SECTION 4. RISK ASSESSMENT

2018 HMP UPDATE CHANGES

- For the 2018 HMP Update, all information on the risk assessment can be found in Section 4, as well as the referenced supporting appendices; previously located in Chapters 4 through 18 of the 2013 HMP. For ease of review, the vulnerability assessment follows each hazard profile, so that all information about a specific hazard is continuous. This section describes the identification of hazards, Presidential disaster declarations, hazard profiles, and the vulnerability assessment.
- In an effort to streamline the risk assessment, previous events captured in the 2013 HMP, lengthy tables and the majority of the maps have been moved to the Appendices (Appendix X – State Profile and Risk Assessment Supplement; Appendix X – Map Atlas).
- The hazards of concern have been reorganized to align with the associated events and impacts on the State, and to be consistent with the THIRA.
- A state building dataset and a more robust critical facility inventory was available and utilized in the risk assessment update.
- Updated hazard and asset spatial data sets were used to assess vulnerability.

4.1 Overview

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 both the hazard mitigation plan and for other emergency management efforts.

Risk

For the purposes of the 2018 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 2018 HMP Update provides the factual basis for developing a mitigation strategy for the State. It makes the connection between vulnerability and the proposed hazard mitigation actions.

The HI-EMA envisions the 2018 HMP Update to serve as a technical reference for local HMP updates. With that in mind, the 2018 HMP Update included a comprehensive update to the 2013 HMP 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, the 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 Review Guide (March 2015) and State Mitigation Planning Key Topics Bulletins: Risk Assessment (June 2016). Therefore, mitigation capabilities and mitigation strategy elements were moved to Sections 5 (Capability Assessment) and Section 6 (Mitigation Strategy) to streamline the risk assessment sections.

For the 2018 HMP Update, the risk assessment for each hazard is divided into two parts: (1) hazard profile and (2) vulnerability assessment. The vulnerability assessment now follows the hazard profile, so that all information about a particular hazard is found in one concise section. The following is the consistent outline for each hazard's risk assessment section (Sections 4.2 through 4.15):

- 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 changes in weather patterns and climate
- Vulnerability Assessment
  - Assessment of State vulnerability and potential losses
  - Assessment of local vulnerability and potential losses
  - Future changes that may impact vulnerability

The 2018 HMP 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 4.16 (Risk Ranking) 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. Meaning, county tabular results and maps presented throughout Sections 4.2 through 4.16 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 plan and studies, the cumulative results are presented in the 2018 HMP Update by county.

4.1.1 Identification of Hazards

The first step of the risk assessment is to identify and profile all-natural hazard occurrences. The goal of this first step is to identify and understand the characteristics of the state's most significant risks (FEMA State Mitigation Planning Key Topics Bulletin: Risk Assessment; 2016).

The HI-EMA considered a full range of hazards that could affect the State for the 2018 HMP Update. The process included a review of the 2013 HMP, a review of state and local hazard planning documents including local HMPs, a review of previous events and losses, as well as information on the frequency, magnitude and costs associated with hazards that have struck the State or could do so. 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 50 federal disasters declared in the State of Hawai‘i from 1955 to May 2018, Hawai‘i received 31 major disaster declarations (DR); 1 emergency declaration (ER); and 18 fire management assistance declarations (FM). Table 4.1-1 outlines each FEMA declarations that the State of Hawai‘i has received since 1955. It should be noted that declarations prior to 1964 do not contain county data as it is not available (FEMA 2018). Additional details regarding declarations during the performance period of the plan are discussed further in Sections 4.2 through 4.15.

Table 4.1-1. FEMA 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
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 Kilauea	FM-2044	Not Reported
January 8, 1988	Severe Storms, Mudslides & Flooding	DR-808	Honolulu
May 18, 1990	Lava Flow, Kilauea 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

Date Declared	Incident Type	Disaster Number	Counties Affected
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

Source: FEMA 2018
** For this event, as per the FEMA website, no additional information was filed for this event*
DR Major Disaster Declaration
EM Emergency Declaration
FEMA Federal Emergency Management Agency
FM Fire Management Assistance Declaration

Local HMP Risk Assessment Roll-Up

44 CFR §201.4(c)(2)(ii): An overview and analysis of the State's vulnerability to the hazards described …based on estimates provided in local risk assessments…

All local HMP risk assessments were reviewed, not only to consider data sources for the 2018 HMP 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 2018 HMP 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 Hawaii's 2023 HMP update.

