEST) historic tsunami inundation scenario (400-year), extreme evacuation zone Great Aleutian Tsunami (GAT) inundation scenario (1,500-year), and the American Society of Civil Engineers (ASCE) design level inundation scenario (3,500-year) was provided by the Hawai‘i Emergency Management Agency (HI-EMA) and Niyam IT for the 2023 SHMP Update. In addition, HI-EMA and Niyam IT ran the Hazus version 5.1 tsunami model for these tsunami inundation scenarios to estimate potential economic losses (i.e., building, content, wage, income, relocation, and lost rent payments) in the state. A statewide spatial analysis was also conducted using the SOEST, GAT, and ASCE inundation areas to determine the state assets at risk to impacts from the tsunami hazard. Refer to Section 4.13 for more information about this hazard of concern.

Volcanic Hazards (Lava Flow and Vog)

The volcanic hazard is limited to the discussion and analysis of the lava flow and vog hazards. There are spatially-delineated lava flow zones for the Counties of Hawai'i and Maui. In collaboration with the volcanic SME, specific zones were selected to assess risk to the lava flow hazard. The following defines all zones for each county and which were selected for the exposure analysis reported in Section 4.14.

Lava flow hazard zones data for the County of Hawai'i was provided by the Hawai'i Statewide GIS Program. In collaboration with the volcanic SME, zones 1 through 4 were selected to assess lava flow risk for the County of Hawai'i. The hazard zones are defined as follows.

- Zone 1 – Includes summits and rift zones of Kīlauea and Mauna Loa, where vents have been repeatedly active in historic time.
- Zone 2 – Areas adjacent to and downslope from Zone 1. 15 to 25 percent of Zone 2 has been covered by lava since 1800, and 25 to 75 percent has been covered within the last 750 years. The relative hazard within Zone 2 decreases gradually as one moves away from Zone 1.
- Zone 3 – Areas less hazardous than Zone 2 because of greater distance from recently active vents and/or because of topography. One to 5 percent of Zone 3 has been covered since 1800, and 15 to 75 percent has been covered within the past 750 years.
- Zone 4 – Includes all of Hualālai, where the frequency of eruptions is lower than that for Kīlauea or Mauna Loa. Lava coverage is proportionally smaller, about 5 percent since 1800, and less than 15 percent within the past 750 years.
- Zone 5 – Includes the area on Kīlauea currently protected by topography.
- Zone 6 – Includes two areas on Mauna Loa, both protected by topography.
- Zone 7 – Includes the younger part of dormant volcano Mauna Kea; 20% of this area was covered by lava in the past 10,000 years.
- Zone 8 is the remaining part of Mauna Kea; only a small percentage of this area has been covered by lava in the past 10,000 years.
- Zone 9 is the Kohala Volcano, which last erupted over 60,000 years ago.

Lava flow hazard zones data for County of Maui was provided by USGS. In collaboration with the volcanic SME, zones 1 and 2 were selected to assess lava flow risk for the County of Maui. This decision was based on the 2006 paper by D.R. Sherrod and others, which suggests that Maui Zone 1 is roughly equivalent to Hawai'i Island Zone 3, Maui Zone 2 is roughly equivalent to Hawai'i Island Zone 4, and Maui Zone 3 is roughly equivalent to Hawai'i Island Zone 6 (Sherrod, 2006). These comparisons are not explicitly stated in the paper, but Dr. Sherrod affirms how Maui lava flow hazard zone numbers compare to Hawai'i Island lava flow hazard zone numbers, which were established by Mullineaux and others (1987). In other words, no place on Maui has volcanic hazards equivalent to Lava Flow Hazard Zones 1 and 2 on Hawai'i Island.

The hazard zones are defined as follows.