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 2018 HMP 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 2013 and 2018 HMP Update hazards of concern.

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

Hazard	2018 State HMP	2013 State HMP	Local HMPs			
			County of Kaua'i	City and County of Honolulu	County of Maui	County of Hawai'i
Climate Change and Sea Level Rise	◆	◆	◆		*	
Chronic Coastal Flood	◆	◆ Coastal Erosion, High Surf	◆	◆ High Surf, Storm Surge	◆ Coastal Erosion, High Surf	
Dam Failure	◆	◆	◆		◆ Dam and Reservoir Failure	
Drought	◆	◆	◆	◆	◆	◆
Earthquake	◆	◆	◆	◆	◆	◆
Event-Based Flood	◆	◆	◆	◆ Stream Flood, Flash Flood	◆	◆ Rainfall flooding, high waves
Hazardous Materials	◆	◆	◆		**	
Health Risks	◆	◆	◆			
High Wind Storms	◆	◆	◆ Hurricanes, strong winds combined	◆	◆	◆ Hurricane, Windstorms
Hurricane	◆	◆ Tropical Cyclone	◆ Hurricanes,	◆ Tropical Cyclones, Hurricanes	◆	◆ Hurricane, Windstorms

Hazard	2018 State HMP	2013 State HMP	Local HMPs			
			County of Kaua‘i	City and County of Honolulu	County of Maui	County of Hawai'i
			strong winds combined			
Landslide and Rockfall	◆	◆	◆	◆ Debris & Rockfall	◆ Landslide, Debris Flow, Rockfall	◆ Landslide, Sea Cliff Erosion
Tsunami	◆	◆	◆	◆	◆	◆
Volcanic hazards (lava flow and VOG)	◆	◆	◆		◆ Lava flow and VOG	◆ Lava Flow
Wildfire	◆	◆	◆		◆	◆

Sources: County of Kaui, 2015; City and County of Honolulu 2012 and 2017; County of Mau 2015; County of Hawai‘i 2015
**The County of Maui did not include climate change as a stand-alone hazard; however, there is a chapter on climate change and a sea-level rise exposure analysis was conducted and impacts on the other hazards of concern were discussed.*
***Hazardous materials may have been included as critical facilities in the local HMPs and therefore estimated potential impacts discussed in all hazard sections.*

2018 HMP Update Hazards of Concern

Based on this review, all hazards of concern in the 2013 HMP are included in the 2018 HMP 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. The hazards of concern evaluated for the 2018 HMP Update are presented below in alphabetical order; the order of the listing does not indicate the hazards' relative severity:

- Climate Change and Sea Level Rise *(formerly Climate Change Effects)*
- Chronic Coastal Flood *(formerly Flood, High Surf and Coastal Erosion)*
- Dam Failure
- Drought
- Earthquake
- Event-Based Flood *(formerly Flood)*
- Hazardous Materials
- Health Risks *(formerly Health Risks and Vulnerability)*
- High Wind Storm
- Hurricane *(formerly Tropical Cyclone)*
- Landslide and Rockfall
- Tsunami
- Volcanic Hazards (VOG and lava flow)
- Wildfire

Changes to the 2013 HMP hazards of concern are summarized below.

- The tropical cyclone hazard is now referred to as the 'hurricane' hazard to be consistent with the THIRA.

- The flood hazard was split into two distinct flood hazards: 1) chronic coastal flood and 2) event-based flood.
  - This separation is consistent with the 2017 Hawai'i Sea Level Rise Vulnerability and Adaptation Report, more accurately reflects events that take place in the state and will allow for more specific and measurable mitigation actions.
  - Coastal erosion and high surf were separate hazards of concern in the 2013 HMP but are now included with the chronic coastal flood hazard.
  - Chronic coastal flood includes passive inundation, annual high waves, coastal erosion, and tidal flooding/king tides with sea level rise.
  - Event-based flood focuses on the 1% annual chance flood.
- Health risks now includes the rat lungworm due to this risk emerging in 2017.
- The climate change effects hazard is now referred to as 'climate change and sea level rise' and includes best available data developed for the sea level rise hazard.

In addition to the separate climate change and sea level rise hazard, each hazard section contains a subsection that discusses the potential changes in future probability resulting from climate change. In addition, there is a subsection that discusses the future changes that may impact vulnerability including climate change impacts where appropriate.

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

44 CFR §201.4(c)(2)(ii): …. State owned or operated critical facilities located in the identified hazard areas shall also be addressed;

44 CFR §201.4(c)(2)(iii): …. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

FEMA requires the state to identify their assets which may include state-owned or operated buildings, infrastructure and critical facilities. For the 2018 HMP Update, the State of Hawai'i assessed 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 dataset did not have attribution to determine the number of owned versus leased buildings; this data will be referred to as state buildings in the 2018 HMP 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 4.15. The dataset included various structural attributes used for the analyses including replacement cost, 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. Refer to Appendix X for more information on FEMA's Hazus model and the default values used. Table 4.1-3 summarizes the state building data set used in the risk assessment.

Table 4.1-3. Summary of State Buildings by Agency

Agency	State Building	
	Count	Total Replacement Cost Value
Dept of Accounting & General Services	66	$946,504,656
Dept of Agriculture	70	$133,065,375
Dept of Attorney General	15	$95,151,863
Dept of Budget & Finance	16	$26,624,294
Dept of Business, Economic Development & Tourism	25	$612,574,032
Dept of Commerce & Consumer Affairs	2	$35,611,360
Dept of Defense	69	$246,099,477
Dept of Education	4,090	$9,604,111,443
Dept of Hawaiian Home Lands	12	$100,471,477
Dept of Health	44	$387,068,440
Dept of Human Resources Development	1	$5,523,320
Dept of Human Services	130	$420,004,555
Dept of Labor & Industrial Relations	22	$79,322,626
Dept of Land & Natural Resources	90	$98,666,185
Dept of Public Safety	154	$427,884,909
Dept of Taxation	1	$6,864,408
Dept of Transportation	68	$2,912,510,888
Hawai'i State Ethics Commission	1	$891,212
Hawai‘i Health Systems Corporation	106	$1,223,962,810
Hawai‘i Housing Finance & Development Corporation	86	$333,526,064
Hawai‘i Public Housing Authority	273	$933,255,767
Hawai‘i State Legislature	2	$43,024,855
Hawai‘i State Public Library System	53	$525,584,082
Judiciary	41	$511,093,204
Legislative Reference Bureau	1	$2,686,408
Office of Hawaiian Affairs	11	$53,991,251
Office of the Auditor	2	$1,789,788
Office of the Governor	1	$2,686,408
Office of the Lieutenant Governor	2	$3,977,640
Office of the Ombudsman	1	$1,620,944
Research Corporation of the University of Hawai'i	3	$3,713,497
University of Hawai'i	637	$5,000,692,783
Total	**6,095**	**$24,780,556,017**

Source: State Risk Management Office 2017
RCV – Replacement Cost Value

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 2016. Economic impact of hazard events on road infrastructure has not been monetized, although exposure is identified and discussed. Appendix X (Map Atlas) includes maps of each island that depict the major transportation assets, highway and airports, located throughout the state.

The 2018 HMP Update risk assessment included the collection and use of an expanded and enhanced asset inventory to estimate state and local vulnerability.

Critical Facilities

The HI-EMA provided a list of 1,542 critical facilities to utilize for the risk assessment. This list of facilities was compiled for the *Makani Pahili 2017 Emergency Power Prioritization Workshop Series Final Report*. The facility type assigned to each core category can be found in Appendix X (State Profile and Risk Assessment Supplement). The list contained spatial coordinates for the majority of the facilities. For the facilities that did not have spatial coordinates or the original coordinates were invalid, other location attributes were used to geocode the facilities. Not all facilities had sufficient location attributes for geocoding. Of the total 1,542 facilities, 1,475 had sufficient data to be geocoded and are included in the spatial analyses reported in Sections 4.2 through 4.15.

An estimated 400 critical facilities are state buildings that appear in both inventories used for the risk assessment. The duplication of these assets is acknowledged; and the datasets are reported separately. The majority of the overlap is with critical facilities in the Government Facilities, Healthcare and Public Health, and Mass Care Support Services (schools) core categories.