- Zone 1 – Encompasses the lower- and middle-altitude reaches of the southwest and east rift zones, Haleakala Crater itself, and an area on the northern flank of the east rift zone—all areas where eruptions have occurred frequently in the past 1500 years. At least five eruptive events, each encompassing several

lava flows, have occurred in each of the designated areas. The attention drawn to Zone 1 hazards presumes that the volcano's short-term future will be similar to that of the past 1,500 years.

- Zone 2 – Encompasses the volcano's flanks downslope of the southwest and east rift zone axes, chiefly areas where lava has encroached at least once in the past 13,000 years. Included are some areas that have never been inundated during the past 50,000–100,000 years but that lie within the topographic boundaries of lava sheds for vents that could be expected to form along the rift zone axes.
- Zone 3 – Demarcates downslope reaches centered low on the Kaupo and Ko'olau lava fans. These areas, although within potentially active lava sheds, have become sheltered by topographic buildup during the past 40,000 years that now would deflect new lava toward the margins of the fans.
- Zone 4 – Encompasses those flanks shielded from lava during the past 100,000 years or for which the sparse eruptive products found are the consequence of off-rift cinder cones from random, infrequent eruptive events. Corresponds to essentially no hazard under most lava inundation conditions.

A qualitative discussion is also included regarding vog and potential impacts in the state. Refer to Section 4.14.

WILDFIRE

Communities at Risk from Wildfire (CAR) data were provided by the Hawai'i Wildfire Management Organization (HWMO). These data are based on HWMO's 2013 statewide Wildfire Hazard Assessment (WHA), which collected quantitative field data and qualitative firefighting capacity data of 36 hazard characteristics that contribute to wildland fire risk in developed communities. The Division of Forestry and Wildlife (DOFAW) personnel reviewed the WHA and then made adjustments to better reflect consistency across CAR maps, which communicate risk levels based on staff experience. Tetra Tech assigned high, moderate and low fire risk categories to the communities delineated in the CAR data using the "DOFAW 2013: Communities at Risk from Wildfire" map published by HWMO as a reference. High, moderate, and low categories were used for the exposure analysis. For the purposes of this risk assessment, an asset is considered potentially vulnerable to wildfire if it is located in a high-risk community. The CAR data focuses on communities or developed areas. Therefore, the wildfire risk to state assets located outside of these communities could not be determined.

HWMO provided the following disclaimer with the CAR data:

- "HWMO will not bear any responsibility for the consequences of using this data set, which are entirely the responsibility of the user. Therefore, the data does not indicate the full range of realistic fire threat, nor does it offer actual quantification of the potential exposure of homes to the ignition, spread, and intensity of wildfires or embers produced by wildfires. Although the data set and subsequent analyses may indicate general wildfire risk for a given area, the actual risk to homes and property can deviate based on the characteristics of the site around an individual home, community, or natural resource area."

An exposure assessment was conducted generating results for the high, moderate, and low wildfire risk areas. For the purposes of the 2023 SHMP Update risk assessment, assets located in the high wildfire risk area are deemed exposed and vulnerable to the wildfire hazard of concern. Refer to Section 4.15 for more information about this hazard of concern. Results for the low and moderate landslide risk areas are reported in Appendix F (State Profile and Risk Assessment Supplement). The wildfire risk rankings used for analysis focus on communities and developed areas. Therefore, assets located outside these areas have not been evaluated, and it cannot be

assumed they are not at risk. The results reported in Section 4.15 may underestimate the state's exposure and vulnerability to wildfire.

Wind Storm

Data showing defined geographical extents of terrain-related amplification of wind speeds were not available to evaluate the high wind storm hazard. A qualitative assessment on the high wind component of the trade winds and kona storm events is presented in Section 4.16.

Data Sources

A list of sources for the data used in this risk assessment are outlined in Table 4.1-9.

Limitations

The spatial hazard data used in this plan was generated by multiple agencies and organizations. Due to differing processes of data generation between these entities, spatial layer boundaries may not accurately align with the coastline.