The original facility list only contained two attributes: facility name and critical facility type. Therefore, assumptions were made to populate the required fields needed to estimate potential losses using Hazus. The average values already populated in Hazus for each facility type (known as default values) for square footage were utilized; however it is recognized that the actual square footage could differ significantly. The replacement cost, or amount it will cost to replace the structure at the time of the loss, was calculated using the default square footage values and 2017 RS Means costs per square foot for each facility. RS Means 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 purposes. The Hazus default attribute data for essential facilities (fire, police, medical care, and school facilities) was used to replace the default attribute values where the essential facilities could be matched to the critical facilities using the facility name.

Table 4.1-4 summarizes the total number and replacement cost value of critical facilities by core category used in the risk assessment.

Table 4.1-4. Summary of Critical Facilities by Core Category

Core Category	Count	Total Replacement Cost Value
Commercial Facilities	60	$206,894,206
Communications	130	$523,848,060
Emergency Services	149	$1,017,628,710
Energy	90	$2,591,975,628
Food & Agriculture	39	$829,869,410
Government Facilities	100	$399,781,575
Healthcare & Public Health	193	$3,399,521,375
Mass Care Support Services	353	$11,497,547,155
Transportation Services	56	$1,739,256,960
Water, Waste, & Wastewater Systems	305	$9,481,445,760
Total	**1,475**	**$31,687,768,838**

Source: HI-EMA Temporary Emergency Power County Workshop Series Report Critical Facilities, 2017

Local Assets

44 CFR §201.4(c)(2)(ii): The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events.

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. As a first step, the four local HMPs were reviewed in an attempt to roll-up the local risk assessment results in the 2018 HMP Update to summarize losses in each county. However, the local plan risk assessment roll-up proved challenging because all four local HMPs and specifically their risk assessments differ in structure, data used and analysis methods. Therefore, the State of Hawaii's 2018 HMP Update risk assessment included a vulnerability assessment for the counties utilizing statewide population, building, environmental resource and cultural asset spatial datasets. Estimated exposure and potential impacts to these assets are reported in each hazard section. In addition, economic impacts are discussed qualitatively for each hazard.

Population

Research has shown that some populations are at greater risk from hazard events because of decreased resources or physical abilities. As discussed in Section 3.0 (State Profile) these vulnerable populations include individuals living near or below the poverty threshold, the elderly, children, ethnic minorities and visitors.

The 2010 U.S. Census block data layers were used to estimate exposure and potential impacts to the general population. The 2010 U.S. Census demographic data available in FEMA's Hazus model was used to estimate potential impacts to the elderly (over 65 years of age) and populations with income below the poverty threshold for the state. The poverty threshold for the State is $24,000/year (Federal Register 2017); however, the demographic data available in FEMA's Hazus model is only available in increments of $10,000. Therefore, the total households with an income of $30,000 or less was utilized for the risk assessment. To obtain an understanding of how many people are living at or near the poverty threshold, the average number of persons

per household (3.03 people) was multiplied by the households with annual incomes of less than $30,000 (U.S. Census Bureau QuickFacts; Hazus v4.2); refer to Table 4.1-5 for a summary of these statistics by county.

Table 4.1-5. Population Statistics by County

County	Total Population	Population Over the Age of 65 years	Population Living with an Income <$30K/year
County of Kaua‘i	67,091	9,985	15,777
City and County of Honolulu	953,207	138,490	177,621
County of Maui	154,924	19,829	33,036
County of Hawai‘i	185,079	26,834	59,055
Total	**1,360,301**	**195,138**	**285,489**

Source: U.S. Census 2010; Hazus 4.2
K = Thousand

General Building Stock

To assess the built environment, the general building stock inventory dataset from Hazus version 4.2 was used for the risk assessment. This building data provides the building valuation for each occupancy classification (e.g., residential, commercial, industrial) developed from the Hazus square footage data by occupancy (derived from data from the U.S. Energy Information Administration and the 2010 U.S. Census for residential data, and adjusted Hazus-MH 2006 square footage data for non-residential data). This dataset was developed by applying 2014 R.S. Means “Square Foot Costs”-based replacement values per square foot for typical building floor areas and construction methods for each specific occupancy. 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. It is important to note that development that has occurred since 2010 is not reflected in the reported risk assessment results.

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 Department of Land and Natural Resources. This information is not available for public review and use at this time and as such, could not be included in the analysis in this plan. It is a goal of the HI-EMA to work with the

Department in the future in order to access this information for inclusion in future state hazard mitigation plan updates.

For the 2018 HMP Update, the Hawaiian Home Lands spatial data was used to assess exposure to the natural hazards evaluated. The spatial hazard layers were overlaid with the Hawaiian Home Lands in GIS to determine the area of land located in the impact area of the hazard.

Changes That Impact Vulnerability

'*State hazard mitigation plans must be revised to reflect changes in development, including recent development, potential and projected land use and development, or conditions that may affect risk and vulnerability to the state and jurisdictions such as changes in population demographics*' (FEMA State Mitigation Planning Key Topics Bulletin: Risk Assessment; 2016).

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 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 2013 HMP; 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 if development has occurred in hazard areas.

Unfortunately, the 2013 HMP did not include an analysis of State owned and/or leased buildings or the same critical facility inventory; therefore, changes in risk and vulnerability of these facilities over the performance period of the plan cannot be assessed. In addition, different critical facility and general building inventories, hazard data and methodologies were used in the 2013 HMP than the 2018 HMP update making it impossible to conduct a side-by-side comparison analysis to determine changes in vulnerability. It is the HI-EMA and the SHMO's vision that the 2018 HMP Update set the new baseline for risk and will be used to assess changes of risk over time as future updates to the plan occur.

It is important to note that development continues to occur in the State. Any new development that has occurred since 2010 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 datasets 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.

Due to the fact that 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 HMP. Climate change and associated impacts are discussed in Section 4.2 (Climate Change and Sea Level Rise).

4.1.3 Hazard-Specific Data and Methodologies

44 CFR §201.4(c)(2)(i): The risk assessment shall include the following: An overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future events, 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 4.1-6 summarizes the types of analyses performed for each hazard followed by a discussion of each approach.

1. **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 judgement.

- **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.

2. **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 X (State Profile and Risk Assessment Supplement) for more information on FEMA's Hazus model.

Table 4.1-6. Summary of Risk Assessment Analyses

Hazard	Data Analyzed						
	State Buildings	State Roads	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
Chronic Coastal Flood	E	E	E	E	E	E	E
Dam Failure	E	E	E	E	E	E	E
Drought	Q	Q	Q	Q	Q	Q	Q
Earthquake	E, H	E, H	E, H	E, H	E, H	E	E

Hazard	Data Analyzed						
	State Buildings	State Roads	Critical Facilities	Population	General Building Stock	Environmental Resources	Cultural Assets
Event-Based Flood	E, H	E, H	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
High Wind Storms	Q	Q	Q	Q	Q	Q	Q
Hurricane	E, H	E, H	E, H	E	E, H	E	E
Landslide and Rockfall	E	E	E	E	E	E	E
Tsunami	E	E	E	E, H	E, H	E	E
Volcanic Hazards	E	E	E	E	E	E	E
Wildfire	E	E	E	E	E	E	E

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 2018 HMP Update process to collaborate with hazard subject-matter-experts to obtain the best available data and methodologies to assess risk (refer to Section 2 and Appendix X – 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 X (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 X (Map Atlas) includes additional maps gathered or generated to support the risk assessment.

Climate Change and Sea Level Rise

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 *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, Molokai and Lanai 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).

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. It is important to note when comparing 1% annual chance flood event with the 1%CFZ-3.2, that the 1%CFZ-3.2 analysis is based on the current regulatory V-zone; whereas the 1% annual chance flood event (Section 4.6 - Event-based flooding) includes the entire Special Flood Hazard Area (V- and A-zones).

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. To estimate loss to the general building stock, the assessed value of both the structure and the land was utilized and reported in Section 4.2 (Climate Change and Sea Level Rise). 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 and the limitations of this are acknowledged.

Summary of New Terms in the 2018 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 4.3.*

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 4.7.*

1% CFZ-3.2– *The 1% annual coastal flood zone (V zones only) 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).*

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 4.2). 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 4.3 (Chronic Coastal Flood) as per the *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 and the limitations of this are acknowledged.

Dam Failure

Statewide dam failure inundation area data was provided by the Pacific Disaster Center (PDC). The dam break scenarios depicted in the reports utilized the Danish Hydrological Institute's MIKE 21 model. Model results, and products were reviewed and approved by a consulting hydrologist. Best available data were utilized in the reports and as input to the model, however, due to variations in data currency and accuracy, final products should be interpreted as "best available estimates" only. Original Individual Assessment Reports prepared under contract for DLNR were not available for the 2018 HMP Update.