The worst-case scenarios used are for planning purposes only, and may not represent the actual worst-case a geographic area may experience. Loss estimates, exposure assessments, and hazard-specific vulnerability evaluations rely on the best-available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. The reader is urged to use caution when interpreting these results as each hazard event is unique, and climate change projections may change over time as technology and science advances. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic, or economic parameter data
- The unique nature, geographic extent, and severity of each hazard event
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate and should be used only to understand relative risk. Over the long term, the State of Hawai'i will continue to collect additional data, and update and refine existing inventories, to assist in estimating potential losses.

Potential economic loss is based on the present value of the state buildings and general building stock utilizing best-available data. The state acknowledges significant impacts may occur to critical facilities and infrastructure (such as roads, airports, harbors, utilities) as a result of these hazard events causing great economic loss not only to one island but potentially cascading impacts throughout the state. However, monetized damage estimates to critical facilities and infrastructure and economic impacts were not quantified and require more detailed loss analyses. In addition, economic impacts to industries such as tourism and the real estate market were not analyzed.

Table 4.1-10. Data Sources for Data Used in the 2023 SHMP Update

Name of Data	Name of Source	Year of Data Update
State-Owned and/or Leased Facilities	State Risk Management Office	2017
Critical Facilities and Lifelines	Hawai'i Emergency Management Agency	2017
General Building Stock	Hawai'i Emergency Management Agency; Niyam IT	2022
State Roadways	State of Hawai'i Department of Transportation	2022
Judicial Districts	County of Hawai'i; Statewide Office of Planning	2021
Socially Vulnerable Population	Centers for Disease and Prevention; American Community Survey	2018; 2020
Critical Habitat	U.S. Fish and Wildlife Service; Pacific Islands Office	2022
Wetlands	U.S. Fish and Wildlife Service	2021
Parks	Hawai'i Department of Land and Natural Resources; Division of State Parks	2021
Coral Reefs	National Oceanic and Atmospheric Administration	2020
Reserves	Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife	2022
Artificial Reefs	Hawai'i SHMP	2018
Hawaiian Homelands	Hawai'i State Department of Hawaiian Homelands	2021
Hawai'i Community Development Authority Community Development Districts	Hawai'i Community Development Authority	2021
Maui Development Projects	Maui County Planning Department	2016
Enterprise Zones	Community Economic Development Program; County Planning Departments	2021
Watershed Partnerships	Hawai'i Department of Land and Natural Resources	2020
Cultural Resources	Hawai'i Department of Land and Natural Resources	2022
Statewide 1-Percent Annual Chance Flood Event	Federal Emergency Management Agency	2021
Countywide 1-Percent Annual Chance Flood Event	Federal Emergency Management Agency	2014; 2015; 2017; 2021
10-Meter Digital Elevation Model	United States Geological Survey	2016
1-Meter Digital Elevation Model	United States Geological Survey	2016
3-Meter Digital Elevation Model	National Oceanic and Atmospheric Administration	2013
Chronic Coastal Flooding	Hawai'i Climate Change Mitigation and Adaptation Commission	2017
High Hazard Dam Inundation Areas	Hawai'i Department of Land and Natural Resources	2021
NEHRP Soils	AECOM; United States Geological Survey	2013
Landslide Susceptibility	Pacific Disaster Center; United States Geological Survey	2017; 2016
Storm Surge (SLOSH) Categories 1-4	National Oceanic and Atmospheric Administration	2017
SLRA-XA 3.2 Feet Sea Level Rise	Hawai'i Emergency Management Agency	2017
1%CFZ 3.2 Feet Sea Level Rise	Hawai'i Emergency Management Agency; Tetra Tech Inc. and Sobis Inc.	2017
Tsunami Inundation Areas	Hawai'i Emergency Management Agency; Niyam IT	2022
CAR Wildfire Risk	Hawai'i Wildfire Management Organization	2013
Volcanic Hazard Zones	Hawai'i Statewide GIS Program; United States Geological Survey	2017; 1992/2006