For the 2018 HMP Update, the total number of state assets located in all spatially-delineated dam failure inundation areas was examined. However, it is important to note that it is highly unlikely that all dams would fail at the same time. To assess local vulnerability, the HI-EMA Mitigation Section asked representatives from each County on the Forum which three dams they would like analyzed as part of the 2018 HMP Update. The following 12 dams were selected and exposure analyses were conducted.

- County of Kaua‘i – Waita Reservoir (HI00099), Huinawai Reservoir (HI00104), Kapaia Reservoir (HI00012)
- City and County of Honolulu – Wahiawa Dam (HI00017), Kaneohe Dam (HI00124), Nuuanu Dam No. 4 (HI00001)
- County of Maui – Horner Reservoir (HI00054), Kualapuu Reservoir (HI00041), Wailuku Water Reservoir 6 (HI00150)
- County of Hawai‘i – Waikoloa Reservoir No. 1 (National ID HI00040), Waikoloa Reservoir No. 2 (HI00122), Waikoloa Reservoir No. 3 (HI00136)

Due to the limited number of dams evaluated to assess local vulnerability, the risk assessment in Section 4.4 (Dam Failure) does not fully represent each county's total exposure nor vulnerability.

DROUGHT

To assess the vulnerability of the State to drought and its associated impacts, a qualitative assessment was conducted. Information from the *Hawai‘i Drought Plan 2017 Update* were used to support this section (Section 4.5).

EARTHQUAKE

ShakeMap data prepared by the U.S. Geological Survey (USGS) and probabilistic earthquake data in Hazus version 4.2 were used to assess the earthquake hazard. The evaluation of the 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 Kau M8.0 scenario with an epicenter approximately 4 miles northwest of Pahala. This scenario represents the Kau District M7.9 earthquake on April 3, 1868.
- The Lanai M7.0 scenario with an epicenter approximately 13 miles north northwest of Lanai City. This scenario represents the Lanai 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 4.2 to estimate potential losses as a result of each scenario (Section 4.6); refer to Appendix X (State Profile and Risk Assessment Supplement) for further details on Hazus and Level 2 analyses. The general building stock data, for the Counties of Hawai‘i and Maui, was enhanced with custom building mapping schemes for earthquake modelling. These customized mapping schemes provide the percentage of single-wall, and post and pier building types for each Census tract and associated Hawai‘i -specific damage functions. These building types are the most vulnerable to earthquake damage. The enhanced general building stock data were provided by the Pacific Disaster Center. The Counties of Kaua‘i and City and County of Honolulu used the general building stock data that was already provided in Hazus v4.2.

The state buildings and critical facilities were imported into Hazus as individual facilities to support this assessment (also known as a Hazus user-defined analysis). 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.
- Landslide susceptibility data for County of Hawai‘i was provided by the Pacific Disaster Center. Landslide susceptibility data categorized for use in Hazus is not available for the other counties.

Event-Based Flood

The National Flood Hazard Layer Digital Flood Insurance Rate Map (DFIRM) data, effective September 29, 2017 with latest Letter of Map Amendment October 2, 2017, was used for the exposure and estimate potential losses from the 1-percent-annual-chance flood event in Hazus (refer to Section 4.7). Table 4-7 summarizes the effective dates of each County's DFIRM.

Using the 1-percent annual chance floodplain boundaries, also known as the Special Flood Hazard Area and inclusive of A- and V-zones, and the best available digital elevation model (DEM) data, flood depth grids were generated and integrated into the Hazus model. The DEM data included NOAA's 3-meter coastal DEM and USGS' 1-meter and 10-meter DEM data.

In Hazus, the dasymetric default general building stock was used to estimate potential loss. 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.

Table 4.1-7. FEMA Digital Flood Insurance Rate Maps Effective Dates

County	DFIRM Effective Date	Latest LOMA Effective Date
County of Kaua'i	11/26/2010	-
City and County of Honolulu	11/5/2014	9/8/2017
County of Maui	11/4/2015	9/8/2017
County of Hawai'i	9/29/2017	10/2/17

Source: FEMA Map Service Center, 2017

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.

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 (Section 4.8).

Health Risks

The health risks hazard is limited to the discussion and analysis of the following: infectious diseases (dengue fever, chikungunya, zika, rat lungworm, Legionnaires' disease, leptospirosis), water-borne 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 4.9). Risks to human health that occur as a result of natural hazard events are discussed throughout Sections 4.2 through 4.15.

High 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 4.9.

Hurricane

A Level 2 analysis was performed in Hazus version 4.2 to assess hurricane exposure and vulnerability for one statewide and four county-specific scenario events created for the 2015 Hawaiʻi Catastrophic Hurricane Plan. Wind field import files created for the Hawaiʻi Catastrophic Hurricane Plan and provided by the Pacific Disaster Center (PDC) were used for the Hazus analyses. A general building stock analysis was performed using the Hazus default data. A user-defined analysis was performed for state buildings and critical facilities. The five scenarios chose for analysis are:

- Statewide – Category 4 hurricane with a maximum wind speed of 140 mph. Approaches from the south traveling approximately 50 miles to the west of Hawaiʻi before turning to the northwest approximately 10 miles south of Lanai and traveling to the northwest off the south coast of Oahu.
- County of Kauaʻi – Category 4 hurricane with a maximum wind speed of 130 mph making landfall on the south coast of Kauaʻi .
- City and County of Honolulu – Category 4 hurricane with a maximum wind speed of 130 mph making landfall on the south coast of Oahu.
- County of Mauʻi – Category 4 hurricane with a maximum wind speed of 120 mph making landfall on the south coast of Kahoolawe.
- County of Hawaiʻi – Category 4 hurricane with a maximum wind speed of 120 mph making landfall on the northwest coast of Hawaiʻi.

Hurricane storm surge (SLOSH) data provided by the National Oceanic and Atmospheric Administration (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 generated for the all category hurricanes. For the purposes of the 2018 HMP Update risk assessment, assets located in the Category 4 storm surge inundation area are reported in Section 4.10 to align with the Hawaiʻi Catastrophic Hurricane Plan and Hazus analysis performed. Exposure assessment results for Category 1 through 3 are reported in Appendix X (State Profile and Risk Assessment Supplement).

The two datasets 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 exposure of state buildings, critical facilities, population, general building stock, and environmental/culture assets losses to the hazard.

Landslide and Rockfall

The landslide and rockfall hazard is limited to discussion and analysis of two types of landslides: debris flow (or mudslides) and rockfall. Landslide susceptibility data for the County of Hawai'i was provided by the Pacific Disaster Center. The following summarizes the criteria used to spatially categorize landslide susceptibility into high, moderate or low areas in the County of Hawai'i.

- **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 - Shallow rock, fresh volcanics
  - Moderate Susceptibility – Clay surficial soils, weathered rock
  - High Susceptibility – Weak soft soils, ash deposits, mapped historic slide talus
- **Soil Moisture** - Soil moisture assignments are derived from NOAA rainfall mapping of the island since regional groundwater and soil moisture data is unavailable island wide. Areas receiving greater than 2000 mm annual precipitation are considered wet soil, corresponding largely to 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, we categorized the Hazus values provided in the PDC source data 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 4.12.

Tsunami

The Great Aleutian Tsunami (GAT) inundation area data provided by the PDC for use in the 2018 HMP Update. In addition, the PDC ran the Hazus v4.2 tsunami model for the GAT scenario to estimate potential losses in the state. A statewide spatial analysis was conducted using the GAT inundation area to determine exposure to state assets. The impacts to population, buildings and the economy were summarized utilizing the Hazus reports provided by the PDC and summarized in Section 4.13.

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 4.13.

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 Kilauea and Mauna Loa, where vents have been repeatedly active in historic time.
- Zone 2 – Areas adjacent to and downslope from Zone 1. Fifteen to twenty-five 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 five 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 Hualalai, where the frequency of eruptions is lower than that for Kilauea 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 Kilauea 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 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 1500 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 was 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 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. It is important to note that 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 and results generated for the high, moderate and low wildfire risk areas. For the purposes of the 2018 HMP Update risk assessment, assets located in the high wildfire risk area are deemed exposed and vulnerable. Refer to Section 4.15; results for the low and moderate landslide risk areas are reported in Appendix X (State Profile and Risk Assessment Supplement). It is important to note that the wildfire risk rankings used for analysis focus on communities and developed areas. Therefore, assets located outside these

areas have not be evaluated and it cannot be assumed they are not as risk. The results reported in Section 4.15 may underestimate the State's exposure and vulnerability to wildfire.

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.

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 buildings 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 that cascades 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 industry such as tourism and the real-estate market were not analyzed.